City of Portland
Bureau of Environmental Services

Fanno and Tryon Creeks Watershed Management Plan

2005

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Introduction

PURPOSE

The Fanno and Tryon Creeks Watershed Plan (Watershed Plan) characterizes watershed conditions, identifies watershed problems and assets, and recommends a comprehensive and strategic set of projects, programs, and activities to improve watershed health.

The Bureau of Environmental Services (BES) has developed the Watershed Plan in collaboration with other City bureaus and jurisdictions and the public. Recommendations are consistent with other efforts to improve the health of Portland's watersheds, including the City's River Renaissance Initiative, Endangered Species Act (ESA) Program and the City's Stormwater Program. The Watershed Plan also helps the City comply with Federal and State regulations, including the ESA and the Clean Water Act.

WATERSHED PLANNING BASIS: KEY DRIVERS

The Fanno/Tryon watershed planning process responded to the following key drivers:

- Public Facilities Plan—Stormwater and Sanitary Systems
- Water Quality—TMDLs and NPDES Regulations
- Endangered Species Act
- Clean River Plan
- River Renaissance
- Land Use Planning/Community Plans
- Natural Resource Assessments
- Citizen Input, Public Outreach, and Community Needs

River Renaissance

River Renaissance is a comprehensive vision that encompasses the entire City of Portland. The River Renaissance Initiative seeks to realize the vision through a partnership of residents, businesses, industry, not-for-profit organizations, and public agencies. Areas of focus include planning (e.g., developing the River Renaissance Plan and continuing work that advances River Renaissance); showcasing early actions; solidifying partnerships; engaging the public; and developing a sustainable funding strategy to implement River Renaissance projects.

BES has taken an active role in the River Renaissance effort, along with other City bureaus, residents, businesses, community groups, property owners, and government agencies. BES's watershed plans constitute the major components of the River Renaissance's 'clean and healthy river' theme.

Endangered Species Act (ESA)

The City's ESA Program finalized the *Framework for Integrated Management of Watershed and River Health* (Framework) in 2003. The initial structure of the Framework was developed in 2001. The framework guides the development of all the City's watershed plans. The ESA program also developed an inventory of culverts and pipes in the watersheds for fish passage implications. In addition, the ESA program used existing information to analyze the watersheds in order to develop components of a fish recovery plan. The Watershed Plan uses the methodology and other information developed by the ESA Program.

BES is the lead City bureau for developing information and implementing strategies to address stormwater quality and quantity, management, and conveyance. BES's stormwater activities are directly tied to the City's recovery efforts for species listed under the ESA.

Citizen Input, Public Outreach, and Community Needs

To be successful and capable of implementation, the Watershed Plan must reflect community and public expectations, input, and feedback. Portland's southwest community has consistently raised and promoted issues that affect, maintain, and/or promote watershed and stream health and water quality. The Watershed Plan process provided numerous opportunities for public involvement and feedback through a well-designed public outreach component. Involved groups included the Tryon Creek Watershed Council, Fans of Fanno, neighborhood associations, and others. Public involvement will continue as specific projects and programs are implemented.

Key issues identified by the community include the need to:
- Link land use planning and development to watershed health.
- Address onsite stormwater management through the land use process.
- Address infrastructure capacity and the need for regional detention facilities to accommodate existing and future land use
- Identify links between zoning and imperviousness
- Develop new development standards in southwest Portland
- Provide interagency coordination
- Address public concerns throughout the planning process

BES is the lead City bureau for developing highly technical, scientific, and objective information used in various City programs and activities that protect and improve water quality and watershed health and provide adequate conveyance facilities for stormwater and sanitary sewage. BES has the lead for providing public involvement opportunities as part of the watershed planning process.

Clean River Plan

The Clean River Plan is the City's conceptual umbrella and guidance for achieving multiple water quality, watershed and stream health, habitat, and other resource objectives in a carefully planned sequence during the next 20 years. Development of the Clean Water Plan involved a three-year Integrated Watershed Planning process (BES 2000), review of the Combined Sewer Overflow (CSO) Program, and review of all the City's sewer and drainage facilities. The Clean River Plan identifies ten actions that provide a holistic approach to solving water quality problems and meeting the overall goals of healthy streams and rivers. Eight of these ten actions are relevant to the Watershed Plan:

Action 1: Plant trees, native vegetation, and create buffers along streams.

Action 3: Reduce stormwater flow and pollutants reaching streams.
Action 5: Control erosion from construction and development.
Action 6: Increase pollution prevention and source control.
Action 7: Education and stewardship.
Action 8: Floodplain restoration.
Action 9: Watershed assessment and monitoring.
Action 10: Coordination and partnerships.

BES has the lead role in implementing the Clean River Plan. The Watershed Plan's recommendations are consistent with the principles of the Clean River Plan.

Land Use Planning/Community Plans

Portland's *Comprehensive Land Use Plan* is the City's most comprehensive tool for guiding land use planning and resource protection. The *Southwest Community Plan* designates base zones and overlay zones in southwest Portland. The Planning Bureau is the lead bureau for administering the *Comprehensive Plan, Southwest Community Plan,* and related city code.

In addition to the base zone designation, the stream corridors and most open areas in southwest Portland also have the environmental protection and/or environmental conservation overlay zone designation. These overlays are designed to protect streams and other significant resource areas.

Key issues related to the Southwest Community Plan and land use planning coordination in southwest Portland include the need to:

- Link land use planning and development to watershed health.
- Provide adequate sanitary and storm infrastructure to accommodate existing and future land uses while improving watershed health.
- Link zoning and impervious surface area.
- Create new development standards.

BES is not responsible for land use planning. As an infrastructure bureau, however, BES provides technical support to the Bureau of Development Services in the land use process. BES's role is critical for providing adequate sanitary and stormwater services—including detention and onsite management—to accommodate proposed changes in the Southwest Community Plan area. Its role is also critical for ensuring protection of watershed health and maintaining a well functioning infrastructure.

Public Facilities Plan – Stormwater and Sanitary Systems

BES completed an update of its *Public Facilities Plan* (PFP) in 1999. This update included an extensive evaluation of the City's stormwater and sanitary systems/infrastructure. The *Fanno Creek Resources Management Plan* (BES 1998) and the *Upper Tryon Creek Corridor Assessment* (BES 1997) were also completed as part of the PFP. The PFP includes extensive information about the capacity, operation, and upgrade needs of the infrastructure and stream corridors. However, the PFP and the Fanno and Tryon Creek reports lack details about upland areas, water quality, surface/groundwater interflow, fisheries/habitat impact, cause/effect analysis, and stormwater characterization.

The Watershed Plan seeks to complement and extend these efforts by addressing the need to:

- Link land use planning and development to infrastructure capacity.
- Conduct hydrologic/hydraulic analysis.
- Integrate the ESA Program's analysis of how the stormwater and sanitary infrastructure affects water quality, habitat, and fish passage.
- Provide adequate sanitary and storm infrastructure to accommodate existing and future land uses while improving watershed health.
- Describe the physical impact of storm and sanitary infrastructure on stream conditions and watershed health.

Natural Resource Assessments

BES completed a stream corridor assessment of Fanno and Tryon Creeks and their major tributaries as part of the *Fanno Creek Resource Management Plan (BES 1998)* and *Upper Tryon Creek Corridor Assessment (BES 1997)*. The Oregon Department of Fish and Wildlife and the City of Portland completed a stream assessment/survey of Tryon and Fanno Creeks and some of their tributaries in 1999-2001. That assessment focused on the streams and immediate riparian areas. BES and the US Army Corps of Engineers signed an interagency agreement and co-funded a riparian and stream corridor assessment for Cedar Mill Creek in Portland. The report, *Riparian and Stream Habitat Assessment for Upper Cedar Mill Creek* (MWH, 2001), will help BES develop management strategies in the Cedar Mill Creek watershed to improve water quality and other watershed functions. The report covers Tualatin Basin drainage area that is not in the Fanno Creek watershed. Stream assessments have not been completed for Ash Creek, , and smaller tributary creeks.

Metro recently conducted wildlife habitat assessments throughout the region. The City's Bureau of Planning conducted general habitat inventories as part of the *Fanno Creek and Tributaries Conservation Plan* (1993) and *Southwest Hills Resources Protection Plan* (1992). There is no overall assessment of watershed functions and resources in terms of response to management activities and land uses in the watershed.

Many of these assessments and plans have made several recommendations for enhancing and restoring streams and the immediate riparian areas. BES has pursued and implemented some of these recommendations in the form of stream restoration and revegetation projects.

Key issues the Watershed Plan must address include the need for:

- A comprehensive assessment of upland areas and an analysis of causes and effects regarding watershed and stream functions, water quality, and habitat value and connectivity.
- Characterization of stormwater, water quality, and the interaction between stormwater routing, infiltration, and stream recharge in the watershed.
- Delineation of the historical stream patterns to determine the level of stream loss, better predict watershed functions, and determine restoration needs.
- A comprehensive soils and slope analysis, and characterization of the potential for stormwater routing and onsite management.

BES has a key interest in completing these tasks because it is a service provider bureau with an extensive network of stormwater and sanitary systems and is responsible for addressing key water quality, quantity, and other environmental and natural resource issues and regulations.

Water Quality – TMDLs and NPDES Regulations

Fanno Creek and its tributaries are subject to the regulations related to the Tualatin Basin total maximum daily loads (TMDLs) for phosphorus, bacteria, dissolved oxygen, and summer temperature. Tryon Creek is on the state of Oregon's 303(d) list for exceeding the water quality standard for summer temperature. Both watersheds are subject to the requirements of the City's municipal stormwater permit under the National Pollutant Discharge Elimination System (NPDES).

Extensive water quality data exist for Fanno Creek and its tributaries. These data have been analyzed to determine trends and to refine the monitoring program in 1996 and 2000. Water quality data have been available from one location on Tryon Creek since 1997. A limited analysis of these data was performed in 2000.

Actual stormwater water quality data in the watersheds are limited. Land use-based stormwater models show that two major stormwater outfalls in the Tryon Creek Watershed are major contributors of pollutants, especially total suspended solids (TSS).

Key water quality issues the Watershed Plan needs to address include:

- Development of water quality improvement strategies specific to TMDL requirements for Fanno Creek (phosphorus, bacteria, dissolved oxygen, and temperature), 303(d) requirements for Tryon Creek (a temperature management plan), and NPDES stormwater parameter requirements. This would include determining timelines for implementation and specific achievement goals and objectives.
  - Delineation, identification, characterization, and ranking of the hydrologic model units in terms of pollutant loading for TMDL, 303(d), and NPDES stormwater parameters

BES has a key interest in completing these tasks because it is a service provider bureau with an extensive network of stormwater and sanitary system, and is responsible for ensuring the City's compliance with all water quality regulations.

WATERSHED PLANNING PROCESS

The *Framework for Integrated Management of Watershed Health* outlines scientific principles, four watershed health goals, and a process for developing and implementing watershed management plans. The Watershed Plan was developed in accordance with these principles, goals, and process.

Figure 1 summarizes the four-phase, ten-step process. The steps represent a sequential assessment and decision-making approach to set watershed goals and objectives, characterize conditions, develop management solutions, and implement actions and assess their success. The circular nature of the process suggests that watershed management involves ongoing adaptive management and important feedback to ensure that watershed goals and objectives are achieved.

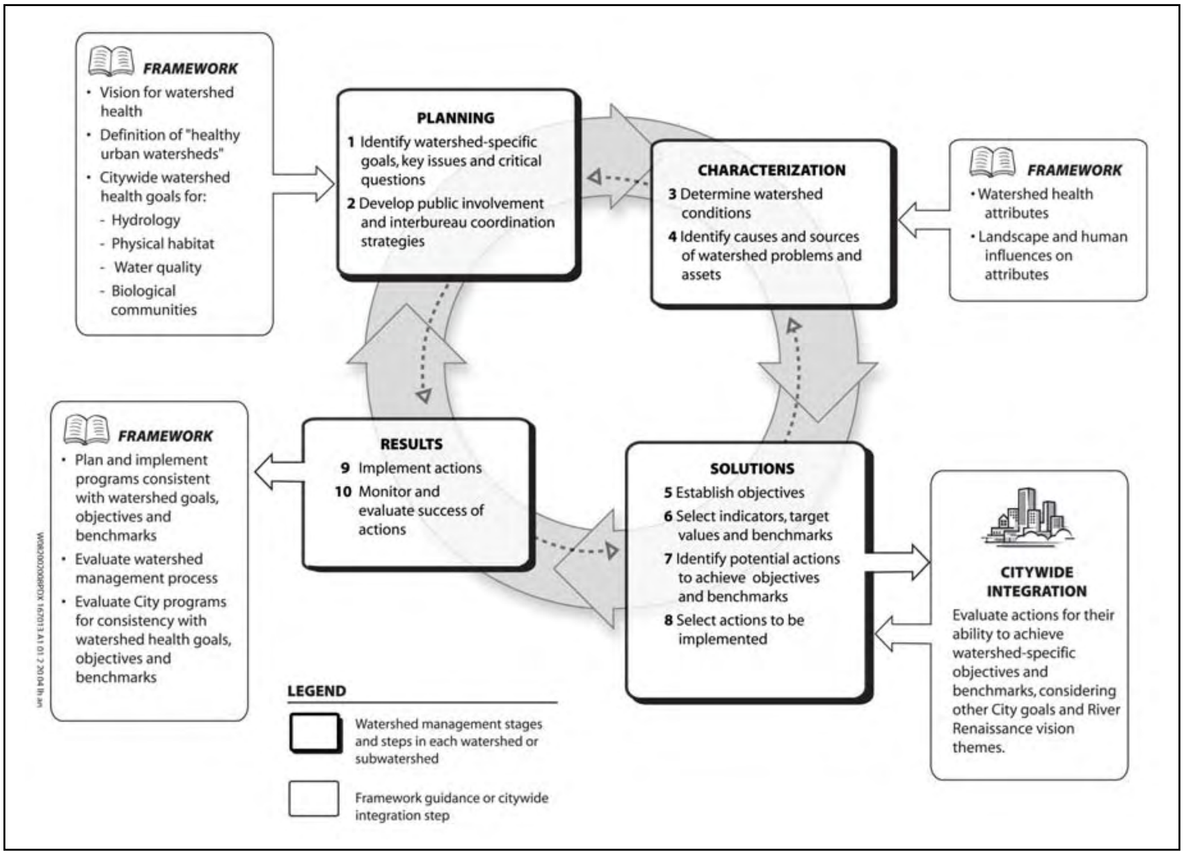

Figure 1
Watershed Management Process.

Phase 1: Planning—Step 1

The first step in the watershed planning process is to develop a Watershed Plan **scope** and **workplan** and identify **watershed-specific goals**, **key issues**, and **critical questions**.

Watershed Plan: Scope and Workplan

The scope and workplan for the Watershed Plan was completed in fall 2001 (see Appendix). In accordance with the Framework, the workplan provides detailed steps and tasks for conducting the watershed characterization and developing the Watershed Plan.

Preliminary Watershed Plan Goals and Objectives

The Framework outlines four goals for watershed health:

- **Hydrology**: Move toward historical flow conditions to protect and improve watershed and stream health, channel function, and public health and safety, while protecting infrastructure.

- **Physical Habitat**: Protect, enhance, and restore where possible aquatic and terrestrial habitat conditions, including sediment, to support key ecological functions and improved productivity, diversity, capacity, and distribution of native fish and wildlife populations and biological communities.
- **Water Quality**: Protect and improve surface water and groundwater quality, and meet or surpass state and federal water quality standards and regulations.
- **Biological Communities**: Protect, enhance, and restore where possible target aquatic and terrestrial species and biological communities to maintain biodiversity in Portland's watersheds.

In addition to the four watershed health goals, the City of Portland has five additional watershed planning goals:

- **Public Participation**: Incorporate public values into watershed plan development, implementation, and refinement, and support long-term community-wide commitment to improve and sustain watershed health.

- **Public Health and Safety**: Protect property and public health by planning, designing, building, operating. and maintaining sanitary sewer and stormwater infrastructure. This goal was incorporated into the hydrology goal later in the planning process.

- **Stewardship**: Maintain long-term community-wide commitment to improve and sustain watershed health.

- **Monitoring and Evaluation**: Assess watershed conditions and trends over time to ensure watershed plan goals and objectives are met.

- **Coordination and Consistency with Plans and Policies**: Meet watershed goals and objectives and achieve consistency with applicable plans and policies through active coordination and participation with other agencies and organizations.

These goals guided the overall development of the Watershed Plan. However, the goals needed to be tailored to each of the City's watersheds. The Fanno/Tryon Watershed Plan project goals and objectives listed below were established to provide an overall framework for developing the project workplan and to provide guidance for describing the critical watershed issues and key questions.

Watershed PlanProject Initial Goals and Objectives

GOAL I: WATER QUANTITY – PROTECT AND IMPROVE STREAMFLOWS FOR PUBLIC HEALTH AND SAFETY AND WATERSHED HEALTH.

Objectives:

- Characterize the watershed elements affecting streamflows and stormwater collection and conveyance.

- Provide infrastructure to support implementation of the Southwest Community Plan.

- Establish interrelationships between flows and stream stability, water quality, fish and wildlife habitat, infrastructure capacity, and property protection.

- Develop flow management and instream strategies to protect and improve the established interrelationships, including but not limited to:

    1. Reduction in the volume, velocities, and peak flow concentration time of storm runoff.

    2. Identification of areas and facility sites to help lessen the impact of stormwater runoff on infrastructure capacity and stream system functions.

    3. Development of a proactive maintenance plan for the storm sewer system to provide for proper functioning and adequate capacity.

    4. Identification, protection, and restoration/stabilization of stream channels.

    5. Identification and prioritization of all public and private stormwater outfalls into the stream and initiation of a program to retrofit these outfalls for water quality and discharge benefits.

    6. Identification of strategies to protect areas critical for groundwater recharge and provision of base flows in the stream channels.

    7. Identification of strategies to minimize stormwater runoff damage to existing public and private structures.

GOAL II: WATER QUALITY – PROTECT AND IMPROVE SURFACE WATER QUALITY AND MEET STATE AND FEDERAL WATER QUALITY STANDARDS.

Objectives:

- Characterize the Watershed Plan area for pollutant loading and develop a water quality management plan to meet the TMDLs for phosphorus, temperature, dissolved oxygen, and bacteria in the Fanno Creek Watershed.

- Develop a temperature management plan for Tryon Creek to meet the water quality standard for temperature.

- Develop a watershed-specific strategy to implement the City's Stormwater Program requirements in the Fanno and Tryon Creek Watersheds.

- Identify and prioritize additional water quality issues of concern in the Fanno and Tryon Creek Watersheds and develop strategies for addressing these issues.

GOAL III: HABITAT – SUPPORT KEY ECOLOGICAL FUNCTIONS, TARGET SPECIES, AND BIOLOGICAL COMMUNITIES BY PROTECTING, ENHANCING, AND RESTORING AQUATIC AND TERRESTRIAL HABITAT CONDITIONS.

Objectives:

- Develop a prioritized, scientifically supported strategy for protection, enhancement, and restoration of habitat conditions for the watershed. Strategy development will involve the following steps:

    1. Inventory physical characteristics affecting key biological communities, target species, and ecological functions in the watershed, taking into account the role of the watershed in the regional habitat "landscape."

    2. Characterize current habitat conditions in the context of biological communities, target species, and ecological functions in the watershed.

    3. Evaluate current and potential future habitat condition relative to identified standards, thresholds, and benchmarks for identified habitat attributes and indicators. Identify limiting factors for biological communities and target species relative to water quantity, habitat structure and productivity (e.g., food, nutrients), water quality, and other key watershed elements.

    4. Identify and evaluate actions and strategies to protect, enhance, and restore habitat conditions, taking into consideration potential interactions and interspecies impacts.

GOAL IV: – BIOLOGICAL COMMUNITIES – PROTECT AND RESTORE TARGET AQUATIC AND TERRESTRIAL SPECIES AND BIOLOGICAL COMMUNITIES TO MAINTAIN BIODIVERSITY IN THE WATERSHED, AND TO MEET APPLICABLE POLICIES AND REGULATORY REQUIREMENTS.

Objectives:

- Develop a method for identifying and prioritizing biological communities and target species to be addressed in the Watershed Plans. Steps will include:

    1. Establish an historical context for biological communities, species, ecological functions, and habitats for the watershed.

    2. Characterize current ecological functions, biological communities, species, and habitats in the watershed, and compare them to the historical context.

    3. Identify focal biological communities and species for purposes of watershed characterization, condition assessment, and strategy development/evaluation. Target communities and species will include but not necessarily be limited to: 1) species currently listed, or proposed to be listed, as sensitive, threatened, or endangered under state or federal law; 2) species that have a direct impact on listed or candidate species; 3)

species that perform key ecological functions and contribute to the “shaping” of the watershed (e.g., food sources, nutrient cycling, seed dispersal, predator/prey balancing); and 4) species or populations that are considered by qualified experts to be important in terms of their location in their range and/or other distinguishing factors.

4. Determine which biological communities and species will be targeted for protection, enhancement, and restoration in the Watershed Plan, taking into consideration compatibility with the urban setting. (Note: Different communities and species may be targeted in different parts of the watershed.)

- Ensure that the Watershed Plan recommendations will contribute toward sustaining healthy biological communities and target species, improving conditions for species at risk, and preventing future state and federal listing.

GOAL V: PUBLIC HEALTH AND SAFETY/INFRASTRUCTURE - ENSURE CONSISTENCY AND COMPATIBILITY BETWEEN CITY WATERSHED PLANS AND THE CITY’S INFRASTRUCTURE PROGRAMS TO PROTECT PUBLIC HEALTH AND SAFETY.

Objectives:

- Characterize current and projected flows and pollutant loads entering the sewer system and discharging from the sewer system to receiving waters.

- Inventory/map the existing and proposed sewer, stormwater, water, and roads infrastructure as an “urban indicator” as part of the watershed assessment process.

- Analyze the physical setting of existing and planned infrastructure to identify current or potential impairments to key watershed functions, conflicts with watershed goals and objectives, and known or anticipated public health or safety risks.

- Develop strategies to prevent and eliminate health and watershed impacts from subsurface/onsite sewage discharges in unsewered areas.

- Establish points of interaction and a clear coordination process to ensure that Watershed Plan information and recommendations are provided in a timely manner and used consistently and effectively to inform City capital and public facilities planning and implementation activities. These activities include: 1) update of City capital infrastructure programs (CIPs) and public facilities plans (PFPs); 2) development of CIP project requests; 3) CIP projects underway; and 4) bureau maintenance priorities and practices.

This goal was incorporated into the hydrology goal later in the planning process.

GOAL VI: PUBLIC INVOLVEMENT – INCORPORATE PUBLIC VALUES INTO WATERSHED PLAN DEVELOPMENT, IMPLEMENTATION, AND REFINEMENT.

Objectives:

- Provide and facilitate coordination and decision-making.

- Provide timely project information to the public.

- Provide opportunities for public input into the project.

- Present the final Fanno and Tryon Creek Watershed Plan and findings to the public.

- Provide and maintain connection to the River Renaissance process.

GOAL VII: STEWARDSHIP – MAINTAIN LONG-TERM COMMUNITY-WIDE COMMITMENT TO IMPROVE AND SUSTAIN WATERSHED HEALTH.

Objectives:

- Establish a strategy for promoting and carrying out community stewardship projects and programs in the watershed. The strategy will identify City services to be provided, establish targeted opportunities for stewardship activities, and identify partnerships and funding opportunities for implementation of community- and City-initiated projects.

- Develop a strategy to inform the public about watershed goals/objectives.

- Create partnerships with agencies, residents, and businesses.

- Establish an evaluation method for stewardship program effectiveness.

GOAL VIII: MONITORING AND EVALUATION - ASSESS WATERSHED CONDITIONS AND TRENDS OVER TIME TO ENSURE WATERSHED PLAN GOALS AND OBJECTIVES ARE MET.

Objectives:

- Develop and implement an integrated monitoring strategy for the watershed.

- Develop an adaptive management approach.

- Assign roles and responsibilities for monitoring, analysis, and compliance reporting.

A chapter on monitoring and evaluation was developed later in the planning process.

GOAL IX: COORDINATION AND CONSISTENCY WITH PLANS AND POLICIES – MEET WATERSHED GOALS AND OBJECTIVES AND ACHIEVE CONSISTENCY WITH APPLICABLE PLANS AND POLICIES, THROUGH ACTIVE COORDINATION AND PARTICIPATION WITH OTHER AGENCIES AND ORGANIZATIONS.

Objectives:

- Ensure that the watershed planning process is coordinated with, and takes into consideration, applicable plans and policies. Steps include, but are not limited to:

1. Identify key plans and policies in the watershed planning area as part of the watershed assessment and characterization process (e.g., River Renaissance, land use plans, urban renewal and redevelopment plans, transportation plans, and parks and recreation plans).

2. Identify and address potential conflicts and opportunities between the Fanno and Tryon Creek Watershed Plan alternatives and other plans and policies.

3. Establish points of interaction and a clear coordination process to ensure that Watershed Plan information and recommendations are provided in a timely manner and used consistently and effectively to inform development and updates of key City plans and policies.

- Establish prioritized strategies and actions for coordination with agencies and organizations within and external to the watershed to ensure that projects, programs, and plans are compatible and that watershed plan goals and objectives are met.

Critical Questions

Critical questions outline the issues the Watershed Plan should address. Their development was based partly on the key drivers for the plan discussed on pages 1-1 – 1-5, in collaboration with the Tryon/Fanno Advisory Committee, and on the goals and objectives above. Critical questions were developed for water quantity, water quality, habitat, biological communities, monitoring, coordination and consistency with other plans and policies, and stewardship. Appendix A contains the critical questions.

Phase 1: Planning—Step 2

The second step in the watershed planning process is to develop **public involvement and interbureau coordination strategies.**

The Watershed Plan project has maintained a strong public involvement component to keep citizens informed and involved and to fulfill the directives of the planning process. Citizen involvement is also required or suggested as a strategy in various local, state, and federal policies. For example, it is incorporated in the Oregon's statewide planning goals, Portland's *Comprehensive Plan*, and the Portland city code.

The variety of strategies used to involve and inform the public can be divided into the following five categories:

1. **Public Involvement in Specific Projects**. Public involvement activities are tailored to the particular circumstances and needs of each program or project. These activities include providing public information about key project issues, providing opportunities for the public to provide input on project elements and decisions, and enhancing existing and creating new long-term partnerships with neighborhood, business, environmental, and citizen interest groups.

2. **Information and Education**. Information and education focuses on the critical questions asked in the Watershed Plan that are of interest to landowners and/or residents affected by

recommended early actions and projects. Specific tools include websites, project information, fact sheets and brochures, special events, newsletters, community bulletin boards, presentations, and educational workshops.

3. **Environmental Stewardship**. Stewardship is essential to the long-term success of the Watershed Plan. Stewardship methods include supporting existing stewardship groups and cultivating new groups; identifying opportunities for businesses to become stewards; offering stewardship grants through BES's Community Watershed Stewardship Grant Program; offering incentives, technical assistance, and cost share programs; and offering resources for stewardship groups. Other tools to implement the Watershed Plan could include partnerships with other bureaus and agencies to provide additional resources for individuals and groups.

4. **Tryon/Fanno Advisory Committee**. The Tryon/Fanno Advisory Committee includes members of the community and representatives from other City bureaus. The Advisory Committee has been involved throughout the development of the Watershed Plan. Members provide critical information and review Watershed Plan documents and other products.

5. **Community Open Houses**. Providing an opportunity for the community to review watershed plan products and actions is a critical part of the watershed planning process. These events also serve as an opportunity for community watershed stewardship groups to present their restoration projects and other activities.

Phase 2: Characterization

The critical questions, developed in Phase 1, define the scope of the Fanno and Tryon watershed characterizations.

The characterizations describe historic (reference) and current watershed conditions and identify potential causes and sources of problems. Reference conditions represent the conditions for proper or suitable ecosystem function, regardless of urban development or other anthropogenic (i.e., human-caused) constraints.
The watershed characterizations include:

- Water Quality (including grid model)
- Hydrology and Infrastructure (including hydraulic and hydrology models)
- Habitat
- Biological Communities (including Ecosystem Diagnosis and Treatment (EDT) model)
- Public Involvement, Education, and Stewardship
- Watershed Overviews (describe landscape characteristics)
- Related Plans, Policies, and Programs

For more information on watershed conditions, see Chapters 1-11 of this document.

Specific watershed problems and assets were identified based on the watershed characterizations. These are provided in Chapter 14-17 of this document. These were used to develop watershed objectives in Phase 3.

Phase 3: Solutions

Watershed Objectives and Indicators

Watershed objectives have been developed for each watershed health goal. They are specific outcomes in watershed functions and conditions that will help achieve those goals. Specifically, watershed objectives specify desired changes in an ecological condition (e.g., reduce summer stream temperatures). Generally, several objectives must be met to achieve a given watershed goal.

Objectives were developed based on problems and assets identified in the watershed characterizations. Four criteria were used to categorize problems and assets into two tiers:

- critical limiting factors that impair ecological health functions
- ESA-listed species
- Regulatory requirements
- The degree to which a condition is well characterized and the link to watershed health is clear.

Tier 1 problems and assets, those meeting one or more of these criteria, were grouped under each of the four watershed health goals. Environmental indicators, readily measurable attributes that capture the condition or aspect of watershed health, were developed to concisely describe all of the Tier 1 problems and assets. Conditions of indicators were described at three scales: reach, subwatershed, and watershed. The scale depends on available data, type of analytical tools used, and the type of indicator. For example, water quality data are collected at only a few locations in Tryon Creek, and the sources of water quality problems often originate from a variety of sources throughout the watershed. Therefore, stream temperature is an indicator that applies at the watershed scale. Aquatic habitat indicators, however, such as channel form and stream complexity are described at the stream reach scale. These indicators were grouped under key attributes for each watershed health goal. Objectives were developed for each key attribute.

Objectives were developed to help return Tier 1 conditions to a condition consistent with the City’s watershed health goals. In addition, objectives for conditions that are functioning well were developed in terms of protecting the attributes and preventing degradation of the conditions that maintain the healthy conditions of that attribute.

For more information on watershed objectives see Chapter 18 of this document. For more information on indicators, see Chapters 19 and 20.

Targets/Desired Future Conditions and Benchmarks

Targets/Desired Future Conditions were set for all indicators. Target values are quantitative and qualitative. For example, water temperature of 64 F is a quantitative target, whereas “continuous corridor of mature native vegetation” is a qualitative target. Target conditions reflect the state of the watershed that will ultimately be necessary for the City to achieve the watershed health goals and objectives. They were generally not established at reference conditions levels. Instead, they take into account major physical, social or even economic constraints that are prevalent within an urban environment.

Watershed condition benchmarks will be developed over the next few years. Implementation benchmarks were established to help prioritize actions to improve conditions.

For more information on Targets and benchmarks, see Chapters 19 and 20 of this document.

Actions and Approach to Improve Watershed Health

An overall approach to prioritize implementation and to improve watershed health was developed for each watershed. This prioritization was based on the spatial distribution of watershed conditions, Tier 1 problems and assets, and watershed objectives. The approach describes 1) the priority problems to be addressed and attributes to be protected, and 2) the spatial and temporal arrangement of actions to improve watershed conditions and make progress toward the Watershed Plan goals and objectives.

Staff conducted field assessments to identify potential projects sites. A list of these sites and associated maps are provided by subwatershed in Chapters 21 and 22 of this document. Additional project sites will be identified through implementation and additional analysis and field work.

Phase 4: Results

Projects and programs will be implemented over the next 2-5 years in accordance with the watershed-specific approaches to improve watershed conditions and make progress toward meeting the Watershed Plan goals and objectives.

Individual projects will be monitored to gauge performance - monitoring overall watershed conditions will continue. Current monitoring is described in Chapters 1 and 2 of this document.

Additional research and analysis will be ongoing. The Watershed Plan and its supporting technical documents will be updated periodically to incorporate new data and analysis.

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CHAPTER 1

Fanno Creek Watershed Overview

INTRODUCTION

This chapter describes some of the landscape features, attributes, and functions of the overall Fanno Creek Watershed and subwatersheds. It also briefly reviews previous studies. The topics discussed include zoning and land use, physical characteristics, habitat and biological communities, public health and safety, water quality, sewerage infrastructure, and public involvement and stewardship.

The watershed characteristics described in this chapter are based mostly on information compiled in the Bureau of Environmental Services' (BES) Geographic Information System (GIS) database and on various studies performed by or for BES and other jurisdictions in the Portland area. The effective date of the information in the GIS database varies, based on the original source of the information.

The Map Atlas provided in the appendix includes detailed maps of the watershed and subwatersheds. These maps are referred to throughout the report.

WATERSHED AND SUBWATERSHED DESCRIPTIONS

The Fanno Creek Watershed, located within the southwest Portland metropolitan area, covers an area of approximately 20,259 acres, or 31.65 square miles (81.98 square kilometers). Approximately 4,529 acres are within Portland's city limits (Map 9-Fanno Creek Contour Maps by subwatershed, Map Atlas). This number does not include areas of northwest Portland along Skyline Boulevard and in the Cedar Mill Creek basin that drain into the Tualatin watershed. The remaining watershed area is within the jurisdictions of Durham, Tigard, and Beaverton. Unless otherwise noted, the data provided in this chapter apply to the portion of the watershed within Portland's jurisdiction.

The Fanno Creek Watershed is divided into eight subwatersheds, as shown on Table 1-1.

Table 1-1
Fanno Creek Subwatersheds

Subwatershed	Acres
Fanno Creek Mainstem	1,830.5
Pendleton Creek	230.4
Vermont Creek	758.1
Woods Creek	575.1
North Ash Creek	282.5
South Ash Creek	359.0
Red Rock Creek	413.1
Sylvan Creek	79.1
Total (Watershed)	**4,528.4**

The mainstem of Fanno Creek originates in the Tualatin Mountains of Southwest Portland and drains an area of approximately 1,831 acres within the city boundary (Map 1- Fanno Creek Aerial Map, Map Atlas). It begins at the intersection of SW 25th Avenue and Beaverton-Hillsdale Highway and flows in a westerly direction through West Portland along and north of Beaverton-Hillsdale Highway. Most of the drainage area to the mainstem is steep-sloping terrain on the north side of the creek (Map 9-Fanno Creek Slope Map, Map Atlas). Vegetation coverage is highest in the northern portions of the subwatershed, particularly around mainstem tributaries (Map 7-Fanno Creek Vegetative Cover Map, Map Atlas).

The mainstem of **Pendleton Creek** originates near SW Fairvale Court and Kanan Street and drains approximately 230 acres within the City's jurisdiction (Map 1-Pendleton Creek Aerial Map, Map Atlas). Pendleton Creek flows west for approximately 0.8 miles and exits the urban services boundary south of Beaverton-Hillsdale Highway around SW 65th Avenue. It then continues west until it joins the mainstem of Fanno Creek near the intersection of Beaverton-Hillsdale Highway and Oleson Road (BES 1999). The upper reaches of the creek are flat or moderately sloped, and become steeper at the base of the subwatershed (Map 9-Pendleton Creek Slope Map, Map Atlas). Vegetation cover is low in the upper reaches but increases around the creek in the lower portions of the subwatershed (Map 7-Pendleton Creek Vegetative Cover Map, Map Atlas).

Vermont Creek originates east of Gabriel Park and drains an area of approximately 758 acres within the City's jurisdiction (Map 1-Vermont Creek Aerial Map, Map Atlas). A southern tributary of Fanno Creek, it flows north paralleling SW 45th Avenue, and joins the mainstem near SW 45th Avenue and Caldew Street. Vermont Creek then flows west from this confluence for approximately 1.4 miles, exits the City of Portland's urban services boundary west of SW Shattuck Road north of SW Vermont Street, and continues west until it joins the mainstem of Fanno Creek west of Oleson Road. The upper portion of the creek, in particular the wooded area of Gabriel Park, is characterized by a moderate to steep steam corridor (Map 9-Vermont Creek Slope Map, Map Atlas) and unstable banks. From SW 37th to nearly 45th, near the off-leash area of Gabriel Park, the creek has been stabilized as part of the Gabriel Park Wet Meadows Project (BES Project number 5096). In general, stream segments in the lower portion of the creek below

SW 45th are slightly to moderately entrenched and have low sinuosity. As Map 7-Vermont Creek Vegetative Cover Map in the Map Atlas indicates, many locations along the creek have sparse vegetation and lack good riparian structure (BES 1999).

Woods Creek originates near SW Taylors Ferry Road and Capital Highway and drains an area of approximately 576 acres within the City's jurisdiction (784 acres total) (Map 1-Woods Creek Aerial Map, Map Atlas). The creek flows northwest for approximately 1.8 miles, crossing Multnomah Boulevard near SW 51st Avenue. It then flows in a westerly direction, exiting Portland approximately 350 feet north of SW Canby Street near 64th Place. Woods Creek continues west until it joins the mainstem of Fanno Creek west of SW Oleson Road near Oregon Episcopal School. The morphology of the stream varies from steep, highly entrenched channels in the upper reaches to moderately entrenched channels with moderate-to-low gradients in the lower segments (Map 9-Woods Creek Slope Map, Map Atlas). Streambank material consists primarily of silty loam and silty clay loam soils. Many areas along the stream corridor are undeveloped, with a well-vegetated riparian buffer and a multilayer canopy (Map 7-Woods Creek Vegetative Cover Map, Map Atlas). Woods Memorial Park, located within the Woods Creek subwatershed, provides about 33 acres of open space (BES 1999).

North Ash Creek originates near SW Bruegger Street and 50th Avenue and drains an area of approximately 282 acres within the City's jurisdiction (Map 1-North Ash Creek Aerial Map, Map Atlas). The creek flows west for approximately 0.8 mile until exiting the urban services boundary at SW Dolph Road (BES 1999). Steep or moderate slopes (Map 9-North Ash Creek Slope Map, Map Atlas) characterize much of the subwatershed. While vegetation cover varies widely throughout the subwatershed, southwest portions of the watershed exhibit higher coverage (Map 7-North Ash Creek Vegetative Cover Map, Map Atlas).

South Ash Creek originates just west of Interstate 5 (I-5) near SW 52nd Avenue and drains an area of approximately 360 acres within the City's jurisdiction (Map 1-South Ash Creek Aerial Map, Map Atlas). Stormwater from sections of I-5 drains into South Ash Creek. The creek flows in a westerly direction and exits the urban services boundary north of SW Dickson Place before joining Fanno Creek (BES 1999). Steep slopes characterize much of the upper reaches of the subwatershed, especially areas around mainstem tributaries (Map 9-South Ash Creek Slope Map, Map Atlas). Vegetation coverage is also highest along these tributaries, but riparian vegetation cover is generally greater than 25 percent (Map 7-South Ash Creek Vegetative Cover Map, Map Atlas).

Red Rock Creek originates just south of I-5 near Capitol Highway and drains approximately 413 acres within the City's jurisdiction (Map 1-Red Rock Creek Aerial Map, Map Atlas). Stormwater from sections of I-5 drains into Red Rock Creek. The creek flows in a westerly direction and exits the urban services boundary near SW 64th Avenue before joining Fanno Creek (BES 1999). Overall, the subwatershed is relatively flat (Map 9-Red Rock Creek Slope Map, Map Atlas). However, steep and moderate slopes dominate the western portion around Red Rock Creek and its tributaries. Vegetation cover is highest in the western half of the subwatershed, including along upper reaches of Red Rock Creek and its tributaries east of I-5 (Map 7-Red Rock Creek Vegetative Cover Map, Map Atlas).

Only a small portion of the overall **Sylvan Creek** drainage area is within the City of Portland. Sylvan Creek is generally addressed with the Fanno Creek mainstem (Map 1-Sylvan Creek Aerial Map, Map Atlas).

ZONING AND LAND USE

The major current land use in the watershed is single-family residential (Map 5-Fanno Creek Current Plan Maps by subwatershed, Map Atlas). Commercial land uses are located primarily along major transportation routes, including Beaverton-Hillsdale Highway, Capital Highway, I-5, and Barbur Boulevard.

Table 1-2
Base Zoning within the Fanno Creek Watershed

Land Use Category	**Current Area**	
	Acres	***Percentage***
Commercial	173	4
Multi-family Residential	353	8
Parks/Open Space	261	6
Single-family Residential	3,741	82
Insufficient Data	1	0
Total	**4,529**	**100**

Parks and Open Space

Parks and open space, including public and private property, total about 309 acres, or nearly seven percent of the watershed. Major parks and open space include Gabriel Park (84 acres), Woods Memorial Park (33 acres), and Mt. Calvary Cemetery (17 acres). As Table 1-3 shows, the Vermont Creek subwatershed has the most open space, most of which is Gabriel Park.

Table 1-3
Open Space in the Fanno Creek Watershed

Subwatershed	Open Space (Acres)*	Subwatershed Area (Acres)	Percentage of Subwatershed
Fanno Creek mainstem	71.0	1,830.5	3.9
Pendleton Creek	9.6	230.4	4.2
Vermont Creek	94.0	758.1	12.4
Woods Creek	45.2	575.1	7.9
North Ash Creek	6.1	282.5	2.2
South Ash Creek	24.5	359.0	6.8
Red Rock Creek	41.3	413.1	10.0
Sylvan Creek	17.2	79.1	21.7
Total (Watershed)	**308.9**	**4,528.3**	**6.8**

* Includes colleges, schools, and public and private open space

Public Land

Over 420 acres of public lands are located throughout the watershed (Table 1-4). About 46 acres are owned by Portland Public Schools, 238 acres by the City of Portland, and 6.6 acres by Metro. Portland Community College, located in the Red Rock Creek subwatershed, owns about 114 acres. The State of Oregon and Multnomah County own the remaining public land.

Table 1-4
Public Land in the Fanno Creek Watershed

Subwatershed	Public Land (Acres)	Subwatershed Area (Acres)	Percentage of Subwatershed
Fanno Creek mainstem	87.6	1,830.5	4.8
Pendleton Creek	12.8	230.4	5.6
Vermont Creek	99.4	758.1	13.1
Woods Creek	45.4	575.1	7.9
North Ash Creek	10.7	282.5	3.8
South Ash Creek	27.8	359.0	7.8
Red Rock Creek	137.6	413.1	33.3
Sylvan Creek	101.0	79.1	1.4
Total (Watershed)	**422.5**	**4,528.3**	**9.3**

Environmental Zones

Portland has established environmental overlay zones to protect and conserve significant natural resources. The environmental overlay zones are the City's tool to implement the City's Comprehensive Plan Goal 8 and also Statewide Land Use Planning Goals 5, 6, and 7. They are based on extensive natural resource inventories that cover areas within the City's jurisdiction.

There are two types of environmental overlay zones, which currently affect approximately 20,000 acres citywide. The **environmental protection zone** has been established in areas that have very high-value resources and function. Development is allowed in the protection zone only in very limited circumstances. The **environmental conservation zone** also limits development in important resource areas. Development is allowed if it meets certain standards and approval criteria to ensure that impacts on significant resources are avoided, limited, and mitigated (City of Portland, Title 33, Chapter 33.430).

Environmental protection zones overlay about 255 acres and conservation zones overlay 434 acres in the Fanno Creek watershed (Map 4-Fanno Creek Current Plan Existing E-Zones Maps by subwatershed, Map Atlas). Overall, about 15 percent of the watershed is within environmental zones (Table 1-5).

Table 1-5
Environmental Conservation Zones in the Fanno Creek Watershed

Subwatershed	C Zone (acres)	P Zone (acres)	Total E Zones (acres)	Subwatershed Area	Percentage of Subwatershed
Fanno Creek mainstem	177.7	119.3	297.0	1830.6	16.2
Pendleton Creek	37.4	7.0	44.4	230.5	19.3
Vermont Creek	26.5	47.4	73.9	758.1	9.8
Woods Creek	60.2	65.0	125.2	575.5	21.8
North Ash Creek	22.3	3.9	26.3	282.5	9.3
South Ash Creek	48.7	8.7	57.4	359.0	16.0
Red Rock Creek	61.5	3.5	65.0	413.1	15.7
Sylvan Creek	0.0	0.7	0.7	79.1	0.9
Total (Watershed)	**434.3**	**255.6**	**689.9**	**4528.4**	**15.2**

Population

The current (US Census 2000) population of the Fanno Creek Watershed within Portland’s city limits is about 28,000. This figure does not include population in the Skyline West and Cedar Mill Watersheds. Map 3- Fanno Creek neighborhood and population maps by subwatershed are located in the Map Atlas.

Public Easements

Extensive public right-of-way and public utility easements exist in the Fanno Creek Watershed for a number of highways, roads, streets, and utilities (such as sanitary and water). These easements are used by agencies and the public, according to the terms of each individual easement.

Recreation

The Fanno Creek Watershed offers valuable recreational opportunities. City parks including Gabriel Park and Woods Park provide opportunities for passive and active recreation..

Cultural Resources

No information has been compiled about cultural and archeological resource identification or inventory.

Transportation Network

Major transportation routes in the watershed include the Beaverton-Hillsdale Highway, Capital Highway, Interstate 5, and Barbur Boulevard. Surface streets are distributed throughout the watershed. As Table 1-6 shows, there are over 130 miles of surface streets. Nearly half of the paved streets are uncurbed. Unimproved streets, which include dirt roads and unimproved rights-of-way, total 19 miles.

Streets and highways, particularly those with high traffic volumes, accumulate pollutants from automobiles. Rain picks up these pollutants and carriers them to streams, where they degrade aquatic habitat for fish and other wildlife. Streets and highways also prevent infiltration, increasing stormwater runoff.

Table 1-6
Miles of Surface Streets in the Fanno Creek Watershed

Subwatershed	Paved/Uncurbed	Paved/Curbed	Other	Unimproved	Total
Fanno Creek mainstem	17.3	20.8	10.7	4.8	53.6
Pendleton Creek	1.5	2.9	0.4	1.8	6.5
Vermont Creek	7.5	9.5	3.0	2.6	22.5
Woods Creek	6.7	4.7	1.3	4.3	17.0
North Ash Creek	3.4	3.9	0.2	1.3	8.9
South Ash Creek	5.9	3.2	0.5	1.6	11.2
Red Rock Creek	3.2	3.5	0.3	2.2	9.1
Sylvan Creek	1.2	0.7	0.0	0.7	2.6
Total (Watershed)	**46.7**	**49.1**	**16.5**	**19.1**	**131.4**

Source: City of Portland, Bureau of Transportation

PHYSICAL CHARACTERISTICS

Fanno Creek Watershed’s topographic features, soils, and hydrology, and impervious surfaces are closely linked to the physical stability of the watershed and stream systems. They are critical in defining channel morphology and structure, slope stability, and soil erosion and sediment transport.

Overall, steep slopes, soils that are slow to infiltrate rainfall, and impervious surfaces result in a “flashy” urban stormwater system. This has severe impacts on the streams, such as channel incision, undercutting of streambanks, landslides and erosion, and sediment deposition (Booth 1991).

Topography

The elevation in Fanno Creek varies from near mean sea level (msl) to 1,070 feet above msl. The lowest point is around 15 feet above msl. The highest point (1,070 feet) is above Council Crest, which is in Portland's West Hills. The Palatine Hills and Mt. Sylvania each summit around 900 feet above msl. Steep slopes are prevalent throughout the watershed (Map 9-Fanno Creek Contour Maps by subwatershed, Map Atlas).

Soils

Geology and soils in the Fanno Creek Watershed are described in the *Natural Resources Evaluation of Pollution Reduction Facilities and Stream Tributaries in Portland's Tualatin Basin* (Scientific Resources, Inc. 1991), and in the *Tualatin Basin Water Quality Management Plan* (BES 1990). Portland's West Hills encompass three primary geologic units: 1) Columbia River Basalt, 2) Boring Lava, and 3) Portland Sands. Columbia River Basalt occupies the central portion of the West Hills and is the most common geologic unit in the Portland area. This formation is of Miocene origin, resulting from outpouring of lava from fissures in the earth's crust. Columbia River Basalt is a dark gray to black, dense, crystalline basalt that is columnar-jointed in places (BES 1990).

Boring Lava occurs on the west flank of the Portland Hills, and Portland Sands is in the lower Fanno Creek Watershed and the Tualatin River floodplain. Another geologic unit, Portland Hills Silt, occurs primarily above 600 feet elevation (BES 1990).

Five soil types are represented in the watershed, but the Cascade series covers approximately half of the watershed. Cascade soils are clay loam, which is moderately to highly erodible and contains relatively high levels of phosphorus. Soils in the watershed typically have a dense subsurface layer (fragipan) that restricts water flow and root penetration. The existence of the fragipan creates low permeability, resulting in saturation and erosion during the rainy season. Soil erodibility in the Fanno Creek Watershed is moderate or high relative to other soils of western Oregon. Phosphorus availability is high in contrast to other regional soils (BES 1990).

Given the urban nature of the upper watershed, the Natural Resources Conservation Services (NRCS) now designates soils in the upper watershed as Urban Land. This designation reflects the increase in impervious surfaces throughout the watershed (Green 1983).

The hydrologic soil group classification for most of the soils in the watershed is Type C, a sandy clay loam (Map 6-Fanno Creek Soils Maps by subwatershed, Map Atlas). Soils with this classification have a slow infiltration rate and high runoff potential. Isolated pockets of Type D (clay loam) soils, which are even slower to drain, also exist in the watershed. The low permeability of the soils limits the function of onsite stormwater and septic systems. Low soil permeability also affects the watershed hydrology through limited soil absorption and interflow, resulting in higher runoff peaks and lower base flows.

Hydrology

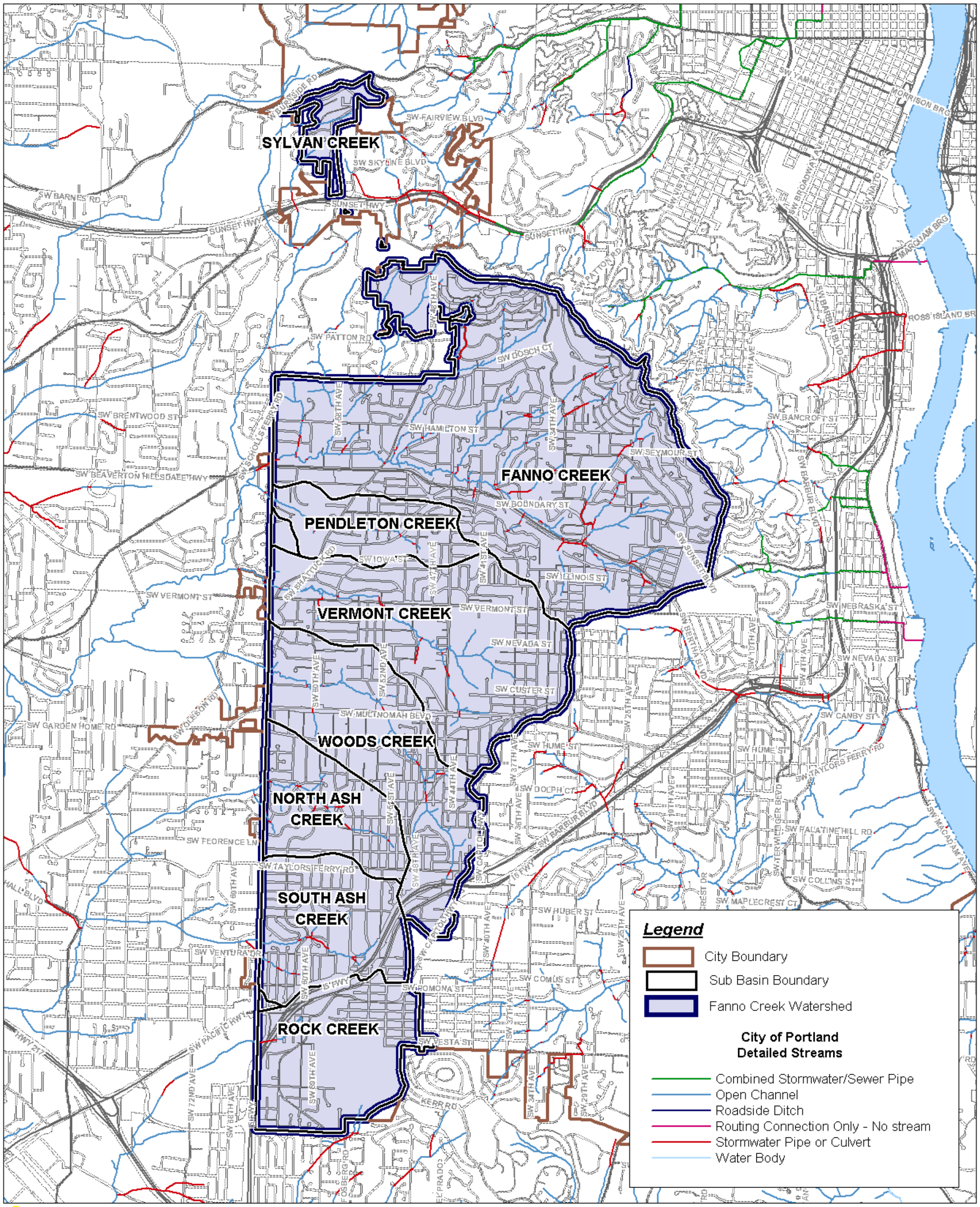
There are about 23 miles of open stream channel in the Fanno Creek Watershed Approximately an additional five miles of streams are in culverts or pipes (Table 1-7). Figure 1-1 depicts the streams within the watershed.

Table 1-7
Miles of Streams in the Fanno Creek Watershed

Subwatershed	Open Channel	Pipe or Culvert	Other
Fanno Creek mainstem	12.2	2.7	0.02
Pendleton Creek	0.9	0.2	0
Vermont Creek	3.5	0.6	0
Woods Creek	2.9	0.4	0
North Ash Creek	1.3	0.3	0
South Ash Creek	1.2	0.3	0
Red Rock Creek	0.4	0.1	0
Sylvan Creek	0.3	0.0	0
Total	22.6	4.6	0.02

Source: City of Portland, OR, Bureau of Planning. Note: numbers include creek tributaries.

Figure 1-1
Detailed Streams in Fanno Creek Watershed



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Intact stream networks contain streams that flow year-round and streams that flow only part of the time. Streams that flow throughout the year containing both base flow and storm flow are classified as perennial or permanent. Ephemeral streams flow only in response to specific storms. Intermittent streams flow for periods of weeks or months, usually during rainy and snowmelt seasons.

Headwater springs or drainages serve as the source of a stream network. Within any intact stream system and river network, headwater streams make up most of the total channel length. Headwater streams are critically important to the health of the watershed. These small intact streams provide natural flood control, recharge groundwater, trap sediments and pollution from fertilizers, recycle nutrients, create and maintain biological diversity, and sustain the biological productivity of downstream rivers, lakes, and estuaries (Meyers et al. 2003).

Impervious Surfaces

Impervious surfaces include streets, parking lots, and buildings. Impervious surfaces comprise nearly 1,500 acres, or 33 percent, of the Fanno Creek Watershed (Table 1-7 and Map 8-Fanno Creek Impervious Area Maps by subwatershed, Map Atlas). Impervious surface coverage is highest along major transportation corridors such as Beaverton-Hillsdale Highway, Capitol Highway, I-5, and Barbur Boulevard.

Impervious surface cover in this range reduces rainfall infiltration, increases stormwater runoff volume and velocity, and degrades stormwater quality. In addition, Booth (1991) found that impervious cover greater than 10 percent reduces urban stream stability, resulting in unstable and eroding stream channels. These changes can degrade instream habitat and affect fish communities.

Table 1-7
Impervious Surface Cover in the Fanno Creek Watershed

Subwatershed	Impervious Area (Acres)	Subwatershed Area (Acres)	Percent of Subwatershed
Fanno Creek mainstem	593.2	1,830.5	32.4
Pendleton Creek	61.3	230.4	26.6
Vermont Creek	238.7	758.1	31.5
Woods Creek	192.6	575.1	33.5
North Ash Creek	91.8	282.5	32.5
South Ash Creek	139.8	359.0	38.9
Red Rock Creek	160.1	413.1	38.8
Sylvan Creek	20.2	79.1	25.5
Total (Watershed)	**1,497.7**	**4,528.3**	**33.1**

Hydraulic Characteristics

The Fanno Creek Watershed is generally characterized by steep slopes and stream gradient. The physiographic characteristics of the watershed and its soil types affect the stream systems in terms of channel incision, undercutting of stream banks, landslides, and exposed sewer pipes.

In addition to open stream channels, stormwater is conveyed through culverts and storm pipes. Approximately 298,311 lineal feet of storm drainpipes are within the watershed (Map 11-Tryon Creek Existing Storm Sewer Maps by subwatershed, Map Atlas) (BES 1999). As the watershed develops further, the ability of these conveyance elements to handle storm events designated as the City's basic level of service (conveyance of the 10-year storm) will be affected. BES completed a basin hydrologic analysis in 1997 that models current and future conditions and conveyance capacity (BES 1997). New ydrologic and hydraulic models were developed to characterize the watershed for this document.

Urbanization in the Fanno Creek Watershed has caused increased runoff from impervious surfaces (see next section), resulting in higher velocities in stream channels and fast rise in streamflow during storm events. This "flashiness" in hydrology weakens bank stability, resulting in erosion and loss of riparian vegetation (Booth 1991). Channelization of many reaches of Fanno Creek and its tributaries, such as the reach adjacent to the Beaverton-Hillsdale Highway, places greater erosive force on areas immediately downstream. This causes a much higher velocity than would have occurred given the natural meandering pattern of the creek. Confinement of the creeks also causes downcutting, resulting in deeply incised channels and sediment loss from undercut banks.

Flow data for the upper Fanno Creek Watershed have been available from the U.S. Geological Survey (USGS) gage at SW 56th Street since January 1990. Analysis of these data indicates that the median average daily flow for water years 1998 and 1999 is 2.75 cubic foot per second (cfs), or approximately 2.75 inches of water across a 10-foot-wide creek flowing at 1 foot per second. Over 80 percent of the flows during this period of record are less than 5 cfs.

Review of data from the Durham USGS gage, downstream of SW 56th Street on Fanno Creek, indicates that flows at SW 56th Street are between 5 percent and 10 percent of the total flow at the downstream end of the watershed (Aroner 2000).

Modeling of surveyed sections of the Fanno Creek mainstem and limited portions of Vermont Creek and Columbia Creek, a tributary in the Fanno Creek subwatershed, indicates that a number of culverts are undersized for the design storms. Along Fanno mainstem, culverts towards the upper end of the watershed generally appear to have enough capacity to pass even the projected 100-year flows. Culverts toward the bottom of the watershed appeared undersized for 5-year or larger storms (BES 1999).

Climate and Rainfall

Climate in the Fanno Creek Watershed is characterized by mild, wet winters and cool, dry summers. Temperatures range from 25 to 45 degrees Fahrenheit (°F) in the winter and from 70 to 90°F in the summer. The Fanno Creek Watershed receives approximately 35 inches of precipitation per year; 98 percent of that total is rain. Almost all the rain falls between October and May (Johnson 1987).

BES maintains a system of rain gages as part of its Hydrologic Data Retrieval and Acquisition (HYDRA) system. Rain data from a HYDRA gage at the Portland Community College (PCC)

Sylvania campus were used to develop rainfall characteristics in the Fanno Creek Watershed (Table 1-8). Design storms were defined for modeling future conditions and testing conveyance system capacity.

Table 1-8
Annual Average Rainfall at PCC Sylvania Campus

Characteristic	Winter (November -May)	Summer (June - October)	Annual
Rainfall (days per season or year)	98	42	140
Rainfall depth (inches per season or year)	25.7	9.5	35.2
Rain events per season or year	36	24	60
Volume per event (inches)	0.74	0.38	0.59
Peak intensity (inches per hour)	0.094	0.091	0.093
Duration per event (hours)	40	20	34
Dry time between storms (hours)	75	155	107

Source: HYDRA system data compiled by BES Modeling Group
Note: Period of record, 1976-1998.

HABITAT AND BIOLOGICAL COMMUNITIES

The *Fanno Creek and Tributaries Conservation Plan* (City of Portland, 1992) includes site-specific inventories conducted throughout the watershed. These inventories describe general habitat types and conditions at each site.

In summer 1996, Fanno, Vermont, and Woods Creeks were walked from the urban services boundary (parallel to SW 66th Street) upstream to their headwaters. The objective of these studies was to provide detailed information about the status of existing stream and riparian resources within the City's portion of the Fanno Creek Watershed (BES 1998). Study elements included riparian and wildlife surveys, instream (fish) habitat surveys, evaluation of streambank erosion potential, and stream classification using the Rosgen methodology (Rosgen 1994).

The Columbia Creek tributary, located near SW 59th and Hamilton, was walked from its confluence with Fanno Creek to a sample point 135 feet upstream. Information about Pendleton, North Ash, and South Ash Creeks was obtained by accessing them at selected points (BES 1998).

The results of these studies are integrated into the discussion below.

In 2001, the Oregon Department of Fish and Wildlife (ODFW) conducted habitat surveys in Fanno Creek mainstem, North Ash Creek, South Ash Creek, Woods Creek, and Vermont Creek (ODFW 2001). Development has altered physical habitat throughout all these subwatersheds.

Riparian corridors are generally narrow, and vegetation cover is low along much of the creeks. The creeks do not substantively interact with the floodplain. Instream habitat suffers from lack of structure (e.g., wood and boulders) and from high proportions of sand and silt substrate, contributed by eroding stream banks resulting partly from increased stormwater runoff from upland development. Numerous culverts severely constrain fish passage. These surveys are discussed in detail in Chapter 8: Habitat and Biological Communities.

The Metro Council is currently working through a three-step planning process to conserve, protect, and restore urban streams and waterways, riparian areas, and significant upland wildlife habitat. During the first step, Metro developed an inventory of approximately 80,000 acres of regionally significant fish and wildlife habitat areas in the region. Approximately 30,000 of those acres (including land and water bodies) are in the City of Portland.

For the habitat inventory, Metro developed a model to identify and rank regionally significant wildlife habitat resources based on habitat characteristics, including habitat patch size, habitat interior area, connectivity and proximity to water resources, connectivity and proximity to other patches, habitats of concern, and habitats for unique and sensitive species. Riparian resources were ranked according to their contribution to specific riparian functions. These functions include microclimate and shade, stream flow moderation and water storage, bank stabilization, sediment and pollution control, large wood and channel dynamics, and organic material sources. The level of function was based primarily on the distance of the landscape feature from the water body, as recommended in current scientific literature.

Metro also identified regionally significant habitats of concern, based on three criteria. The first criterion recognizes regionally at-risk, or priority, conservation habitat types, such as oak savannas, grasslands, and wetlands. These habitats are at risk because they formerly covered much more extensive areas, and they tend to be declining in quality where they still remain. The second criterion recognizes the extraordinary and unique value of riverine islands and delta areas. The third criterion recognizes known habitat patches that provide unique or critical wildlife functions. To qualify as a habitat of concern, an area needs to meet only one of the three criteria (Metro 2002).

The second step is an economic, social, environment and energy (ESEE) analysis. For this analysis, Metro classified habitat into six classes, under two main categories: Riparian/wildlife and Upland Habitat. Each class covers a geographically discrete portion of the inventory, and may include riparian and/or wildlife functions and also may be a habitat of concern. Class 1 Riparian/wildlife and Class A Upland Wildlife Habitat are the highest value. Impact areas are areas where land uses and activities such as development, landscaping, and road construction may impact fish and wildlife habitat. In the third step, Metro will work with stakeholders throughout the region to formulate an integrated habitat protection and restoration program that is balanced with other goals for the region.

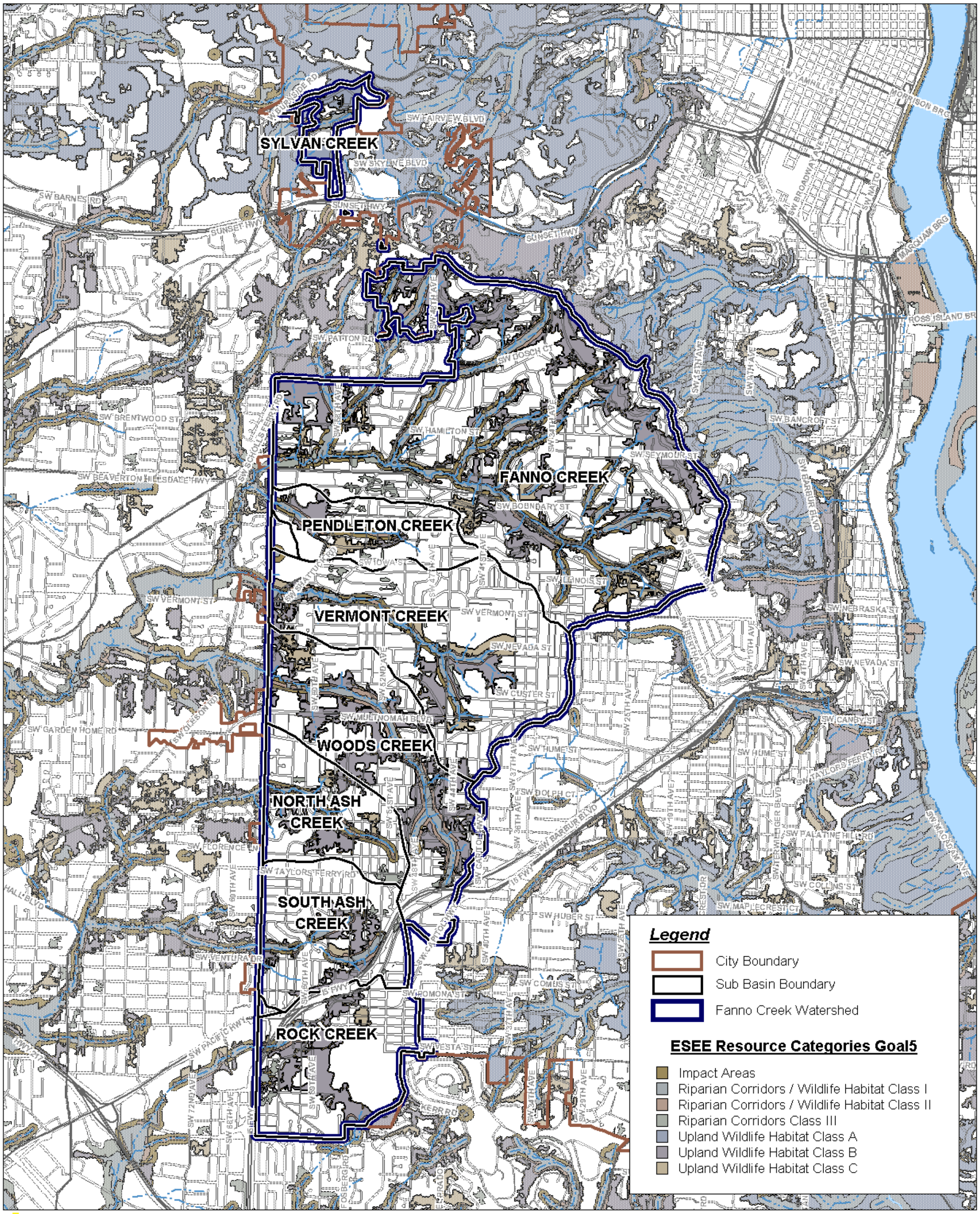
The inventory and ESEE analysis identified over 292 acres as Class 1 Riparian/Wildlife Habitat and over 36 acres as Class A Upland Wildlife Habitat in the Fanno Creek watershed, as shown in Table 1-9. Figure 1-2 shows the areas designated within each resource category in the watershed.

Table 1-9
Metro Fish and Wildlife Classes for the Fanno Creek Watershed

Subwatershed	Fish and Wildlife Habitat Classes	Acres
Fanno Creek (mainstem)	Impact Areas	229.2
	Riparian Corridors / Wildlife Habitat Class I	154.6
	Riparian Corridors / Wildlife Habitat Class II	69.2
	Riparian Corridors Class III	29.9
	Upland Wildlife Habitat Class A	0.8
	Upland Wildlife Habitat Class B	289.8
	Upland Wildlife Habitat Class C	43.2
Pendleton Creek	Impact Areas	21.2
	Riparian Corridors / Wildlife Habitat Class I	9.0
	Riparian Corridors / Wildlife Habitat Class II	7.4
	Riparian Corridors Class III	4.2
	Upland Wildlife Habitat Class B	16.4
	Upland Wildlife Habitat Class C	8.7
Vermont Creek	Impact Areas	46.4
	Riparian Corridors / Wildlife Habitat Class I	37.1
	Riparian Corridors / Wildlife Habitat Class II	20.1
	Riparian Corridors Class III	7.2
	Upland Wildlife Habitat Class B	53.4
	Upland Wildlife Habitat Class C	20.2
Woods Creek	Impact Areas	59.5
	Riparian Corridors / Wildlife Habitat Class I	43.7
	Riparian Corridors / Wildlife Habitat Class II	32.8
	Riparian Corridors Class III	0.8
	Upland Wildlife Habitat Class B	131.0
	Upland Wildlife Habitat Class C	9.8
North Ash Creek	Impact Areas	34.2
	Riparian Corridors / Wildlife Habitat Class I	9.3
	Riparian Corridors / Wildlife Habitat Class II	9.1
	Riparian Corridors Class III	7.5
	Upland Wildlife Habitat Class B	33.0
	Upland Wildlife Habitat Class C	6.9
South Ash Creek	Impact Areas	23.3
	Riparian Corridors / Wildlife Habitat Class I	17.9
	Riparian Corridors / Wildlife Habitat Class II	9.1
	Riparian Corridors Class III	3.8
	Upland Wildlife Habitat Class B	36.4
	Upland Wildlife Habitat Class C	2.7
Red Rock Creek	Impact Areas	26.8
	Riparian Corridors / Wildlife Habitat Class I	12.0

	Riparian Corridors / Wildlife Habitat Class II	6.5
	Riparian Corridors Class III	4.0
	Upland Wildlife Habitat Class A	0.0
	Upland Wildlife Habitat Class B	73.1
	Upland Wildlife Habitat Class C	4.8
Sylvan Creek	Impact Areas	8.3
	Riparian Corridors / Wildlife Habitat Class I	8.5
	Riparian Corridors / Wildlife Habitat Class II	0.1
	Upland Wildlife Habitat Class A	35.4
	Upland Wildlife Habitat Class C	0.1
Total (Watershed)		**1718.6**

Figure 1-2
ESEE Resource Categories Goal 5



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Vegetation

In the remaining forested areas of the Fanno Creek Watershed, the most common native conifer species are western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and Douglas fir (*Pseudotsuga menziesii*). Red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), and Oregon ash (*Fraxinus latifolia*) are the most common deciduous trees. Native shrubs include vine maple (*Acer circinatum*), Indian plum (*Oemleria cerasiformes*), and salmonberry (*Rubus spectabilis*). Sword fern (*Polystichum munitum*) and lady fern (*Athyrium filix-femina*) are common along each of the streams. In addition to these native species, numerous ornamental trees, shrubs, and groundcovers have been introduced to the watershed. Some of these, such as Himalayan blackberry (*Rubus discolor*) and English ivy (*Helix hedera*), are invasive and have crowded out native plants in many areas (BES 1998).

Vegetation provides many benefits to the watershed. Vegetation moderates hydrology, shades streams helping to keep them cool, and stabilizes stream banks and slopes helping to prevent erosion. Vegetation also provides woody material to streams, which creates critical refuge for fish.

Riparian Corridor

The *Fanno Creek Resource Management Plan* (BES 1998) evaluated high-quality and sensitive habitat in terms of assessed riparian conditions, instream habitat conditions, bank erosion potential, and landslide data. The assessment concluded that riparian habitat quality was most limited in reaches where development has encroached on the riparian corridor and native vegetation has been removed. This encroachment has caused subsequent erosion and/or bank failure, leading to further vegetation loss. Native vegetation has been replaced by invasive plants that tend to prevent development of habitat and structural diversity. Habitat enhancement opportunities were identified to the extent possible within the project scope.

In 2001, ODFW conducted a habitat survey for Fanno Creek and four of its tributaries within the City's boundaries on a reach-by-reach basis (ODFW 2001) (Map 14-Fanno Creek ODFW survey map 1 by subwatershed, Map Atlas). Table 1-10 summarizes percentage of stream shading, which was one of the survey parameters.

Table 1-10
ODFW 2001 Stream Shade Survey

Creek Name	**Average Shade (%)***
Fanno Creek Mainstem	90 %
Vermont Creek	91 %
Woods Creek	85 %
North Ash Creek	89 %
South Ash Creek	90 %

* Averages are for reaches within the City

The Fanno Creek Watershed is typical of other rapidly urbanizing watersheds in the Pacific Northwest. Development within the riparian corridor has resulted in the conversion of conifer and mixed forests to parking lots, streets, landscaped yards, apartments, houses, and commercial buildings. The loss of mature forests, together with conversion of forest floor to impervious surfaces, has caused some dramatic changes in Fanno Creek's hydrograph. Degraded riparian conditions contribute to increased stream flow and channel incision, streambank instability, erosion and sedimentation, and lack of shading, which increases water temperature. The eroding sediment (Map 12-Fanno Creek Pollution-Total Suspended Solids Maps by subwatershed, Map Atlas), and associated phosphorus (Map 13-Fanno Creek Pollution-Total Phosphorus Maps by subwatershed, Map Atlas) are delivered directly to the stream instead of being filtered and stored in the riparian zone (BES 1998).

Floodplain

The Fanno Creek mainstem floodplain area has been hardened, filled, and topped with impervious surfaces, effectively reducing historical floodplain interactions. Floodplain interaction, the process by which streams overflow into surrounding flat riparian areas, creates habitat, deposits nutrients, and accommodates high stream flows. Fanno Creek mainstem is more confined than other key tributaries, particularly Ash Creek and Woods Creek. Within Fanno Creek mainstem, stream reaches from Patton Creek upstream to Kelly Creek at SW 39th Drive are believed to provide the greatest existing floodplain functions.

Floodplain functions are believed to be relatively intact in portions of South Ash Creek and Woods Creek (lower and middle reaches). North Ash Creek, Red Rock Creek, and Pendleton Creek generally exhibit impaired floodplain conditions. The US Federal Emergency Management Agencie's floodplain map covers Fanno Creek within the City up to SW 56th.

Aquatic Biology

Fish

BES sampled fish populations in the upper Fanno Creek Watershed in 1993 (Harza Northwest 1994). This survey was a component of a project that resulted in preliminary designs for water quality improvement and stream enhancement between SW 56th Street and 45th Street. Fish sampling was conducted along 680 feet of Fanno Creek mainstem, upstream of Shattuck Road, during both high- and low-runoff periods. The objective of the high-flow survey, conducted in June 1993, was to determine the relative abundance and species composition of fish inhabiting the upper portion of the creek. Sampling during September was conducted to determine whether cutthroat trout used the creek during the low-flow period. Presence during the fall would indicate a resident cutthroat population, in contrast to a proto-anadromous population, which would spawn in the upper creek during high flows and return to the Tualatin River or lower creek during low flows. Both populations are thought to exist in the Fanno Creek Watershed (BES 1998).

In order of dominance of both biomass and numbers, four fish species were identified in the June 1993 sampling: reticulate sculpin (*Cottus perplexus*), redside shiner (*Richardsonius balteatus*), cutthroat trout (*Salmo clarki*), and peamouth (*Mylocheilus caurinus*). Each is native to Oregon and commonly found in small headwater streams. Hughes and Gammon (1987) classified fish species in the Willamette River based on their tolerance to organic pollution, temperature, and warm water. These authors assigned ratings of tolerant to reticulate sculpin, intermediate to redside shiner, and intolerant to cutthroat trout.

Cutthroat trout were also captured during the fall survey, and juveniles were captured during both surveys. These studies indicate that salmonid spawning does occur in the upper portion of Fanno Creek, and there appears to be a year-round (although small) trout population (Harza Northwest 1994).

The presence of juvenile and adult cutthroat trout in the upper reaches of Fanno Creek indicates that temperature and water quality are not entirely preventing production. However, the low numbers of fish suggest that other factors, such as low summer flows, sedimentation, and lack of suitable substrate for prey organisms, may also be limiting population size. Small populations are more vulnerable to competition, predation, disease, and catastrophic events, and they would not be expected to persist in the upper watershed unless overall habitat conditions can be improved. No data exist for other Fanno Creek tributaries (BES 1998).

In 1991-2001, ODFW conducted fish, habitat, and water quality surveys in 16 tributaries of the lower Tualatin River, including lower Fanno and Ash Creeks. The study was a follow up to similar worked conducted by ODFW from 1993-1995. Compared with the 1993-1995 surveys the number of native species collected decreased and the number of introducted species increased. All of the biotic integrity scores were either marginally impaired or severely impaired.

In 1999-2001, ODFW conducted fish Index of Biotic Integrity (IBI) evaluations and surveys to assess the biological integrity of Fanno Creek and Ash Creek. The results show that Upper Fanno Creek is severely impaired much of the year. Ash Creek is severely impaired year round. Coho are assumed to inhabit the greater portion of Fanno Creek mainstem up to river mile 11.5. Steelhead (winter-run) have been observed in upper Fanno Creek and Ash Creek. Cutthroat were observed in middle and upper Fanno Creek year round.

Macroinvertebrates

BES also collected benthic macroinvertebrates during in 1993 (Harza Northwest 1994). Modified Rapid Bioassessment Protocols (Plafkin 1989; Wisseman 1996) were used to “score” the Fanno Creek samples. Results of this analysis indicated a benthic community low in diversity and number of organisms. Lack of suitable substrate, particularly cobble and gravel size particles, was the primary reason for the poor macroinvertebrate scores. The predominantly silt substrate in Fanno Creek limits periphyton growth, which in turn limits the food base for “scraper” organisms such as snails and caddisflies (BES 1998).

Wetlands

Wetlands were observed in three units in Fanno Creek, three units in Vermont Creek, eight units in Woods Creek, and along lower Columbia Creek, a small tributary in the Fanno Creek subwatershed (BES 1998). Palustrine forests and scrub-shrub wetlands in are thought to provide breeding and/or foraging habitat for over 200 wildlife species (Brown & Caldwell et al. 1975). Herbaceous wetlands are expected to provide breeding habitat for approximately 70 species and foraging for 178 wildlife species (BES 1998).

Wildlife

The wildlife species most commonly observed in the Fanno Creek Watershed are those that can tolerate a wide variety of habitats and the disturbance usually associated with residential and commercial development. Based on the geographic location of the watershed, amphibians that may be present include the northwestern salamander (*Ambystoma gracile*), long-toed salamander (*A. macrodactylum*), ensatina (*Ensatina eschscholtzii*), Pacific chorus frog (*Hyla regilla*), and others. Garter snakes (*Thamnophis* species) are common. At least 100 bird species are thought to use the Fanno Creek watershed. Black-capped chickadees (*Parus atricapillus*), American robins (*Turdus migratorius*), song sparrows (*Melospiza melodia*), Steller's jays (*Cyanocitta stelleri*), American crows (*Corvus brachyrhynchos*), and northern flickers (*Colaptes auratus*) are commonly seen. Great blue herons (*Ardea herodias*) and mallards (*Anas platyrhynchos*) are observed occasionally. Mammals typical of the Fanno Creek watershed include raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), skunks (*Mephitis mephitis*), muskrats (*Ondatra zibethicus*), and fox squirrels (*Sciurus niger*). Several species of mice, shrews, moles, and voles are also likely to occur (BES 1998).

PUBLIC HEALTH AND SAFETY

No chronic public health advisories are linked to contamination of Fanno Creek or its tributaries. Advisories may be posted if any unacceptable bacterial contamination of the water occurs as a result of sanitary sewer breakage or leaks. However, such episodes are rare.

Flooding

A major flood event occurred in the Portland metropolitan area in February 1996. It surpassed the conveyance capacity of numerous facilities citywide. Although the flood event caused severe landslide, streambank, and streambed damage to Fanno Creek and its tributaries, it did not cause any significant flooding or property damage in the watershed (BES 1998). The effects of flooding will likely remain the same in the future. Changing hydrologic conditions may continue to cause damage to the stream system in the watershed, but may not result in any significant flooding of properties. Property damage resulting from excessive rainfall could occur in the form of landslides on steep and unstable slopes and along stream channels.

WATER QUALITY

Fanno Creek and its tributaries within the City of Portland are small headwater streams located within an urban environment. They exhibit many of the characteristics typical of urban streams, including altered flow patterns and degraded water quality. These characteristics result from changes in hydrology and increased pollutant loadings from urban development.

Water quality concerns in the Fanno Creek watershed include:

- During a typical year, Fanno Creek does not meet the state standard for water temperature in the summer. Water temperature is influenced by the lack of riparian vegetation and consequent lack of shade the vegetation provides. High stream temperatures can also be caused by stormwater runoff coming from impervious surfaces exposed to sunlight.
- High bacteria levels are likely caused by both human sources (sanitary sewer overflows, illegal sanitary connections and dumping to storm drains, and failing septic systems) and non-human sources (birds, dogs, cats, raccoons, and other animals).

- Low dissolved oxygen (DO) levels occur, caused by a combination of increased water temperature and the decay of organic matter in the stream.
- High silt and sediment loads from upland urban sources and stream channel erosion.
- High phosphorus levels during storm events.
- Generally, stormwater runoff from major transportation corridors and areas with concentrations of commercial land uses exhibit higher potential pollutant loads.

Detailed descriptions of water quality conditions are provided in Chapter 5: Water Quality – Fanno Creek Watershed.

Beneficial Uses

Pursuant to Oregon Administrative Rules (OAR), the Oregon Water Resources Commission establishes the beneficial uses of waters of the state. Numeric and narrative water quality standards are designed to protect the most sensitive beneficial uses. DEQ has identified Fanno Creek and tributaries in the Tualatin Basin as waters of the state. Table 1-11 identifies the designated beneficial uses for Fanno Creek and its tributaries.

Table 1-11
Beneficial Uses of Fanno Creek

Public Domestic Water Supply
Private Domestic Water Supply
Industrial Water Supply
Irrigation
Livestock Watering
Anadromous Fish Passage
Salmonid Fish Rearing
Salmonid Fish Spawning
Resident Fish and Aquatic Life
Wildlife and Hunting
Fishing
Boating
Water Contact Recreation
Aesthetic Quality
Hydro Power
Commercial Navigation and Transportation

Under the federal Clean Water Act, DEQ established total maximum daily loads (TMDLs) for bacteria, dissolved oxygen, and temperature in 2001.

Given the naturally high phosphorus content of the watershed soils (Map 6-Fanno Creek Soil Types Maps by subwatershed, Map Atlas), increased bank erosion leads to high phosphorus contributions to Fanno Creek and the Tualatin River.

Loss of riparian vegetation and associated groundcover increases the erosive force of raindrops, increases stream temperature, and results in less filtration of pollutants in runoff. (BES 1998).

Monitoring Data

Fixed-Station Water Quality, Temperature, and Flow Monitoring

BES has been monitoring the water quality of Fanno Creek and its tributaries since 1989, at ten locations within the city's Tualatin Basin drainage area (Table 1-12). The monitoring includes Fanno Creek, all its tributaries that eventually flow into Fanno Creek in Washington County, and Cedar Mill Creek. It is conducted year-round, with more intense monitoring during the phosphorus TMDL compliance period of May-October. Four of the eight sites are monitored weekly and all ten were monitored monthly. Water quality analyses included 13 field and laboratory parameters. Table 1-13 summarizes the water quality monitoring.

Table 1-12
Current BES Water Quality Monitoring Sites for Fanno Creek Watershed

Site	Description	Start	Frequency
1	10610 SW 63rd St. (South Fork Ash Creek)	5/30/90	Monthly
2	6315 SW Dolph Dr. (North Fork Ash Creek)	5/30/90	Monthly
3	SW Oleson Rd. (Woods Creek)	5/30/90	Monthly
4	SW Dover Ln. & Oleson Rd. (Vermont Creek)	5/30/90	Weekly (May-Oct) then Monthly
5	6900 SW Beaverton-Hillsdale Hwy. (East Main Channel)	7/20/93	Weekly (May-Oct) then Monthly
6	4916 SW 56th St. (Fanno main channel)	5/30/90	Weekly (May-Oct) then Monthly
7	3975 SW Beaverton-Hillsdale Hwy. (Fanno main channel)	5/30/90	Monthly
8	NE Forest Heights (Cedar Mill Creek)	5/30/90	Monthly

Table 1-13
Water Quality Monitoring Summary for Fanno Creek Watershed

Parameter	Reporting Limit Units	Monitoring Frequency
Ammonia Nitrogen	1 mg/l	Monthly
Nitrate-Nitrogen	0.1 mg/l	Monthly
Nitrite–Nitrogen	0.01 mg/l	Monthly
Ortho Phosphorous	0.02 mg/l	Monthly
Total Phosphorous	0.03 mg/l	Monthly
Total Solids	1 mg/l	Monthly
Total Suspended Solids	1 mg/l	Monthly
E. Coli	2 CFU/100ml	Monthly
Temperature	Degrees Celsius	Hourly (May-Oct)
Dissolved Oxygen	0.1 mg/l	Monthly
Turbidity	1 NTU	Monthly
pH	0.1	Monthly
Conductivity	1 micro ohms/cm	Monthly

BES provides matching funds to the U.S. Geological Survey to operate and maintain a streamflow monitoring station on Fanno Creek at SW 56th Avenue in Portland. BES’s water quality and flow monitoring program has an average annual cost of about $60,000. One of BES’s stormwater monitoring stations for the City’s National Pollutant Discharge Elimination System (NPDES) stormwater program is also located on Fanno Creek at SW 56th Avenue. Stormwater data from this station provide another avenue for assessing water quality related to specific storm events and can be compared with BES's routine monitoring.

BES maintains and operates continuous temperature monitoring gages at SW 56th Avenue and on the Woods Creek tributary. These gages record temperature on an hourly basis between May and October each year. BES’s water quality data are available on the EPA STORET data network.

BES conducted storm sampling at two stormwater source locations from September 2001 through January 2002 to estimate pollutant loadings from various land uses. The sampling indicated that stormwater loads are generally higher from commercial and transportation land uses. The data was used to analyze stormwater quality and to calibrate the pollutant load model in the watershed, which in turn helped with the selection and application of appropriate best management practices (BMPs) and strategies to meet TMDL requirements.

Water Quality Data and Trend Analyses

WQHYDRO Consulting evaluated BES's monitoring program in the Tualatin Basin and analyzed the water quality data. The resulting reports (Aroner 1996 and 2000) have been provided to DEQ, and the analyses and recommendations have been instrumental in streamlining Portland’s monitoring program. The current monitoring plan reflects nearly all of WQHYDRO’s recommendations.

The WQHYDRO summary by Aroner (1996) points to the continued need to improve stormwater management practices and reduce pollutant runoff to surface waters in the Fanno Creek Watershed.

The 2000 WQHYDRO analyses and evaluation gave high marks to BES's monitoring program for its coverage, comprehensiveness, and success in meeting its objective. The analyses show that most of the water quality monitoring stations show improving water quality trends. Of particular importance is the **significantly decreasing trend** for total suspended solids and total phosphorus. This trend is important for achieving compliance with the phosphorus TMDL and decreasing water quality constituents that enter the stream attached to total suspended solids such as nutrients and metals (Aroner 2000).

Additional water quality analyses were conducted for this report (see Chapter 6 Water Quality Tryon Creek Watershed).

Inter-laboratory Sample Split

Designated Management Agencies (DMAs) are agencies with responsibilities for TMDLs within the Tualatin River Basin. Each year, the DMAs take part in an inter-laboratory quality control sample split with eight other laboratories that are analyzing samples from the Tualatin Basin, in order to supplement their individual quality control programs. The results are submitted each year to DEQ. BES's water pollution control laboratory performs well in the sample split.

Modeling

BES has developed models to characterize water quality in the Fanno Creek Watershed through the pollutant loadings and the current characterization work uses the following two models:

- The GIS/GRID model, developed by BES, is a GIS-based model that estimates potential pollutant loadings based on land use, topography, impervious area, vegetation, soil type, slope, and precipitation. The model uses 100-foot by 100-foot grid areas as the basis for analysis.

The MIKE 11 (DHI) model is a physically based water quality model that uses the same grid system as the BES GIS/GRID model. It is coupled with the MIKE SHE (DHI) hydrologic/hydraulics model.

Chapter 5: Water Quality, and technical memos in appendices F and G of this report further describe the water quality modeling for the Fanno Creek Watershed.

Upland Stormwater Management

Portland's NPDES stormwater program is critical with respect to water quality in the watershed. The program was initiated in 1990 in response to federal regulations that require municipalities to control pollutants in stormwater discharges to the maximum extent practicable. DEQ issued the City's municipal NPDES stormwater permit in September 1995. The City continues to implement activities and report on accomplishments in annual compliance reports to DEQ. A new MS4 permit was issued to the City in July 2005.

SEWERAGE INFRASTRUCTURE

The sewerage infrastructure in the Fanno Creek Watershed comprises the sanitary system and the stormwater system, as described below. The descriptions are based on the City of Portland's *Public Facilities Plan* (BES 1999).

Sanitary System

Fanno Creek Mainstem

The Fanno Creek sanitary sewer basin (Map 10-Fanno Creek Existing Sanitary Sewer System Map, Map Atlas) serves an area extending from the Sunset Highway (U.S. 26) on the north to the Portland Golf Club on the south. The western boundary is Scholls Ferry Road, and the eastern boundary is SW 33rd Avenue. The 2,480-acre basin is dominated by single-family residences. The basin is hilly, with significant ravines and flat areas at the lower end near the Portland Golf Club. The collection system in the basin comprises gravity pipelines to convey flows to the recently constructed (2001) Fanno Creek Pump Station, located near the Portland Golf Club.

The sanitary sewer system within the basin is 99 percent separated from the stormwater system. The remaining one percent consists of small pockets that drain into either the Sheridan or Carolina combined sewer basin.

Sewage flows generated in the basin can be discharged to three different treatment plants. Primarily, the low-elevation areas are gravity fed to the Fanno Creek Pump Station. From there, sewage is routed to the SW 31st Avenue and Multnomah Boulevard diversion structure through a pressure line under SW Garden Home and Multnomah Blvd. At the diversion structure, the flows can either be routed to the Columbia Boulevard Water Treatment Plant (CBWTP) or the Tryon Creek Water Treatment Plant (TCWTP). During an emergency, the flows can also be diverted to Clean Water Services' Durham Wastewater Treatment Plant.

The main trunkline for the basin originates just east of the basin boundary at the existing Cambridge Village Pump Station and generally follows an alignment that parallels Fanno Creek. The trunkline varies from 12 inches in diameter at the Cambridge Village Pump Station to 33 inches (550 gallons per minute [gpm]) at the Fanno Creek Pump Station. Local collectors enter the trunkline from the north at SW 30th Place, SW 39th Drive, SW Shattuck Road, and SW Seymour Drive. The sanitary trunk flows to the Fanno Creek Pump Station.

SANITARY SYSTEM DEFICIENCIES

For a modeling analysis in the public facilities planning process, the basin boundary was extended past the USB to the west to encompass all the area that is tributary to the location of the new pump station. Many of the pipes in the model are identified as deficient due to their shallow depth. Although in the basin, their locations are not near the modeled system. Consequently, it is not clear that the shallow deficiencies actually represent problems in this area. It is also possible that the terrain of the basin results in above-ground basements that are not directly affected by the hydraulic grade lines generated by shallow pipe. Model results for the

2015 condition indicate one non-shallow deficiency at the west end of the basin, north of SW Beaverton –Hillsdale Highway (BES 1999).

In addition, flow monitoring indicated inflow/infiltration (I/I) in the Metzger (see below) and lower Fanno Creek basins. Inflow is water that is dumped into the sewer system through improper connections, such as downspouts. Infiltration is groundwater that enters the sewer system through leaks in the pipe.

PROJECTS RECOMMENDED IN PORTLAND'S PUBLIC FACILITIES PLAN

The BES 1999 Public Facilities Plan (PFP) does not recommend any projects for the Fanno Creek basin. However, it does recommend modifying the basin's boundaries to reflect changes in flow resulting from the new Fanno Creek Pump Station. In addition, based on flow monitoring data, additional I/I reduction studies and/or efforts were recommended and are currently underway in the lower Fanno subbasins.

Metzger Basin

The Metzger sanitary sewer basin is located in the southwest corner of Portland's urban services boundary. The 1,858-acre basin is dominated by residential land use. Four collectors discharge flow from the Metzger basin: Woods Creek, North Ash Creek, South Ash Creek, and Red Rock Creek. All of the collectors convey flow west to the Clean Water Services collection system, which then conveys the flow to the Durham Wastewater Treatment Plant.

SANITARY SYSTEM DEFICIENCIES

Based on projected 2015 conditions, there are no hydraulic deficiencies within the Metzger basin. The PFP analysis showed a significant portion of the Woods Creek collector to be hydraulically deficient; however, further review determined that all pipe segment deficiencies were associated with shallow pipe depths rather than capacity limitations.

PROJECTS RECOMMENDED IN PORTLAND'S PUBLIC FACILITIES PLAN

The PFP does not recommend any projects for the Metzger basin. However, it does recommend modifying the basin's boundaries; because the Woods Creek collector sewer now flows to the new Fanno Creek Pump Station, the collector and its tributary area should be added to the existing Fanno Creek basin.

Stormwater System

Fanno Creek Mainstem

The Fanno Creek subwatershed stormwater basin (Map 11-Fanno Creek Existing Storm Sewer Map, Map Atlas) drains an area of approximately 2,100 acres. The basin contains approximately 147,500 lineal feet (approximately 30 miles) of storm drain pipes and 200 culverts, ranging in diameter from 12 inches to one 96-inch pipe under a building in the low reaches of the mainstem. Thirteen stormwater detention facilities and one sedimentation box at SW 38th and 39th Avenues are currently in operation in the basin. Approximately 27 miles of extremely confined channels, with very little sinuosity, are bounded by steep banks entrenched in the floodplain.

Stormwater System Deficiencies

Oversteepened bank angles (60 percent), poor bank vegetation, and moderate root densities suggest that Fanno Creek and its tributaries have a moderate to high bank erosion potential, resulting in unstable channels with grade control problems and severe channelization over much of their length.

Model results (1997) indicate that 41 segments of Fanno Creek mainstem exceed seven feet per second (fps) under existing conditions. Fifty segments will exceed seven fps under the future condition (2040); of these, 30 will exceed eight fps and 12 will exceed 10 fps. Stream velocities in excess of seven fps for a two-year storm are a serious threat to the natural balance in the conveyance of the flows. The combination of erosive processes, lack of vegetation, and low to moderate stream gradient results in excessive deposition of fine sediments, which degrades water quality and instream aquatic habitat.

Hydraulic modeling within the drainage basin indicates that a number of culverts along the mainstem and its tributaries are undersized for the 25-year design storm under existing and future conditions. However, only a few of the culverts appear to be threatened, most significantly where Fanno Creek passes under SW Shattuck Road.

Culverts on the upper end of Fanno Creek mainstem tend to have sufficient capacity to convey the projected 100-year flows; however, the culverts toward the lower end of the watershed appear to be undersized for the five-year or larger storm.

A serious known problem area in the past has been the apartment area upstream of SW 56th Avenue. The area between SW 59th Avenue and the Raleigh West Shopping Center has the potential for flooding low-lying apartments.

Chapter 3: Hydrology, discusses system deficiencies in more detail.

PROJECTS RECOMMENDED IN PORTLAND'S PUBLIC FACILITIES PLAN

The PFP and *Fanno Creek Resources Management Plan* identify over 100 improvement projects within the Fanno Creek stormwater basin, such as stream bank stabilization, pollution reduction facilities, culvert replacement, and various stewardship projects. Because of the large number of identified improvements, a predesign study is recommended for the entire Fanno Creek mainstem and Fanno Creek tributaries. The system-wide predesign will evaluate the appropriate projects necessary to meet federal mandates and improve the conveyance of Fanno Creek and its tributaries. It will build on the work already accomplished in the RMP and PFP by developing additional field data, enhancing the existing hydraulic model (including water quality modeling), and evaluating upland areas for water quality and quantity improvements.

Several of the projects recommended in the PFP were listed in the Capital Improvement Projects (CIP) list and have been completed. These projects include the SW 45th Avenue and Shattuck Road stream rehabilitation project (CIP No. 6487), which, because of cumulative impacts, includes rehabilitation of segment of Fanno Creek upstream to SW 39th and participation in the design and construction of the Tower site project with Clean Water Services (CIP No. 6409).

Vermont Creek

Vermont Creek and its tributaries drain approximately 758 acres total (Map 1-Vermont Creek Aerial Map, Map Atlas). The Vermont Creek subwatershed stormwater basin is primarily developed, with low-density residential and some commercial uses at SW Vermont St and 45th Ave. The 84-acre Gabriel Park is a prominent feature within the Vermont Creek subwatershed.

The Vermont Creek subwatershed contains 15 major stormwater culverts, ranging from 18 to 72 inches in diameter (Map 11-Vermont Creek Existing Storm Sewer Map, Map Atlas). Major culverts are located at four locations along the mainstem: at SW 45th Avenue near Caldew; near the intersection of SW 52nd Avenue and Vermont; north of the Vermont crossing at SW 55th Avenue; and north of the Vermont crossing at SW Shattuck. The southern tributary, paralleling SW 45th between Multnomah Boulevard and Caldew Street, contains major culverts at two locations.

SYSTEM DEFICIENCIES

Erodible banks with sparse vegetation characterize streambanks in the Vermont creek subwatershed. Field evaluations have confirmed erosion problems; approximately 30 percent of the streambank had active erosion problems influenced primarily by entrenched, incised, and oversteepened banks. Stream velocities in excess of 7 fps in the lower portion of the creek also contribute to bank erosion through scour.

The combination of erosive processes, lack of streambank vegetation, and low –to moderate stream gradient results in excessive sediment deposition within the channel, which in turn degrades water quality and impairs instream aquatic habitat.

Hydraulic modeling of the drainage basin has identified nine areas where the flow associated with the 25-year design storm exceeds culvert capacity.

Woods Creek

Woods Creek and its tributaries (Map 1-Woods Creek Aerial Map, Map Atlas) drain approximately 575 acres. The Woods Creek subwatershed stormwater system contains 12 major stormwater culverts, ranging from 18 to 60 inches in diameter (Woods Creek Existing Storm Sewer Map, Map Atlas). Major culverts are located at four locations along the mainstem: at Taylors Ferry Road, 470 feet west of SW Capitol Highway; SW Marigold Drive and 45th Drive, 40 feet east of SW 47th Avenue; SW Garden Home Road, 150 feet east of SW 49th Avenue; SW Multnomah Boulevard 350 feet west of SW 51st Avenue and along Canby Street at 59th and 60th Avenues.

SYSTEM DEFICIENCIES

The moderate to high bank erosion potential is influenced mostly by oversteepened bank angles, moderate to poor bank surface protection provided by vegetation, and moderate to poor root densities.

Some upland areas in the headwater areas are especially susceptible to landslides. Most notably, numerous streamside slump blocks and shallow-rapid landslides in the upper reach of Woods Creek indicate a large area of deep-seated instability. Further evidence of instability are tension cracks on nearby roadways and side slopes above the channel.

Almost the entire length of Woods Creek is subject to velocities in excess of 7 fps during the two-year design storm, indicating that erosion will be further exacerbated.

Hydrologic modeling has identified four culverts along Woods Creek with insufficient capacity to convey the flow associated with the 25-year storm event.

PUBLIC INVOLVEMENT AND STEWARDSHIP

Partnerships among agencies and community groups provide opportunities for collaborative restoration, education, and technical assistance for local area residents. Free programs such as Naturescaping for Clean Rivers are available to help raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. BES's Community Watershed Stewardship Grants Program supports community groups and citizens working to improve the health of Portland's watersheds.

Partners in the Fanno Creek mainstem subwatershed include SW Neighborhoods, Inc. (SWNI), Bridlemile Creek Stewards (BCS), Fans of Fanno, Southwest Watershed Resource Center, Portland Parks and Recreation, BES Revegetation Program, SOLV, schools, and congregations. Active stewardship sites include St. Andrews Presbyterian Church parking lot bioswales (St. Andrews members and BES), Trillium Creek restoration (neighbors, SOLV, congregations, BES), Albert Kelly and Hamilton Parks stream restorations (BCS, Parks, BES, neighbors), and Bridlemile School Naturescape and bioswales (students, teachers, parents). BES's Revegetation Program has several active sites along the mainstem and in Hamilton Park.

No neighborhood groups are active in the North Ash Creek subwatershed. However, potential partners include SWNI, Smith Elementary School, and the Ash Creek Neighborhood Association.

The Pendleton Creek subwatershed has no active 'friends" group. However, other community groups provide collaborative restoration and education opportunities for local area residents. Active projects include the Cedar Sinai Park/Hayhurst Neighborhood Watershed Project and the Naturescaped courtyard project at Hayhurst Elementary School.

BES staff members coordinate restoration and education opportunities for students at PCC Sylvania in the Red Rock Creek subwatershed. Other partners in this subwatershed include BES's Community Watershed Stewardship Grants Program and Revegetation Program. Active stewardship sites include the PCC Sylvania Habitat Restoration Project at Ball Creek and a BES revegetation project along Red Rock Creek. Potential partners could include the Far Southwest and West Portland Park Neighborhoods.

Partners in the South Ash Creek subwatershed include SWNI, Crestwood Neighborhood Association, Dickinson Park Stewards, Portland Parks and Recreation, and BES's Revegetation Program. Active stewardship sites include Dickenson Park, Taylor's Woods, and a stormwater swale at a private residence.

The Southwest Watershed Resource Center is located in the Vermont Creek subwatershed. The resource center is currently helping launch Friends of Vermont Creek, in partnership with SWNI, Americorps, and Portland Parks and Recreation. BES’s stewardship projects in this subwatershed include the Maplewood Elementary asphalt removal and Naturescaping projects, and the Gabriel Park Adopt a Plot Program (in coordination with Portland Parks and schools). BES's Revegetation Program has active projects at Gabriel Park, the Birkland site, and private properties along Vermont near SW 49th Avenue.

Neighborhood groups are active in the Woods Creek subwatershed. Partners include SWNI, Crestwood Neighborhood Association, Friends of Woods Park, Portland Parks and Recreation, and BES’s Revegetation Program. BES’s Revegetation Program has active sites at April Hill and Woods Park, in cooperation with homeowners just downstream of April Hill.

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CHAPTER 2

Tryon Creek Watershed Overview

INTRODUCTION

This chapter describes some of the landscape features, attributes, and functions of the overall Tryon Creek Watershed and subwatersheds. It also briefly reviews previous studies. The topics discussed include zoning and land use, physical characteristics, habitat and biological communities, public health and safety, water quality, sewerage infrastructure, and public involvement and stewardship.

The watershed characteristics described in this chapter are based mostly on information compiled in the Bureau of Environmental Services' (BES) Geographic Information System (GIS) database and on various studies performed by or for BES and other jurisdictions in the Portland area. The effective date of the information in the GIS database varies, based on the original source of the information.

The Map Atlas provided in the appendix includes detailed maps of the watersheds and subwatersheds. These maps are referred to throughout the report.

WATERSHED AND SUBWATERSHED DESCRIPTIONS

The Tryon Creek Watershed in southwest Portland covers an area of approximately 4,142 acres, or 6.5 square miles (Map 9-Tryon Creek Contour Maps by subwatershed, Map Atlas). Approximately 3,058 acres (nearly 80 percent of the watershed) is within Portland's city limits. The remaining watershed area is within the jurisdictions of Multnomah County, Clackamas County, and the City of Lake Oswego.

The Tryon Creek Watershed is bounded by the Fanno Creek Watershed to the west and north, Stephens Creek to the north, the Willamette River drainage basin to the east, and Lake Oswego to the south. The watershed is intersected by =highways and surface streets including Interstate 5, Highway 99, Boones Ferry Road, Taylors Ferry Road, and Terwilliger Boulevard.

The Tryon Creek Watershed is divided into three subwatersheds: Tryon Creek mainstem, Arnold Creek, and Falling Creek (Table 2-1).

Table 2-1
Tryon Creek Subwatersheds

Tryon Creek Subwatersheds	Acres
Tryon Creek Mainstem	3,083.7
Arnold Creek	775.2
Falling Creek	283.6
Total	4,142.5

The Tryon Creek mainstem is about seven miles long and flows southeast from its headwaters near Multnomah Village (just north of Interstate 5 and Highway 99) to its confluence with the Willamette River in Lake Oswego at the Highway 43 crossing (Map 2-Tryon Creek Subbasin Map, Map Atlas). The Tryon Creek mainstem subwatershed is about 3,083 acres.

Arnold Creek joins Tryon Creek at the Boones Ferry Road crossing (Map 2-Arnold Creek Subbasin Map, Map Atlas). The Arnold Creek subwatershed comprises about 775 acres.

Falling Creek joins Tryon Creek at SW 26th Avenue and Taylors Ferry Road (Map 2-Falling Creek Subbasin Map, Map Atlas). The Falling Creek subwatershed is about 283 acres.

Other smaller tributaries flow into Tryon Creek both within and outside Portland's city limits.

ZONING AND LAND USE

Zoning

The predominant base zone in the Tryon Creek Watershed is single-family residential (Table 2-2 and Map 5-Tryon Creek Current Plan Maps by subwatershed, Map Atlas). Commercial and multi-family residential land uses are concentrated along major transportation corridors, including Interstate 5 and Barbur Boulevard.

Table 2-2
Base Zoning within the Tryon Creek Watershed

Land Use Category	**Current Area**	
	Area (acres)	***Percentage***
Commercial	127	3
Multi-family Residential	185	5
Parks/Open Space	592	14
Single-family Residential	2,289	55
Outside City Boundary	857	21
Insufficient Data	92	2
Total	**4,142**	**100**

Parks and Open Space

Parks and open space, including public and private property, total about 870 acres, or nearly 21 percent of the watershed (Table 2-3). The Tryon Creek mainstem subwatershed contains most of the open space, largely because of Tryon Creek State Natural Area (approx. 630 acres). Other major parks and open space throughout the watershed include Marshall Park (25 acres), Lewis and Clark College (23 acres), West Portland Park (21 acres), and Maricara Nature Park (17 acres).

Table 2-3
Open Space in the Tryon Creek Watershed

Subwatershed	Open Space (Acres)*	Subwatershed Area (Acres)	Percentage of Subwatershed
Tryon Creek Mainstem	768.2	3,083.7	24.9
Arnold Creek	74.0	775.2	9.5
Falling Creek	27.6	283.6	9.8
Total (Watershed)	**869.8**	**4,142.3**	**21.0**

***** Includes colleges, schools, and public and private open space

Public Land

About 780 acres of public lands are located throughout the watershed (Table 2-4). Portland Public Schools owns about 58 acres; the City of Portland (including the Parks Bureau and BES) owns 73 acres; and Metro owns about 34 acres. The State of Oregon owns most of the remaining public land, including the 630-acre Tryon Creek State Natural Area. The Tryon Creek mainstem subwatershed contains the most public land, most of which is Tryon Creek State Natural Area.

Table 2-4
Public Land in the Tryon Creek Watershed

Subwatershed	Public Land (Acres)	Subwatershed Area (Acres)	Percentage of Subwatershed
Tryon Creek Mainstem	681.5	3,083.7	22.1
Arnold Creek	55.8	775.2	19.7
Falling Creek	44.9	283.6	5.8
Total (Watershed)	**782.3**	**4,142.3**	**18.9**

Environmental Zones

Portland has established environmental overlay zones to protect and conserve significant natural resources. The environmental overlay zones are the City's tool to implement the City's Comprehensive Plan Goal 8 and also Statewide Land Use Planning Goals 5, 6, and 7. They are based on extensive natural resource inventories that cover areas within the City's jurisdiction.

There are two types of environmental overlay zones, which currently affect approximately 20,000 acres city-wide. The **environmental protection zone** has been established in areas that have very high-value resources and function. Development is allowed in the protection zone only in very limited circumstances. The **environmental conservation zone** also limits development in important resource areas. Development is allowed if it meets certain standards and approval criteria to ensure that impacts on significant resources are avoided, limited, and mitigated (City of Portland, Title 33, Chapter 33.430).

Environmental protection zones overlay about 550 acres and conservation zones overlay about 446 acres in the Tryon Creek Watershed. Overall, about 24 percent of the watershed is within environmental zones (Table 2-5). The Tryon Creek mainstem subwatershed has the most area covered by the environmental protection zone, most of which is located in Marshall Park and Tryon Creek State Natural Area (Map 4-Tryon Creek Current Plan Existing E-Zones Maps by subwatershed).

Table 2-5
Environmental Zones in the Tryon Creek Watershed

Subwatershed	C zone (acres)	P zone (acres)	Total E zones (acres)	Subwatershed Area (acres)	Percentage of Subwatershed
Tryon Creek Mainstem	237.0	499.6	736.6	3,083.7	23.9
Arnold Creek	211.4	47.6	259.1	775.2	33.4
Falling Creek	17.6	4.2	21.7	283.6	7.7
Total (Watershed)	**466.0**	**551.4**	**1,017.4**	**4,142.3**	**24.6**

Population
The current (US Census 2000) population of the Tryon Creek Watershed within Portland's city limits is about 18,000. Map 3-Tryon Creek Neighborhood and Population Maps in the Map Atlas shows population breakdown in each subwatershed.

Public Easements
Extensive public right-of-way and public utility easements exist in the Tryon Creek Watershed for a number of highways, roads, streets, and utilities (such as sanitary and water). In some cases, sewer easements are located in stream corridors. These easements are used by agencies and the public according to the terms of each individual easement.

Recreation
The Tryon Creek Watershed offers valuable recreational opportunities in the Portland metropolitan area. Tryon Creek State Natural Area provides the core of these opportunities through 8 miles of hiking trails, 3 miles of bike trails, and 3.5 miles of horse trails. In addition, city parks, open areas, and public schools provide opportunities for passive and active recreation.

Cultural Resources
No information has been compiled about cultural and archeological resource identification or inventory.

Transportation Network

Major transportation routes in the watershed include Interstate 5, Highway 99, Boones Ferry Road, Taylors Ferry Road, and Terwilliger Boulevard. Surface streets are distributed throughout the upper and southwestern portions of the watershed. As Table 2-6 shows, there are over 70 miles of surface streets. Nearly half of the paved streets are uncurbed. Unimproved streets, which include dirt roads and unimproved rights-of-way, total 13 miles.

Streets and highways, particularly those with high traffic volumes, accumulate pollutants from automobiles. Rain picks up these pollutants and carries them to streams, where they degrade aquatic habitat for fish and other wildlife. Streets and highways also prevent infiltration, increasing stormwater runoff.

Table 2-6
Miles of Surface Streets in the Tryon Creek Watershed

Subwatershed	Paved/Uncurbed	Paved/Curbed	Other	Unimproved	Total
Tryon Creek Mainstem	19.8	15.3	5.1	8.1	48.2
Arnold Creek	6.1	7.7	0.0	3.9	17.7
Falling Creek	1.8	4.6	0.2	1.1	7.7
Total (Watershed)	**27.8**	**27.6**	**5.3**	**13.1**	**73.7**

Source: City of Portland, Bureau of Transportation

PHYSICAL CHARACTERISTICS

Tryon Creek Watershed’s topographic features, soils, hydrology, impervious surfaces, hydraulic characteristics, climate, and rainfall are closely linked to the physical stability of the watershed and stream systems. These factors influence channel morphology and structure, slope stability, and soil erosion and sediment transport.

Overall, steep slopes, soils that are slow to infiltrate rainfall, and impervious surfaces result in a “flashy” urban stormwater system. This has severe impacts on the streams, such as channel incision, undercutting of streambanks, landslides and erosion, and sediment deposition (Booth 1991).

Topography

Topography (elevation) in the Tryon Creek Watershed varies from near mean sea level (msl) to 970 feet above msl. The lowest point in the watershed, about 10 feet above msl, is the confluence of Tryon Creek with the Willamette River; the highest point is at the top of Mt. Sylvania (BES 1997). Approximately 60 to 75 percent of the slopes within the watershed exceed a 30 percent grade (BES 1997). Some slopes exceed 50 percent grade, especially in the upper watershed (Map 9-Tryon Creek Contour Maps by subwatershed, Map Atlas). The *Southwest Hills Resource Protection Plan* (Bureau of Planning 1992) classifies slopes in excess of 30 percent grade as generally having “severe landslide potential.” Prominent topographic features in the Tryon Creek Watershed are the Palatine Hills, Portland’s West Hills, and Mt. Sylvania.

Soils

The Natural Resources Conservation Service (NRCS) places soils in the Tryon Creek Watershed in the Cascade series. The Cascade series consists primarily of silt loam that is high in aluminum-rich volcanic ash. The watershed's soils are poorly drained, dark-brown silt loam of about 8 inches. Below this layer is about 19 inches of dark-brown silt loam subsoil (PSU and Metro 1995). The Cascade silt loam includes a layer of low permeability from 24 to 60 inches deep, called fragipan (BES 1997). Most of the surface water and roots of trees do not penetrate the fragipan; trees therefore grow in shallow soils and can be easily toppled by high winds and mudslides. The fragipan contributes to slope instability and erosion by limiting the rooting depth of plants to 30 to 48 inches and by serving as a failure plane.

The hydrologic soil group classification for most of the soils in the Tryon Creek Watershed is Type C, a sandy clay loam (Map 6-Tryon Creek Soil Types Maps by subwatershed, Map Atlas). Soils with this classification have a slow infiltration rate and high runoff potential. Isolated pockets of Type D (clay loam) soils, which are even slower to drain, also exist in the watershed. The low permeability of the soils limits the function of onsite stormwater and septic systems. Low soil permeability also affects the watershed hydrology through limited soil absorption and interflow, resulting in higher runoff peaks and lower base flows.

Given the urban nature of the upper watershed, the NRCS now designates soils in the upper watershed as Urban Land. This designation reflects the increase in impervious surfaces throughout the watershed (Green 1983).

Hydrology

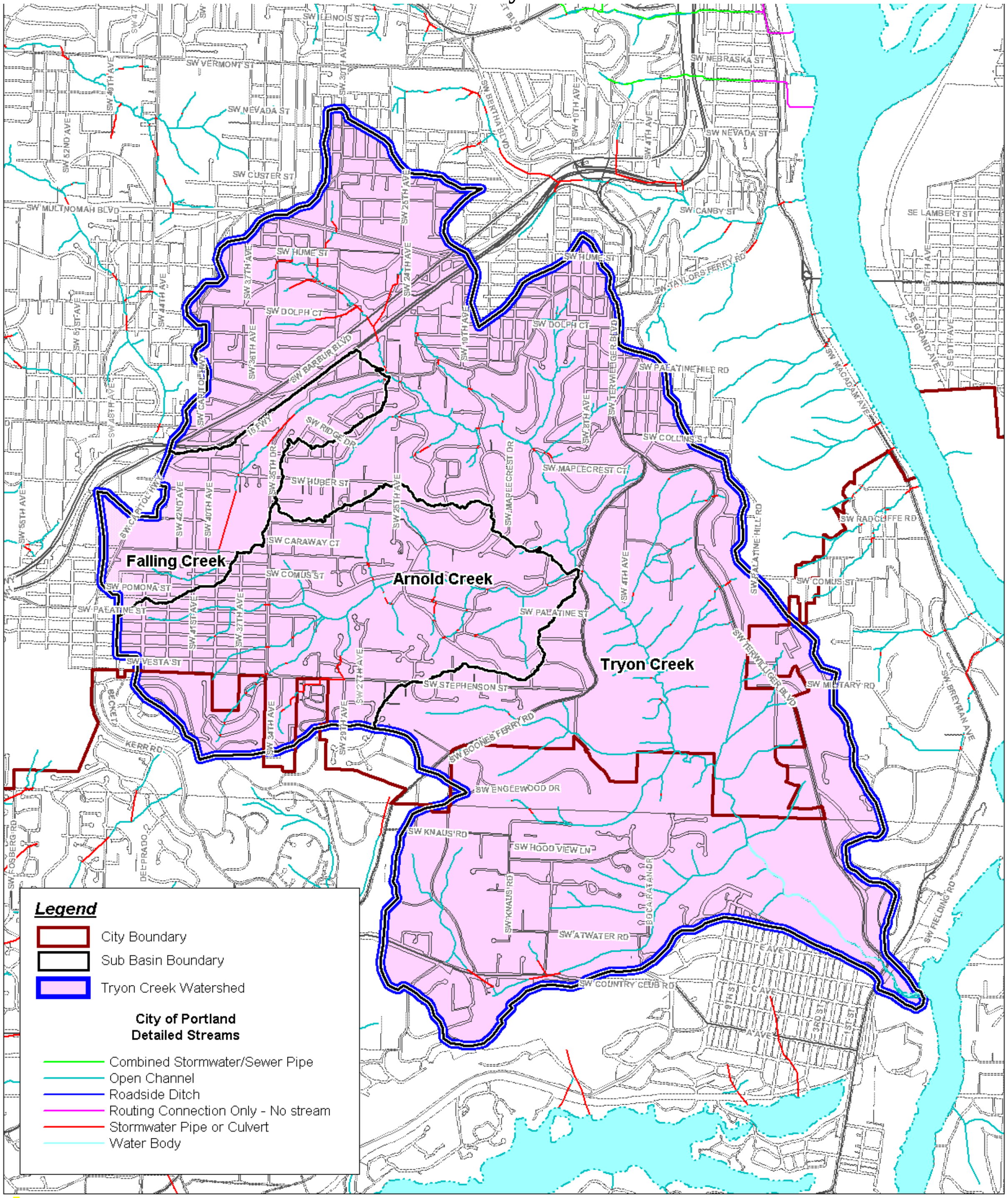
There are about 27 miles of open stream channel in the Tryon Creek Watershed. An additional three miles of streams are in culverts or pipes (Table 2-7). Figure 2-1 depicts the streams the within the watershed.

Table 2-7
Miles of Streams in the Tryon Creek Watershed

Subwatershed	Open Channel	Pipe or Culvert	Other
Tryon Creek Mainstem	20.9	2.1	0.0
Arnold Creek	5.6	0.9	0.0
Falling Creek	1.0	0.5	1.5
Total	**27.5**	**3.4**	**1.5**

Source: City of Portland, OR, Bureau of Planning. Note: numbers include creek tributaries.

Figure 2-1
Detailed Streams in Tryon Creek Watershed



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Tryon Creek mainstem is a perennial stream that originates in the West Hills of Portland and flows southeast from Multnomah Village, through Tryon Creek State Natural Area, to its confluence with the Willamette River at the Highway 43 crossing in Lake Oswego. It is one of the major remaining free-flowing tributaries that descend from Portland's West Hills. Tryon

Creek is primarily a high-gradient, open-stream system, with the exception of culverts at road crossings (Map 9-Tryon Creek Contour Map, Map Atlas).

Tryon Creek's tributaries include Arnold Creek, Falling Creek, Oak Creek, Park Creek, and Nettle Creek.

Intact stream networks contain streams that flow year-round and streams that flow only part of the time. Streams that flow throughout the year containing both base flow and storm flow are classified as perennial or permanent. Ephemeral streams flow only in response to specific storms. Intermittent streams flow for periods of weeks or months, usually during rainy and snowmelt seasons.

Headwater springs or drainages serve as the source of a stream network. Within any intact stream system and river network, headwater streams make up most of the total channel length. Headwater streams are critically important to the health of the watershed. These small intact streams provide natural flood control, recharge groundwater, trap sediments and pollution from fertilizers, recycle nutrients, create and maintain biological diversity, and sustain the biological productivity of downstream rivers, lakes, and estuaries (Meyers et al. 2003).

Impervious Surfaces

Impervious surfaces include streets, parking lots, and buildings. Impervious surfaces comprise about 990 acres, or 24 percent, of the Tryon Creek Watershed (Table 2-8 and Map 8-Tryon Creek Impervious Areas Maps by subwatershed, Map Atlas). Impervious surface coverage is highest in the upper portions of Tryon Creek, particularly along Interstate 5 and SW Barbur Boulevard.

Impervious surface cover in this range reduces rainfall infiltration, increases storm water runoff volume and velocity, and degrades storm water quality. In addition, Booth (1991) found that impervious cover greater than 10 percent reduces urban stream stability, resulting in unstable and eroding stream channels. These changes can degrade in-stream habitat and affect fish communities.

Table 2-8
Impervious Surface Cover in the Tryon Creek Watershed

Subwatershed	Impervious Area (Acres)	Subwatershed Area (Acres)	Percentage of Subwatershed
Tryon Creek Mainstem*	696.1	3,083.7	22.6
Arnold Creek	192.9	775.2	24.9
Falling Creek	105.9	283.6	37.3
Total (Watershed)	**994.9**	**4,142.3**	**24.0**

*Areas outside of the City of Portland derived from multi-spectral analysis layer

Hydraulic Characteristics

The Tryon Creek Watershed is characterized by steep slopes and stream gradients. The physiographic characteristics of the watershed and its soil types have had severe impacts on the stream systems in terms of channel incision, undercutting of stream banks, landslides, and exposed sewer pipes.

In addition to open stream channels, stormwater is conveyed through culverts and storm pipes. Approximately 145,538 lineal feet of storm drainpipes and 11 stormwater detention basins are within the watershed (Map 11-Tryon Creek Existing Storm Sewer Maps by subwatershed, Map Atlas) (BES 1997). As the watershed develops further, the ability of these conveyance elements to handle storm events designated as the City's basic level of service (conveyance of the 10-year storm) will be affected. BES completed a basin hydrologic analysis in 1997 that models current and future conditions and conveyance capacity (BES 1997). New hydrologic and hydraulic models were developed to characterize the watershed for this document.

Under an intergovernmental agreement with BES, the U.S. Geological Survey (USGS) installed a flow monitoring station on Tryon Creek mainstem in August 2001. BES and USGS will continue to fund operation of this station.

Climate and Rainfall

Climate in the Tryon Creek Watershed is characterized by mild, wet winters and cool, dry summers. Temperatures range from 25 to 45 degrees Fahrenheit (°F) in the winter and from 70 to 90°F in the summer. The Tryon Creek Watershed receives approximately 35 inches of precipitation per year; 98 percent of that total is rain. Almost all the rain falls between October and May (Johnson 1987).

BES maintains a system of rain gages as part of its Hydrologic Data Retrieval and Acquisition (HYDRA) system. Rain data from a HYDRA gage at the Portland Community College (PCC) Sylvania campus in the adjacent Fanno Creek Watershed were used to develop rainfall characteristics in the Tryon Creek Watershed. Design storms were defined for modeling future conditions and testing conveyance system capacity. These storms were based on BES's design standards (BES 1991; BES 1997). Table 2-9 shows rainfall statistics for southwest Portland, including the Tryon Creek Watershed.

Table 2-9
Annual Average Rainfall at PCC Sylvania Campus

Characteristic	Winter (November - May)	Summer (June - October)	Annual
Rainfall (days per season or year)	98	42	140
Rainfall depth (inches per season or year)	25.7	9.5	35.2
Rain events per season or year	36	24	60
Volume per event (inches)	0.74	0.38	0.59
Peak intensity (inches per hour)	0.094	0.091	0.093
Duration per event (hours)	40	20	34
Dry time between storms (hours)	75	155	107

Source: HYDRA system data compiled by BES Modeling Group
Note: Period of record, 1976-1998

HABITAT AND BIOLOGICAL COMMUNITIES

The *Southwest Hills Resource Protection Plan* (City of Portland 1992) includes site-specific inventories of Arnold Creek headwaters, Marshall Park/Capitol Hill, Falling Creek, and Tryon Creek State Natural Area. These inventories describe each site's natural resources and wildlife

Existing conditions of riparian habitat, wildlife habitat, fish habitat, and streambank erosion potential in the upper watershed were characterized during development of the *Upper Tryon Creek Corridor Assessment* (BES 1997).

Pacific Habitat Services, Inc. performed a survey of Tryon Creek within Tryon Creek State Natural Area and its riparian area, and developed a management plan in 1996 (Pacific Habitat Services 1997). The plan describes the existing characteristics of Tryon Creek, including channel morphology, hydrologic and flood flow characteristics, sediment transport, areas of groundwater inflow, fish habitat such as pools and riffles, riparian vegetation and shade, temperature, and bank erosion.

More recently, the Oregon Department of Fish and Wildlife (ODFW) conducted habitat surveys of portions of Tryon and Arnold Creeks. These assessments, along with other available information and work performed by other agencies, are integrated into Chapter 9: Habitat and Biological Communities – Tryon Creek Watershed.

The Metro Council is currently working through a three-step planning process to conserve, protect, and restore urban streams and waterways, riparian areas, and significant upland wildlife habitat. During the first step, Metro developed an inventory of approximately 80,000 acres of regionally significant fish and wildlife habitat areas in the region. Approximately 30,000 of those acres (including land and water bodies) are in the City of Portland.

For the habitat inventory, Metro developed a model to identify and rank regionally significant wildlife habitat resources based on habitat characteristics, including habitat patch size, habitat interior area, connectivity and proximity to water resources, connectivity and proximity to other patches, habitats of concern, and habitats for unique and sensitive species. Riparian resources were ranked according to their contribution to specific riparian functions. These functions include microclimate and shade, stream flow moderation and water storage, bank stabilization, sediment and pollution control, large wood and channel dynamics, and organic material sources. The level of function was based primarily on the distance of the landscape feature from the water body, as recommended in current scientific literature.

Metro also identified regionally significant habitats of concern, based on three criteria. The first criterion recognizes regionally at-risk, or priority, conservation habitat types, such as oak savannas, grasslands, and wetlands. These habitats are at risk because they formerly covered much more extensive areas, and they tend to be declining in quality where they still remain. The second criterion recognizes the extraordinary and unique value of riverine islands and delta areas. The third criterion recognizes known habitat patches that provide unique or critical wildlife functions. To qualify as a habitat of concern, an area needs to meet only one of the three criteria (Metro 2002).

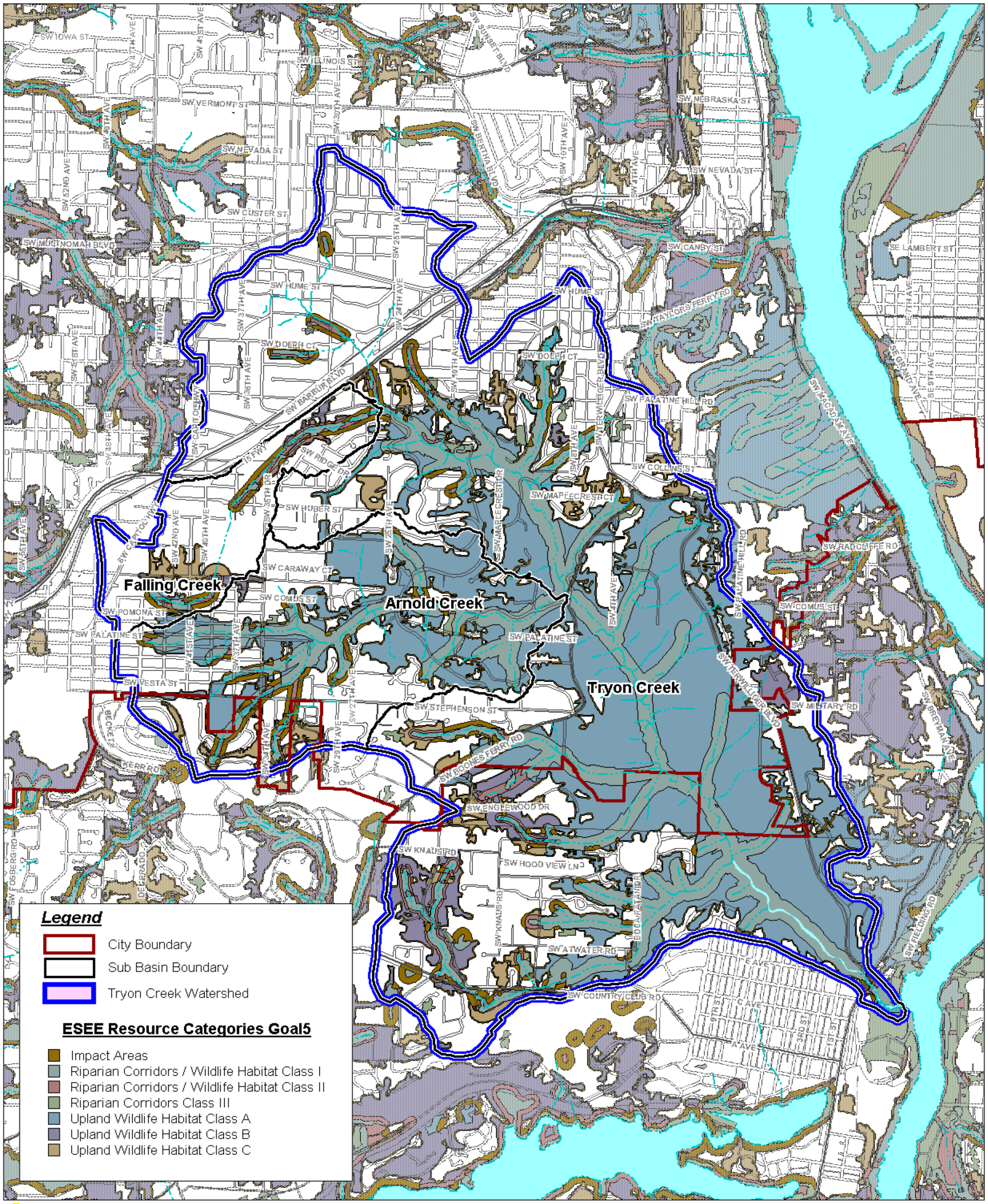
The second step is an economic, social, environment and energy (ESEE) analysis. For this analysis, Metro classified habitat into six classes, under two main categories: Riparian/wildlife and Upland Habitat. Each class covers a geographically discrete portion of the inventory, and may include riparian and/or wildlife functions and also may be a habitat of concern. Class 1 Riparian/wildlife and Class A Upland Wildlife Habitat are the highest value. Impact areas are areas where land uses and activities such as development, landscaping, and road construction may impact fish and wildlife habitat. In the third step, Metro will work with stakeholders throughout the region to formulate an integrated habitat protection and restoration program that is balanced with other goals for the region.

The inventory and ESEE analysis identified over 600 acres as Class 1 Riparian/Wildlife Habitat and over 1,000 acres as Class A Upland Wildlife Habitat in the Tryon Creek watershed, as shown in Table 2-10. Figure 2-2 shows the areas designated within each habitat resource category in the watershed.

Table 2-10
Metro Fish and Wildlife Classes for the Tryon Creek Watershed

Subwatershed	**Fish and Wildlife Habitat Classes**	**Acres**
Tryon Creek (mainstem)	Impact Areas	217.9
	Riparian Corridors / Wildlife Habitat Class I	474.9
	Riparian Corridors / Wildlife Habitat Class II	41.6
	Riparian Corridors Class III	23.3
	Upland Wildlife Habitat Class A	788.5
	Upland Wildlife Habitat Class B	76.5
	Upland Wildlife Habitat Class C	66.7
Arnold Creek	Impact Areas	77.3
	Riparian Corridors / Wildlife Habitat Class I	139.9
	Riparian Corridors / Wildlife Habitat Class II	10.1
	Riparian Corridors Class III	3.2
	Upland Wildlife Habitat Class A	217.1
	Upland Wildlife Habitat Class B	2.3
	Upland Wildlife Habitat Class C	17.1
Falling Creek	Impact Areas	29.3
	Riparian Corridors / Wildlife Habitat Class I	12.6
	Riparian Corridors / Wildlife Habitat Class II	11.2
	Riparian Corridors Class III	0.0
	Upland Wildlife Habitat Class A	6.4
	Upland Wildlife Habitat Class B	4.3
	Upland Wildlife Habitat Class C	14.4
Total (Watershed)		**2234.7**

Figure 2-2
ESEE Resource Categories Goal 5



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Vegetation

Where vegetation has not been altered by human activities, the Tryon Creek Watershed is wooded. Nearly 37 percent of the watershed is a mix of forested areas (Map 7-Tryon Creek Vegetative Cover Maps by subwatershed, Map Atlas). The wooded areas have both coniferous and deciduous trees, including Douglas and grand fir, western hemlock, western red cedar, broadleaf maple, Oregon ash, Pacific dogwood, red alder, and vine maple. In addition to trees, there are numerous species of shrubs, grasses, wildflowers, ferns, mosses, lichens, and fungi throughout the watershed (Pacific Habitat Services 1997; BES 1997; PSU and Metro 1995). Many forested areas in the watershed, including Tryon Creek State Natural Area, are adversely affected by non-native invasive plants such as English ivy, Himalayan blackberry, English holly, garlic mustard, and western clematis (BES 1997).

Vegetation provides many benefits to the watershed. Vegetation moderates hydrology, shades streams helping to keep them cool, and stabilizes stream banks and slopes helping to prevent erosion. Vegetation also provides woody material to streams, which creates critical refuge for fish.

Riparian Corridor

The *Upper Tryon Creek Corridor Assessment* (BES 1997) evaluated high-quality and sensitive habitat in terms of assessed riparian conditions, instream habitat conditions, bank erosion potential, and landslide data. The assessment concluded that riparian habitat quality was most limited in reaches where development has encroached on the riparian corridor and native vegetation has been removed. This encroachment has caused subsequent erosion and/or bank failure, leading to further vegetation loss. Native vegetation has been replaced by invasive plants that tend to prevent development of habitat and structural diversity. Habitat enhancement opportunities were identified to the extent possible within the project scope.

In 2001, ODFW conducted a habitat surveys for Tryon Creek mainstem and Arnold Creek (Map 14-Tryon Creek ODFW Survey Map 1 by subwatershed, Map Atlas) (ODFW 2002). Table 2-11 summarizes percentage of stream shading, which was one of the survey parameters. Percentages indicate the portion of each creek where shade cover exceeds 90 percent.

Table 2-11
ODFW 2001 Stream Shade Survey

Creek Name	Average Shade (%)
Tryon Creek Mainstem	84
Arnold Creek	80

* Averages are for reaches within the City

Generally, riparian integrity is largely intact throughout much of the lower portion of the Tryon Creek mainstem subwatershed. Riparian integrity varies upstream within Marshall Park, but is generally considered fair. Stream segments farther upstream exhibit marginal riparian condition as residential development becomes a dominant landscape feature along the streambank.

Much of Arnold Creek exhibits high riparian integrity, with riparian widths greater than 100 feet. Riparian integrity declines in upper Arnold Creek. Falling Creek exhibits poor riparian integrity because residential development surrounds much of the stream corridor.

Degraded riparian conditions contribute to increased stream flow and channel incision, streambank instability, erosion and sedimentation, and lack of shading, which increases water temperature.

Floodplain

Floodplain interaction, the process by which streams overflow into surrounding flat riparian areas, creates habitat, deposits nutrients, and accommodates high stream flows. Throughout much of the Tryon Creek Watershed, steep slopes and stream gradients limit floodplain interaction. In addition, development is a prominent landscape feature upstream of (and including) Quail Creek, and potential floodplain interactions are limited by residential land use, impervious surfaces, road crossings, and vegetation composition. Additionally, much of the streambank area in these upper reaches of the watershed has been hardened and is incised. Tryon Creek, Arnold Creek, and Falling Creek do not experience prolonged floodplain interactions. Stream reaches with the lowest gradients and largest (and most integral) floodplains are located in Tryon Creek State Natural Area and are protected from near-stream urban development.

Aquatic Biology

Tryon Creek and its tributaries provided important habitat for various fish and other aquatic species before the turn of the century. Over the past decades, however, many major modifications have been made in the watershed and have significantly affected fish and aquatic habitat and passage (BES 1997; Pacific Habitat Services 1997; PSU and Metro 1995).

Fish

Tryon Creek is entirely free- flowing within the Tryon Creek State Natural Area, where it seems to provide the best available habitat in the watershed. However, the Highway 43 crossing near the creek’s confluence and the Boones Ferry Road crossing appear to restrict fish movement.

Most of the fish populations in the watershed are tolerant resident species (Friends of Tryon Creek State Park 1998). Over the past 17 years, ODFW has conducted several fish surveys in Tryon Creek State Park, with the following results:

- Surveys in July 1987 counted 25 coho salmon up to 7.3 centimeters (cm), one rainbow trout at 17 cm, five sculpin, one lamprey, and one crayfish. Numerous young fish were spotted, but were not counted because of recent stocking by ODWF.

- A 1994 stream survey (fish habitat) reported a few small fish and a few crawfish.

- In July 1995, a juvenile fish survey performed by Friends of Tryon Creek State Park and supervised by ODWF reported 20 cutthroat up to 24 cm, 19 rainbow/steelhead up to 8.4 cm, and 69 sculpin. One large fish was reported in 1995.

- Surveys in July 1996 counted five cutthroat up to 25 cm long, four rainbow steelhead up to 8.4 cm, 124 sculpin, and one lamprey.

- Surveys in July 1997 counted 22 cutthroat up to 18 cm, four rainbow/steelhead up to 8.5 cm, and 145 sculpin. One redd, a gravel nest in a stream where salmonids deposit their eggs, was possibly seen in April 1997.

- No large fish were reported in 1998.

In 2002, ODFW conducted extensive (spring, summer, and fall) and intensive (summer) stream surveys in Tryon Creek (ODFW 2002) (Maps 14 and 15-Tryon Creek ODFW Survey Maps 1 and 2 by subwatershed, Map Atlas). Coho, Chinook, steelhead, and cutthroat were observed in different parts of Tryon Creek during different seasons of the year. Of all the salmonid species observed, cutthroat trout were most abundant, with population estimates of 53 individuals in spring, 36 in summer, and 24 in fall. Salmonid densities averaged 0.059 fish per square meter basinwide, and ranged from 0.047 fish per square meter in lower Tryon Creek to 0.068 fish per square meter at the confluence of Tryon Creek and the Willamette confluence reach. Although the stream reachs running through Tryon Creek State Natural Area and above resulted in lower biotic integrity (IBI) scores, species density per water surface area was relatively equal throughout all of the Tryon Creek Watershed. IBI reflects important components of an ecosystem; taxonomic richness (number of native families and number of native species present), habitat guilds (benthic species, native water column species, hider species, sensitive species, nester species, and proportion of tolerant individuals), trophic guilds (percent filter-feeding individuals and percent omnivores) and individual health and abundance (percent of target species and percent individuals with anomalies). Fish survey data is queried to make-up the IBI rankings and subsequent scores. Large numbers of steelhead, Chinook, coho and cutthroat were not encountered in Tryon Creek, but individuals are present and use Tryon Creek during all or parts of their freshwater life stage.

Macroinvertebrates

To date, information on macroinvertebrates in Tryon Creek and its tributaries is limited to observations by ODFW fish biologists as part of their work to assess fish and fish habitat. These observations have consistently pointed to unsuccessful spawning of salmonids and the absence of aquatic insects. In one report, the absence of aquatic insects was theoretically linked to some form of water quality problem.

Wetlands

Wetlands, even those without any obvious surface connection to streams, contribute to watershed hydrology by storing and slowly releasing water into streams and groundwater. No jurisdictional wetlands have been identified in the upper Tryon Creek Watershed. In general, the steep gradient of Tryon Creek and its tributaries and the steep/hilly terrain of the watershed do not provide the necessary hydraulic connectivity and supply to allow formation of well-functioning wetlands. Most of the “wetland” type areas are in the stream corridor areas and mainly within Tryon Creek State Natural Area.

According to the 1989 national wetlands inventory prepared by the U.S. Fish and Wildlife Service, the only significant wetlands in the Tryon Creek Watershed are within the stream regime. The lower end of Tryon Creek is classified as riverine system, upper perennial subsystem, open-water class, non-tidal water regime, and intermittently exposed/permanent. The upper reaches of Tryon Creek and its tributaries are classified as palustrine system, forested class, broadleaf deciduous subclass (indicating non-tidal water regime temporarily/intermittently flooded and saturated semi-permanent or seasonal flooding).

Wildlife

The Tryon Creek Watershed provides shelter to several wildlife species, most of which are nocturnal (BES 1997; Pacific Habitat Services 1997; PSU 1995). Black bear, cougar, and Roosevelt elk existed before development. Today, the watershed is still home to smaller, more adaptive mammals. The greenspace of the West Hills and the forested refuge of Tryon Creek State Natural Area provide the primary habitat for the wildlife species in the watershed. The most common mammals are bats, beavers, blacktail deer, chipmunks, coyotes, flying squirrels, mice, moles, opossums, rabbits, raccoons, red foxes, shrews, skunks, and squirrels.

More than 60 species of birds reside within the watershed for at least a portion of the year. Birds are attracted to the variety of habitats found within the watershed’s evergreen forests, deciduous woods, stream corridors, fringes of open fields, and numerous backyard birdhouses. Some of the birds found in the Tryon Creek Watershed include chickadees, Cooper's hawks, ducks, great horned owls, great blue herons, hummingbirds, jays, juncos, kingfishers, nuthatches, robins, sparrows, thrushes, towhees, warblers, waxwings, western screech owls, woodpeckers, and wrens (BES 1997; Pacific Habitat Services 1997; PSU 1995).

Smaller creatures often go unnoticed. Many live in the West Hills streams, in the humus of the forest floor, or high up in the canopy of Tryon Creek State Natural Area. The mild and damp conditions of the watershed are ideal for a number of amphibians and reptiles, including frogs, salamanders, snakes, toads, and turtles.

PUBLIC HEALTH AND SAFETY

No chronic public health advisories are linked to contamination of Tryon Creek or its tributaries. Advisories may be posted if any unacceptable bacterial contamination of the water occurs as a result of sanitary sewer breakage or leaks. However, such episodes are rare. During storm events, bacteria counts in the water can be high as a result of animal waste washing off into the creeks. Private septic systems are another potential source of bacterial contamination. A cursory review of BES and Water Bureau billings in the Tryon Creek Watershed shows that about 90 properties/structures (less than five percent) do not pay for sewer service, which may be an indication of properties on private septic systems.

Flooding

A major flood event occurred in the Portland metropolitan area in February 1996. It surpassed the conveyance capacity of numerous facilities citywide. Although the flood event caused severe landslide, streambank, and streambed damage to Tryon Creek and its tributaries, it did not cause any significant flooding or property damage in the watershed (BES 1998). The effects of flooding will likely remain the same in the future. Changing hydrologic conditions may continue to cause damage to the stream system in the watershed, but may not result in any significant flooding of properties. Property damage resulting from excessive rainfall could occur in the form of landslides on steep and unstable slopes and along stream channels.

WATER QUALITY

Tryon Creek and its tributaries within the City of Portland are small headwater streams located within an urban environment. They exhibit many of the characteristics typical of urban streams, including altered flow patterns and degraded water quality. These characteristics result from changes in hydrology and increased pollutant loadings from urban development.

Water quality concerns in the Tryon Creek Watershed include:

- Stream temperatures do not meet state standard in the summer. The elevated temperatures are likely caused by very low streamflows during the summer months, warmer air temperature resulting from urban heat island effects, reduced riparian vegetation (and consequent lack of stream shading), and stormwater runoff from impervious surfaces exposed to sunlight.
- Bacteria levels sometimes do not meet standards. Potential bacteria sources include both human sources (illegal sanitary connections and dumping to storm drains and failing septic systems) non-human sources (birds, dogs, cats, raccoons, and other animals).
- Elevated levels of suspended sediments and nutrients (phosphorous and nitrogen), especially during storm events. Sediment smothers fish spawning beds and transports a variety of pollutants, such as oil, grease, metals and pesticides. Excess nutrients can contribute to low dissolved oxygen levels in the creek, which is harmful to fish. Sedimentation may result from vegetation removal, landslides, and erosion caused by increased stormwater runoff. Excess nutrients are probably associated with sediments and with runoff from landscaped residential areas.
- Stormwater carries pollutants from upland land uses, including residential areas and transportation corridors such as Interstate 5, Barbur Boulevard, and Terwilliger Boulevard.

Detailed descriptions of water quality conditions are provided in Chapter 9: Water Quality – Tryon Creek Watershed.

Beneficial Uses

Pursuant to Oregon Administrative Rules (OAR), the Oregon Water Resources Commission establishes the beneficial uses of waters of the state. Numeric and narrative water quality standards are designed to protect the most sensitive beneficial uses. The Oregon Department of Environmental quality (DEQ) has identified Tryon Creek and its tributaries as waters of the state. Table 2-12 identifies the designated beneficial uses for Tryon Creek and its tributaries.

Table 2-12
Designated Beneficial Uses of Tryon Creek

Public Domestic Water Supply
Private Domestic Water Supply
Industrial Water Supply
Irrigation
Livestock Watering
Anadromous Fish Passage
Salmonid Fish Rearing
Salmonid Fish Spawning
Resident Fish and Aquatic Life
Wildlife and Hunting
Fishing
Boating
Water Contact Recreation
Aesthetic Quality
Hydro Power
Commercial Navigation and Transportation

DEQ maintains a state 303(d) list that identifies water bodies that are “water quality limited” because they do not meet water quality standards for certain parameters. Tryon Creek is listed for temperature. DEQ established a draft total maximum daily load (TMDL) for temperature in the Tryon Creek Watershed in October 2004. The TMDL will require local jurisdictions to develop a temperature management plan to address the temperature problem in the creek. A TMDL may not be established if a temperature management plan is developed first; it is assumed that beneficial uses are not impaired as long as water quality standards are met.

Monitoring Data

BES established an instream water quality monitoring program in Tryon Creek in 1997. This monitoring is necessary to determine the existing status of water quality in relation to DEQ standards and criteria. The monitoring is also essential for watershed planning and impact assessment related to various management activities in the watershed.

BES’s water pollution control laboratory collects monthly grab samples from Tryon Creek at Boones Ferry Road. The samples are analyzed for 13 water quality parameters (Table 2-13). Analyses can be performed for additional parameters or constituents if needed. Although most of the parameters are analyzed in the laboratory, some are monitored in the field.

In May 1998, BES installed a continuous temperature monitoring device to collect hourly temperature data from May through October. BES’s water quality and temperature monitoring data are electronically stored and available for retrieval.

BES established two new fixed monitoring stations in Tryon Creek in November 2004 at 9323 SW Lancaster Road and at SW 26th Way and Barbur Boulevard.

Table 2-13
Water Quality Monitoring Summary for the Tryon Creek Watershed

Parameter	Reporting Limit Units	Monitoring Frequency
Ammonia Nitrogen	1 mg/l	Monthly
Nitrate-Nitrogen	0.1 mg/l	Monthly
Nitrite–Nitrogen	0.01 mg/l	Monthly
Ortho Phosphorous	0.02 mg/l	Monthly
Total Phosphorous	0.03 mg/l	Monthly
Total Solids	1 mg/l	Monthly
Total Suspended Solids	1 mg/l	Monthly
E. Coli	2 CFU/100ml	Monthly
Temperature	Degrees Celsius	Hourly (May-Oct)
Dissolved Oxygen	0.1 mg/l	Monthly
Turbidity	1 NTU	Monthly
pH	0.1	Monthly
Conductivity	1 micro ohms/cm	Monthly

To further characterize pollutant loads from different land uses, BES established four stormwater sampling sites in the Fanno Creek and Tryon Creek Watersheds, representing the predominant land use types in these watersheds: residential, multi-family residential, commercial, and transportation (highways). Four storms were sampled at these sites between September 2001 and January 2002.

Modeling

No water quality models have been developed for the Tryon Creek Watershed, with the exception of pollutant load models for the City's National Pollutant Discharge Elimination System (NPDES) Stormwater Program. No specific water quality studies or assessments have been performed in the watershed to date. BES conducted a GIS-based pollutant load analysis and will develop physically based water quality models for the watershed.

Upland Stormwater Management

Point sources of pollution to Tryon Creek include two stormwater outfalls classified as major outfalls under the City's NPDES stormwater permit: WCMS #3826 – 243D and WCMS # 3826-367D. Combined, these outfalls drain an area of 368 acres (BES 1993) and discharge directly into Tryon Creek at Interstate 5 and the Pacific Highway in the upper part of the watershed. A new MS4 permit was issued to the City in July 2005. The City is required to calculate seasonal pollutant load, investigate illicit connections, and evaluate the need for pollution reduction facilities for stormwater mitigation. These two outfalls contribute much of the total suspended solids (TSS) watershed load that enters Tryon Creek in both the wet and dry seasons (as calculated by the NPDES Stormwater Program, based on land use).

SEWERAGE INFRASTRUCTURE

Separate sanitary and stormwater sewer systems serve the Tryon Creek Watershed. The sanitary sewer conduits generally run down the main channels of creeks and tributaries. Flow can be directed either to the Tryon Creek Wastewater Treatment Plant (TCWTP) in Lake Oswego or the Columbia Boulevard Wastewater Treatment Plant (CBWTP) in Portland (BES 1999b). Treated effluent is discharged into the Willamette River under an NPDES wastewater discharge permit from DEQ. Stormwater from developed areas is conveyed by a network of storm sewers and roadside ditches into the streams (BES 1997).

Sanitary System

The Tryon Creek sanitary sewer system serves a total area of approximately 4,454 acres. Of this area, 217 acres are outside the watershed drainage boundaries. The sanitary sewer basin contains a mixture of land uses, with significant areas of commercial and multi-family development along the Barbur Boulevard/I-5 corridor, Capitol Highway, and the Multnomah district. About 90 structures in the watershed are served by private septic systems (PSU and Metro 1995; BES 1999b).

There are three primary sewer lines in the watershed: the Tryon Creek sanitary trunk, the Falling Creek collector, and the Arnold Creek collector (Map 10-Tryon Creek Existing Sanitary Sewer System Maps by subwatershed, Map Atlas). The Tryon Creek sanitary trunk is the primary north-south conveyance line servicing the basin and ranges from 18 to 30 inches in diameter. The Arnold Creek and Falling Creek collectors are the main branches to the Tryon Creek sanitary trunk below the diversion manhole at SW 31 St. Avenue. The Falling Creek collector ranges from 10 to 12 inches in diameter. It begins south of I-5 and follows Falling Creek until it meets the lower basin trunk at the intersection of SW Taylors Ferry Road and Spring Garden Road. The Arnold Creek collector ranges from 10 to 15 inches in diameter and collects flow in the lower southwest portion of the basin. It runs along SW Arnold Street until it joins the lower basin trunk at the intersection of SW Arnold and Boones Ferry Road (BES 1999b).

Sanitary System Deficiencies

Projected land use planning for the Tryon Creek Watershed calls for expansion of all the existing high-density uses along major corridors, as well as development of a multi-family residential corridor along SW Boones Ferry Road. The lower portion of the Tryon Creek sanitary basin is not likely to change noticeably because it is mostly in the Tryon Creek State Natural Area (BES 1999b).

There are few system deficiencies specific to the Tryon Creek sanitary basin. The Tryon Creek sanitary basin is linked to the Fanno sanitary basin, however, which has a direct impact on the operation and capacity of the Tryon Creek sanitary system. Deficiencies in the Fanno basin are described in Chapter 3 Hydrology – Fanno Creek Watershed.

Recommended/Planned Modifications to the Sanitary System

Flow monitoring data have been collected in Tryon Creek sanitary basin as part of the BES 1999 Public Facilities Plan (PFP) development. The infiltration/inflow (I/I) rates in three subbasins were determined to be 11,771, 14,643, and 21,040 gallons per acres per day, respectively. Inflow is water that is dumped into the sanitary sewer system through improper connections, such as downspouts. Infiltration is groundwater that enters the sanitary sewer system through leaks in the pipe. These rates are considered extreme by common practice. The TCWTP

Facilities Plan (BES 1999c) includes specific recommendations associated with local capacity deficiencies and potential I/I reduction improvements.

Wastewater Treatment

The TCWTP is located within the Lake Oswego city limits just north of Foothills Road, adjacent to the Willamette River. The plant is owned and operated by the City of Portland and also serves areas outside the Tryon Creek Watershed. Roughly half of the flow to the TCWTP comes from the City of Portland's Tryon Creek, Fanno Creek, and Riverview sanitary sewer basins, which discharge to the 30-inch-diameter Tryon Creek interceptor. The other half originates in the City of Lake Oswego sewer service area and discharges to a 24-inch-diameter line. Treatment is provided for both Lake Oswego and the City of Portland, in accordance with an interagency contract.

The existing TCWTP is designed for an average dry weather flow of 8.3 million gallons per day (mgd), with the capability to treat hourly peak flows of 35 mgd for short periods of time. The current average dry weather flow is 7.6 mgd, which is about 92 percent of design capacity (BES 1999b).

A facilities plan for the TCWTP was prepared in December 1989, and an update was completed in June 1999. The updated plan assesses the adequacy of existing facilities through the year 2040 and identifies necessary capital improvements, including new or modified facilities to meet wastewater treatment needs through the year 2040.

The TCWTP does not have capacity problems in terms of meeting future growth needs. Improvements at the plant are primarily process improvements for reliability, energy and treatment efficiency, and odor control. Specific areas of improvement include new headworks equipment, including odor control, replacement of the aeration system with a new diffused air system, addition of a third secondary clarifier, and odor control for solids handling facilities.

Stormwater System

The Tryon Creek stormwater system consists of 27 miles of open stream channels, 145,538lineal feet of storm drain pipes (about 27.5 miles), and 11 detention basins (BES 1999) (Map 11-Tryon Creek Existing Storm Sewer Maps by subwatershed, Map Atlas).

Hydrologic models of the upper mainstem of Tryon Creek, Falling Creek, and Arnold Creek were developed as part of the *Upper Tryon Creek Corridor Assessment* (BES 1997). Modeling goals included evaluating the existing flows in relation to pipe capacities and evaluating channel flow velocities relative to factors affecting riparian habitat areas. Velocity information was used to evaluate the impact on stream channel morphology and capacity restrictions.

Stormwater System Deficiencies

Hydrologic models confirm that major development of the upper, hilly portion of the watershed has resulted in bank erosion, channel incision, bank failure, and landslides. Most downstream portions of the Tryon Creek Watershed are in Tryon Creek State Natural Area. Although this park remains in natural condition, upstream development has had an impact on the stream channels within it.

The *Upper Tryon Creek Corridor Assessment* documents numerous localized areas of concern because of active erosion from streambank instability. The study included detailed site inspection of the Tryon Creek mainstem, Falling Creek, and Arnold Creek. A channel assessment was performed, using the Rosgen stream classification method for characterizing channel stability and habitat (Rosgen 1994). Streamwalks performed as part of the studies verified that high velocities routinely occur in the upper reaches of the urbanized creeks and tributaries, contributing to general stream degradation.

A comparison of the channel conditions with the hydrologic analysis indicated that several reaches have velocities exceeding seven feet per second (fps) over most of the reach during the two-year storm. Velocities in excess of seven fps are likely to cause severe erosion and accelerate the stream erosional process. The two-year storm was selected to demonstrate steady, continuous conditions rather than infrequent, short-duration conditions. Field observations generally confirmed that stream reaches that exhibited high velocities showed a higher level of degradation in terms of channel incision, unstable slopes, and lack of channel structure complexity.

Storm pipe and culvert capacities were evaluated based on conveying the 25-year storm. Ten out of 73 storm-modeled storm pipes and culverts on upper Tryon Creek were found to be undersized for existing flow conditions. Three reaches were modeled on Falling Creek; one storm pipe out of 12 was found to be undersized. No storm pipe or culvert was found to be undersized on the mainstem of Arnold Creek, and the tributaries were not modeled.

Locations of recent flooding (recorded from 1988 to 1996) correspond to the addresses of residents who have called the city to report property flooding or other stormwater system operational concerns. Most of these complaints have been mainly linked to storm pipe and culvert flooding, stream backup against roads, and/or other constrictions. Some complaints have also been recorded concerning localized basement flooding and standing water in the streets during storm events.

Recommended/Planned Modifications for the Stormwater System

The PFP recommends two projects to address stream channel protection and culvert replacement/upsizing. Efforts were also made to identify feasible stormwater detention sites. Only one site appeared to meet the criteria for size, location, and accessibility; however, it was not forwarded as a recommended detention project. The PFP planning process did not identify any stormwater quality projects.

PUBLIC INVOLVEMENT AND STEWARDSHIP

Partnerships among agencies and community groups provide opportunities for collaborative restoration, education, and technical assistance for local area residents. Free programs such as Naturescaping for Clean Rivers are available to help raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. BES’s Community Watershed Stewardship Grants Program supports community groups and citizens working to improve the health of Portland’s watersheds.

Partners in the Tryon Creek mainstem subwatershed include the Tryon Creek Watershed Council, Friends of Tryon Creek State Natural Area, Southwest Neighborhoods, Inc. (SWNI), neighborhood associations, SOLV, the National Oceanic and Atmospheric Administration (NOAA), Portland Parks and Recreation, Oregon State Parks, Lewis and Clark College, BES's Watershed Planning, Revegetation, and Stewardship Grant Programs, schools, and neighbors. Active stewardship sites include Tryon Creek State Natural Area, Marshall Park, Tryon "Headwaters," Foley Balmer Natural Area, and four private property sites coordinated by SOLV (Primrose, Plum Pocket, Quail Creek, and Spring Garden).

Multnomah Village has examples of stormwater solutions, such as porous pavement at the Lucky Lab and bioswales with porous parking lot at the Multnomah Center. The Tryon Creek Watershed Council has ranked Reach 4 of the Tryon mainstem, which extends from upper Tryon Creek State Natural Area to Taylors Ferry Road, as a high priority for restoration on private land.

Partners in the Arnold Creek subwatershed include the Tryon Creek Watershed Council, SWNI, neighborhood associations, Portland Parks and Recreation, BES's Watershed Planning, Revegetation, and Stewardship Grant Programs, schools, and neighbors. Active stewardship sites include Maricara Nature Park and Stevenson Elementary School (Naturescaped garden). West Portland Park and the Kerr site are additional Portland Parks sites that could host community stewards.

BES's Revegetation Program is working with private landowners along Oak Creek, a tributary to Arnold Creek. The Tryon Creek Watershed Council has ranked Arnold Creek as a high priority for restoration on private land.

Partners in the Falling Creek subwatershed include the Tryon Creek Watershed Council, SWNI, neighborhood associations, BES's Watershed Planning, Revegetation, and Stewardship Grant Programs, Jackson Middle School, and neighbors. Active stewardship sites include Jackson Middle School revegetation and a BES revegetation site along Falling Creek at Indian Hills. The Tryon Creek Watershed Council has identified upper Falling Creek as a high priority for restoration on private land.

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CHAPTER 3

Hydrology: Fanno Creek Watershed

This chapter characterizes the hydrology of the Fanno Creek Watershed. The first section provides information about the Fanno Creek Watershed as a whole, including:

- Watershed Description
- Historic Conditions
- Landscape Factors
- Human Influences
- Gaged Stream Flows
- Previous Hydrology Studies
- Current Hydrologic Assessment

The following sections then provide information for subwatersheds within the Fanno Creek Watershed, including:
    - Description
    - Landscape Factors
    - Human Influences
    - Modeling Results

- Summary of Findings

WATERSHED DESCRIPTION[*]

The Fanno Creek Watershed, located within the southwest Portland metropolitan area, covers an area of approximately 20,259 acres, or 31.65 square miles. Of this, approximately 4,529 acres are within the City of Portland. The remaining watershed area is within the jurisdictions of Multnomah County, Clackamas County, City of Lake Oswego, and Clean Water Services.

Within the City of Portland, the Fanno Creek Watershed is divided into eight subwatersheds: the Fanno Creek mainstem and the headwaters of seven tributary creeks that all join Fanno Creek outside the City, before Fanno Creek's confluence with the Tualatin River.

- The **Fanno Creek mainstem** originates in the Tualatin Mountains (West Hills) of Southwest Portland near the intersection of SW 25th Avenue and Beaverton-Hillsdale Highway. It flows west through West Portland along SW Beaverton-Hillsdale Highway before it leaves the City's jurisdiction at SW Scholls Ferry Road. The Fanno Creek mainstem watershed comprises approximately 1,831 acres.

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[*] Refer to Chapter 1: Fanno Creek Watershed Overview, for additional description and maps.

- **Pendleton Creek mainstem** originates near SW Fairvale Court and Kanan Street and flows west for about 0.8 mile before it exits the urban services boundary south of SW Beaverton-Hillsdale Highway around SW 65th Avenue. The Pendleton Creek subwatershed comprises about 230 acres.

- **Vermont Creek** originates east of Gabriel Park, just north of SW Multnomah Boulevard, and flows north parallel to SW 45th Avenue. It exits the urban services boundary west of SW Shattuck Road north of SW Vermont Street. The Vermont Creek subwatershed comprises about 758 acres.

- **Woods Creek** originates near SW Taylors Ferry Road and Capitol Highway. It flows northwest for approximately 1.8 miles, crossing SW Multnomah Boulevard near 51st Avenue. It then flows west, exiting Portland approximately 350 feet north of SW Canby Street near 64th Place. The Woods Creek subwatershed comprises about 576 acres.

- **North Ash Creek** originates near SW Bruegger Street and 50th Avenue and flows west for approximately 0.8 mile until it exits the urban services boundary at SW Dolph Road. The North Ash Creek subwatershed comprises about 282 acres.

- **South Ash Creek** originates just west of Interstate 5 (I-5) near SW 52nd Avenue. It flows west and exits the urban services boundary north of SW Dickson Place. The South Ash Creek subwatershed comprises about 360 acres.

- **Red Rock Creek** originates just south of I-5 near SW Capitol Highway. It flows west and exits the urban services boundary near SW 64th Avenue. The Red Rock Creek subwatershed comprises about 413 acres.

- Only a small portion of the overall **Sylvan Creek** drainage area is within the City of Portland. Sylvan Creek is generally addressed with the Fanno Creek mainstem.

HISTORIC CONDITIONS

The historic hydrology of Fanno Creek and its tributaries was typical of moderate-gradient Willamette Valley headwater streams with steep landscape slopes. The annual hydrograph reflected the climatic precipitation pattern, with an extended wet period exhibiting higher flows and frequent storm flow events from approximately October through June, followed by a dry summer season with low base flows from June through September. Stream flows during the summer low-flow period were dominated by groundwater recharge to the streams. The topography, including steep slopes, and the native soil characteristics, which limited infiltration, contributed to a rapid response of flows to storm events and moderate runoff volume. This response was moderated by the native vegetation, including a mature forest with a surficial forest duff layer that provided precipitation storage (May et al. 1997). Topographic features confined many of the headwater tributary stream channels, with lower reaches of the streams exhibiting more meandering and interaction with the floodplain (e.g., lower Fanno Creek mainstem).

LANDSCAPE FACTORS

Landscape factors are broad-scale influences such as climate, rainfall/precipitation, topography, geology, and soils that play a major role in determining the structure, dynamics, and function of a watershed. Landscape factors set constraints on, and can be a determining factor in, the form and function of a watershed (City of Portland 2004).

Climate

The climate in the Fanno Creek Watershed is classified as Mediterranean, characterized by mild winters with prolonged winter rainfall and cool, dry summers. Temperatures range from 25 to 45 degrees Fahrenheit (°F) in the winter and from 70 to 90°F in the summer. (Johnson 1987).

Rainfall/Precipitation

Rainfall data are available from the Bureau of Environmental Services' (BES) Hydrologic Data and Acquisition (HYDRA) system, which collects five-minute rainfall data from rain gages located throughout the City of Portland, including the Fanno Creek Watershed. Table 3-1 summarizes the seasonal frequency of rainfall events. Table 3-2 shows the average seasonal and annual rainfall amounts for the four operational rainfall gages located within or near the Fanno Creek watershed. Figure 3-1 shows the average annual precipitation by month.

Table 3-1
Annual Average Rainfall at PCC Sylvania Campus (PCC)[1]
and Portland International Airport (PDX)[2]

Characteristic	**Winter (November through May)**		**Summer (June through October)**		**Annual**	
Station	***PCC***	***PDX***	***PCC***	***PDX***	***PCC***	***PDX***
Rainfall, days per season or year	98	101	42	48	140	149
Rainfall depth, inches per season or year	**25.7**	**27.7**	**9.5**	**9.7**	**35.2**	**37.4**
Rain events per season or year	36	37	24	25	60	62
Volume per event, inches	0.74	0.75	0.38	0.39	0.59	0.61
Peak intensity, inches per hour	0.094	.095	0.091	0.092	0.093	0.094
Duration per event, hours	40	45	20	24	34	36
Dry time between storms, hours	75	74	155	154	107	106

[1] PCC period of record, 1976-1998; Source: HYDRA system data compiled by the BES Modeling Group.

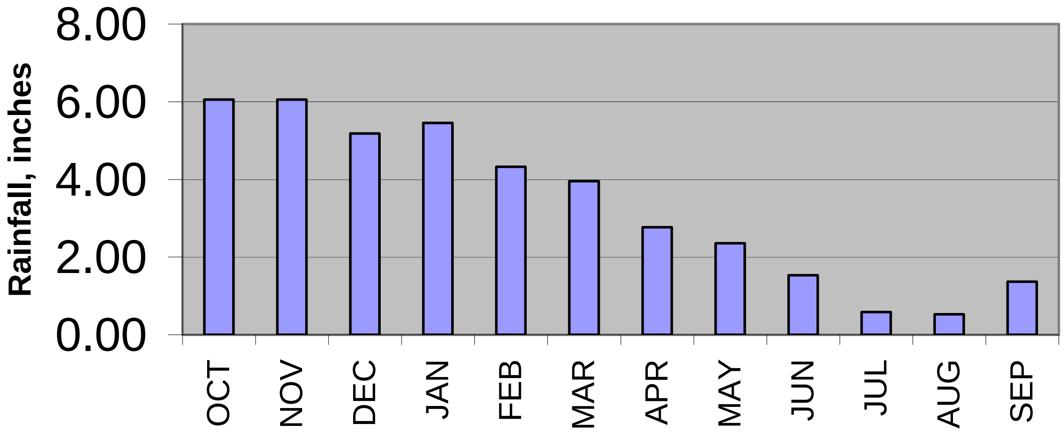
[2] PDX period of record, 1946-1991; Source: Combined Sewer Overflow Management Plan; Characterization Report, December 1992. BES

Table 3-2
Annual Average Rainfall
(Rainfall depth, inches per season or year)

Gage station	Winter (November through May)	Summer (June through October)	Annual
Thomas Gage	33.53	9.40	42.92
Vermont Hills	32.46	9.81	42.26
Collins	31.63	10.47	42.11
Sylvania	31.47	9.77	42.13
AVERAGE	**32.27**	**9.86**	**42.13**

Note: Period of record, 1995-2002.

Figure 3-1
Average Monthly Rainfall



Source: BES Modeling Group

The rainfall monitoring results show the pattern typical of the Mediterranean-type climate. The average annual precipitation is 42.13 inches, with 77 percent (32.27 inches) of the precipitation occurring during the winter season and only 23 percent (9.86 inches) occurring during the summer season. The summer season typically has extended periods without any precipitation, with both July and August averaging approximately 0.5 inch of rain.

The monitoring results also show fairly uniform rainfall amounts over the region. However, localized variability in precipitation patterns could be expected, based on orographic effects (i.e., increased precipitation at higher elevation in the watershed).

The annual rainfall pattern strongly influences stream flow regimes in the watershed, particularly the low flows that are characteristic during the late summer. In addition, the typical storm pattern in the watershed is frontal storms that move from west to east. This storm pattern can be significant in influencing stream responses to precipitation in the watershed, since most of the streams generally flow in the opposite direction, from east to west.

Topography

The Fanno Creek Watershed is located on the southwest sides of the Tualatin Mountains (West Hills). Elevation in the watershed ranges from a low of 200 feet above mean sea level (msl) to the highest point in the watershed, Council Crest, approximately 1,070 feet above msl. Steep-sloping terrain from the crest of the West Hills drains south to the mainstem of Fanno Creek, with slopes averaging over 25 percent. Slopes lower in the mainstem basin and in the other tributary basins generally range between 11 and 25 percent, with steeper slopes common along stream corridors. These steep to moderate slopes throughout the watershed contribute to high runoff volumes, rapid hydrologic response to rainfall (flashiness of streams), and a high potential for soil erosion. (For more elevation detail, see Map 9 Fanno Creek Contour Maps by subwatershed, Map Atlas).

Geology/Soils

The Fanno Creek Watershed area is composed of remnants of historic volcanic activity known as Columbia River basalt. In addition, lava tunnels have been found throughout this Tualatin Mountain area. When the Columbia River basalts were exposed, 50,000 years ago, the Portland area enjoyed a tropic-like climate. During this period, the basalts weathered and broke down into silts and clays. These silts and clays are the predominant soils within the Fanno Creek Watershed today. One such clay, laterite, is prevalent throughout the West Hills.

The Soil Conservation Service (now the Natural Resource Conservation Service) Soil Survey Manual for Multnomah County shows the prevailing (91.7 percent) soil classification in the Fanno Creek Watershed to be the Cascade series. The Cascade series is a moderately deep, poorly draining soil consisting primarily of dark brown silty loam. The remaining soils are made up of the Cornelius series (4.9 percent), Delena series (3.1 percent), and others (0.2 percent).

A fragipan layer exists throughout the Cascade series soil type at a depth of 20 to 30 inches below the ground surface. This layer consists of a subsurface horizon of low porosity that is low in clays but high in silt or very fine sands, forming what appears to be a cemented layer that restricts root formation and infiltration. The fragipan layer ranges in thickness from two to four feet. When dry, the fragipan layer is very hard and dense. When wet, it tends to rupture suddenly under pressure, resulting in slope failures and slides.

During the summer months, the Cascade soils can be dry to a depth of 4 to 12 inches, for up to 60 consecutive days. As a result of this dryness, the ground is hard and can act as an impervious surface, particularly for high-intensity, short-duration summer storms. In areas of relatively undisturbed soils, the permeability is slow, and available water capacity is between five and eight inches. In the months from December to April, the Cascade soils tend to have a water table at a depth of approximately 30 inches. The water table is typically perched on the fragipan layer. Depending on its location relative to the surface, the perched water table reduces the storage capacity of the soils, thus increasing the volume of runoff to the stormwater system during the winter season.

The Cascade series is further separated in two categories: Cascade silt loam and Cascade urban land complex. The Cascade silt loam is primarily native material, while the Cascade urban land complex consists of areas that are disrupted by urban development. The Cascade series is further divided into subclassifications based on land slope, with higher slopes having higher rates of runoff and erosion potential. The Cascade urban land complex is the predominant soil classification in the Fanno Creek Watershed as a result of the existing urban development.

The Delena soils are predominantly along the stream corridors and flat slope areas of the basin. These soils are also poorly drained and predominantly silty soils. The Delena soils make up the boundary surfaces of the streams and influence the streams' stability.

The Cornelius and other soil types have minimal effect because of their limited distribution and area within the watershed.

Figures 3-2 and 3-3 shows the percentage of soil classifications in the Fanno Creek Watershed. (See Map 6-Fanno Creek Soils Maps by subwatershed in the Map Atlas for a detailed distribution of these soils.)

Figure 3-2
Fanno Creek Watershed Soil Types

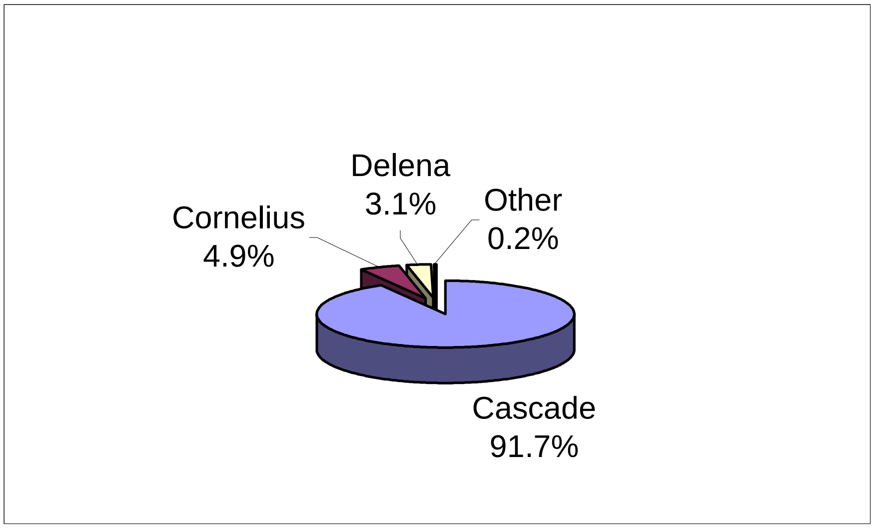
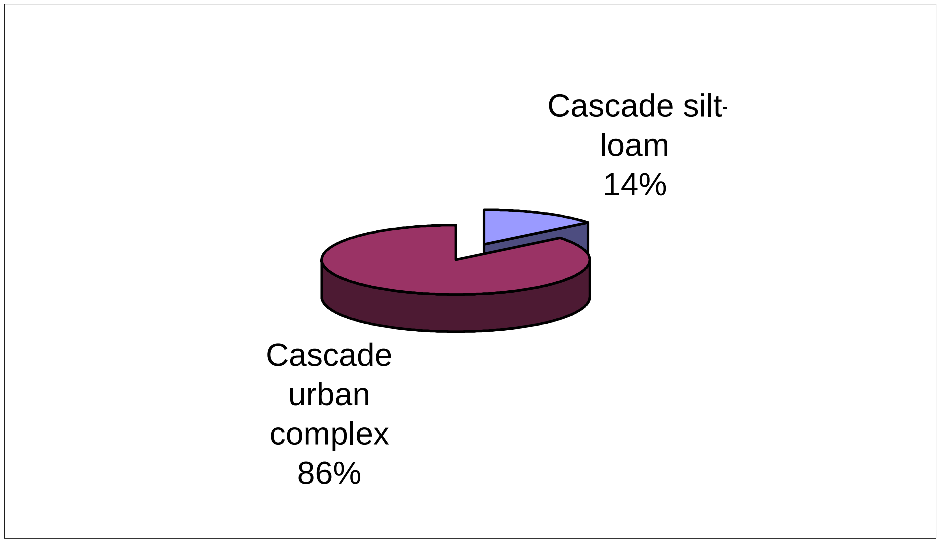


Figure 3-3
Cascade Series Breakdown



Given the characteristics of the soils within the Fanno Creek Watershed, it may not be feasible to use infiltration devices for water quantity control and water quality treatment in most locations because of the low infiltration rates and the underlying fragipan layer. Site-specific soil investigations would be required to confirm design criteria for these facilities. The seasonal variation in infiltration capacities and soil characteristics would also have to be considered. In summer, the infiltration rates are further reduced as the clays dry; in winter, the soils become saturated with the water table perched on the fragipan layer. The saturated soils above the fragipan can also result in unstable soils conditions, with possible slope failures and slides.

HUMAN INFLUENCES

Land Use

Land use is a general indicator of the types of human and urban activities present in the watershed. Impacts from land use changes can include increased impervious area, alteration of natural flow patterns through development of urban infrastructure, and increased pollutant loads.

The European settlement of the Fanno Creek Watershed began in the mid 1800s. In 1846, Agustus Fanno settled on 640 acres in the low flatlands of the watershed, near what is known today as Hall Boulevard and Greenway Park. The early settlers, woodsmen, farmers, and dairymen had to carry their goods over Council Crest to Portland. The construction of the South Pacific Railway around 1870 (currently the Bertha Road alignment) and the Oregon & Electric Railway around 1900 (today's Multnomah Boulevard right-of-way) contributed to the pace of growth within the basin.

The predominant existing land use within the Fanno Creek Watershed is single-family residential development (82.6 percent). Other uses include multi-family residential (9.1 percent), commercial (2.5 percent) and parks and open space (5.8 percent). Figure 3-4 and Table 3-3 show land uses and associated coverage areas, based on current zoning adopted in the *Southwest Community Plan* (Bureau of Planning 2001).

Figure 3-4
Fanno Creek Watershed
Existing Zoning

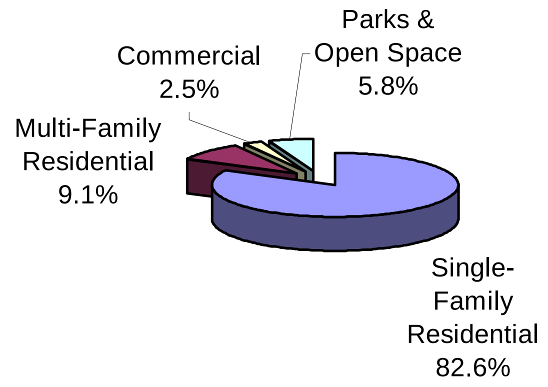


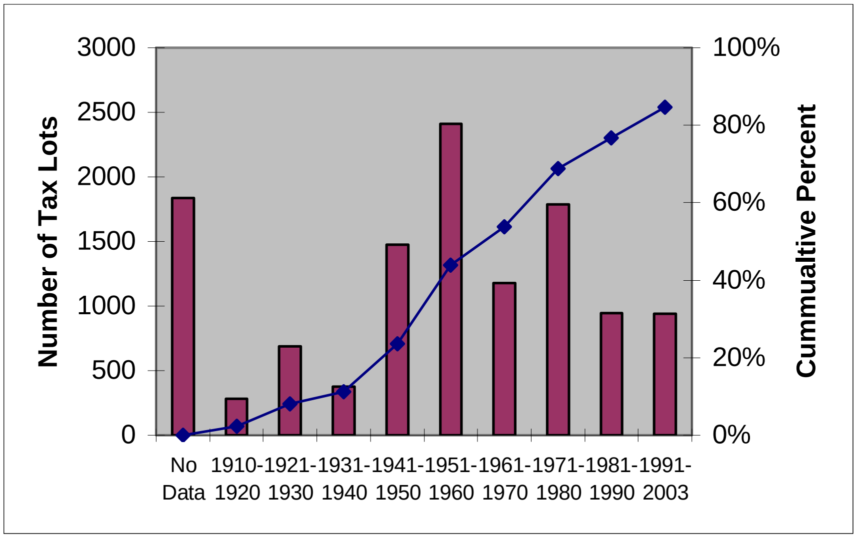
Table 3-3
Fanno Creek Watershed Current Land Use Zoning

Land Use Category	Area (acres)	Percentage
Single-Family Residential	3,742	82.6
Multi-Family Residential	410	9.1
Commercial	114	2.5
Parks & Open Space	261	5.8
Total	**4,528**	**100.0**

Figure 3-5 shows the percentage of tax lots built on between 1910 and 2003 in the Fanno Creek Watershed. Fifty-seven percent of the tax lots were built on between 1941 and 1980; most development within the basin is therefore between 24 and 63 years old. An additional 16 percent of the tax lots were built on between 1981 and 2003.

Based on tax lot data, it is estimated that the watershed is currently 85 percent built out. Future growth will probably occur by in-filling of vacant land or minor parceling of large existing occupied lots, rather than by large land development projects. Based on the extent and age of development within the watershed, it would be expected that some impacts from construction and urbanization within the watershed have stabilized.

Figure 3-5
Tax Lots Built on in Fanno Creek Watershed



In addition to land use designations, Portland has established environmental overlay zones to protect and conserve significant natural resources. The environmental overlay zones are based on extensive natural resource inventories that cover areas within the City. The environmental zoning program is also the City's primary tool for complying with State Land Use Planning Goal 5 to protect significant natural resources.

There are two types of environmental overlay zones, which currently affect approximately 689.9 acres in the Fanno Creek Watershed. Protection (P) zones have been established in areas that have very high-value resources and functional values. Development is approved in the protection zone only in very limited circumstances. Within conservation (C) zones**,** development is allowed if it meets certain standards and approval criteria to ensure that impacts on significant resources are avoided, limited, and/or mitigated.

Environmental overlay zones encompass many of the existing stream channels and riparian areas within the watershed and therefore serve to protect the natural hydrologic processes.
Table 3-4 summarizes environmental overlay zone coverages. (Also see Map 4 - Fanno Creek Current Plan Existing E-Zones Maps by subwatershed in the Map Atlas).

Table 3-4
Environmental Zone Coverage in Fanno Creek Watershed

Subwatershed	C Zone (acres)	P Zone (acres)	Total E Zones (acres)	Subwatershed Area (acres)	Percentage of Subwatershed
Fanno Creek mainstem	177.7	119.3	297.0	1,830.6	16.2
Pendleton Creek	37.4	7.0	44.4	230.5	19.3
Vermont Creek	26.5	47.4	73.9	758.1	9.8
Woods Creek	60.2	65.0	125.2	575.5	21.8
North Ash Creek	22.3	3.9	26.3	282.5	9.3
South Ash Creek	48.7	8.7	57.4	359.0	16.0
Red Rock Creek	61.5	3.5	65.0	413.1	15.7
Sylvan Creek	0.0	0.7	0.7	79.1	0.9
Total (Watershed)	**434.3**	**255.6**	**689.9**	**4,528.4**	**15.2**

Impervious Area

One of the most pervasive and obvious changes to the natural system as the result of urbanization is an increase in impervious cover and a corresponding loss of natural vegetation (May et al. 1997). The increase of impervious area includes the construction of roads, parking lots, driveways, sidewalks and rooftops. These construction activities also often result in the compaction of native soils. The effect of this increased impervious area is the alteration of the natural hydrologic cycle by changing flow paths, increasing runoff, and decreasing infiltration. These changes subsequently drive many of the physical and biological responses that affect urban streams.

The total impervious area in a watershed is often used as a measure of urbanization and corresponding effects on watershed health (Schueler 1994; Arnold and Gibbons 1996). Research on urban streams has shown that significant impairment of stream ecosystems (including hydrologic factors) begins when total impervious area in a watershed reaches a threshold of approximately 10 percent. A second threshold appears at about 25-30 percent total impervious area, when most indicators of stream health shift to a poor condition (Schueler 1994; SMRC 2004).

The Center for Watershed Protection has developed the impervious cover model, which classifies urban stream ecological health based on total impervious area (SMRC 2004). Stream classifications, with key associated hydrologic factors, are summarized below:

- Sensitive Streams (0-10 percent total impervious area): These streams are generally characterized by stable channels and do not exhibit frequent flooding and other hydrological changes resulting from urbanization.

- Impacted Streams (11-25 percent total impervious area): These streams have elevated storm flows that begin to alter stream geometry. Erosion and channel widening are evident, and streambanks become unstable.

- Non-Supporting Streams (more than 25 percent total impervious area): These streams exhibit highly unstable stream channels, with many reaches with severe widening, downcutting, and stream bank erosion.

Table 3-5 summarizes total impervious area for the Fanno Creek Watershed and tributary subwatersheds. The average total impervious area for the Fanno Creek Watershed is 33.1 percent. Subwatershed total impervious areas range from 25.5 to 38.9 percent. Based on the impervious cover model, all of these streams would be classified as non-supporting streams. The actual effects from impervious areas would be expected to vary within the watershed, based on a combination of other related factors, including localized impervious area percentages, land slope, location relative to the stream, the stormwater conveyance system, and any implementation of onsite stormwater control measures. In the Fanno Creek Watershed, the effects of impervious area may be moderated because the “effective impervious area” (i.e., the impervious area directly connected to the stream or storm conveyance system) is estimated to be lower than the total impervious area. Still, most streams within the watershed have reaches that exhibit characteristics of impacted, or non-supporting streams (increased storm flows, unstable stream banks, downcutting and stream bank erosion).

Table 3-5
Fanno Creek Watershed Impervious Area

Subwatershed	Impervious Area (acres)	Subwatershed Area (acres)	Percentage of Subwatershed
Fanno Creek Mainstem	593.2	1,830.5	32.4
Pendleton Creek	61.3	230.4	26.6
Vermont Creek	238.7	758.1	31.5
Woods Creek	192.6	575.1	33.5
North Ash Creek	91.8	282.5	32.5
South Ash Creek	139.8	359.0	38.9
Red Rock Creek	160.1	413.1	38.8
Sylvan Creek	20.2	79.1	25.5
Total	**1,497.7**	**4,528.3**	**33.1**

Infrastructure

Stormwater System

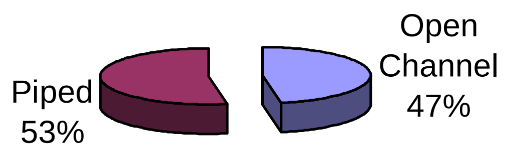
Along with increased impervious areas resulting from urbanization, the construction of urban stormwater drainage systems is a major factor that impacts the hydrology of urban streams. These drainage systems invariably increase the drainage density of the subcatchment and reduce the time necessary for overland flow to reach the stream. This results in faster runoff and higher stream velocities, along with higher and “flashier” flood flows (Hollis 1975).

The construction of the urban stormwater system also typically results in the loss of small headwater streams that are critically important to watershed health. Small intact streams provide natural flood control, recharge groundwater, trap sediments and pollution from fertilizers, recycle nutrients, create and maintain biological diversity, and sustain the biological productivity of downstream rivers, lakes, and estuaries (Moyers et al. 2003).

The construction of the stormwater system in the Fanno Creek Watershed has followed the development pattern within the watershed. Stormwater systems have been constructed as required to convey stormwater from constructed impervious surfaces, redirect natural flow paths to allow for construction of structures, and convey stormwater from roads and streets. The highest density of stormwater infrastructure is typically located in the upper portions of the subwatersheds. The stormwater systems are typically small systems that provide for localized drainage, with discharge to the local stream systems for further conveyance.

The stormwater system is divided almost equally between open channel systems (47 percent) and piped systems (53 percent), as shown on Figure 3-6. (Also see Map 11-Fanno Creek Existing Storm Sewer Maps by subwatershed in the Map Atlas)

Figure 3-6
Fanno Creek Watershed
Stormwater System



Culverts are another major element of the stormwater conveyance system in the Fanno Creek Watershed. Culverts are typically located at all roadway stream crossings in the watershed. Smaller private culverts are also commonly found at local access points to the public street system. In addition to protecting public health and property by conveying flood flows, the culverts often act as hydraulic controls and modify the natural hydraulic response of the stream systems by restricting and detaining flow. This is typically most pronounced during larger storm events.

Sanitary Sewer System

The Fanno Creek Watershed is divided into four sanitary sewer basins: Fanno, Metzger, Tryon, and Southwest, as shown on Figure 3-7. The boundaries of the sanitary basins cross the drainage subwatershed boundaries.

Figure 3-7
Fanno Creek Watershed Sanitary Sewer System

(on next page)

Sewage flows generated in the basin can be discharged to three different treatment plants. Sewage flows from the Fanno sanitary basin (primarily the Fanno mainstem and Pendleton subwatersheds) are gravity fed to the Fanno Creek pump station, where sewage is routed to the SW 31st Avenue and Multnomah Boulevard diversion structure through a pressure line under SW Garden Home and SW Multnomah Boulevard. At the 31st Avenue diversion structure, the flows can either be routed to the Columbia Boulevard Water Treatment Plant (CBWTP) or the Tryon Creek Water Treatment Plant (TCWTP).

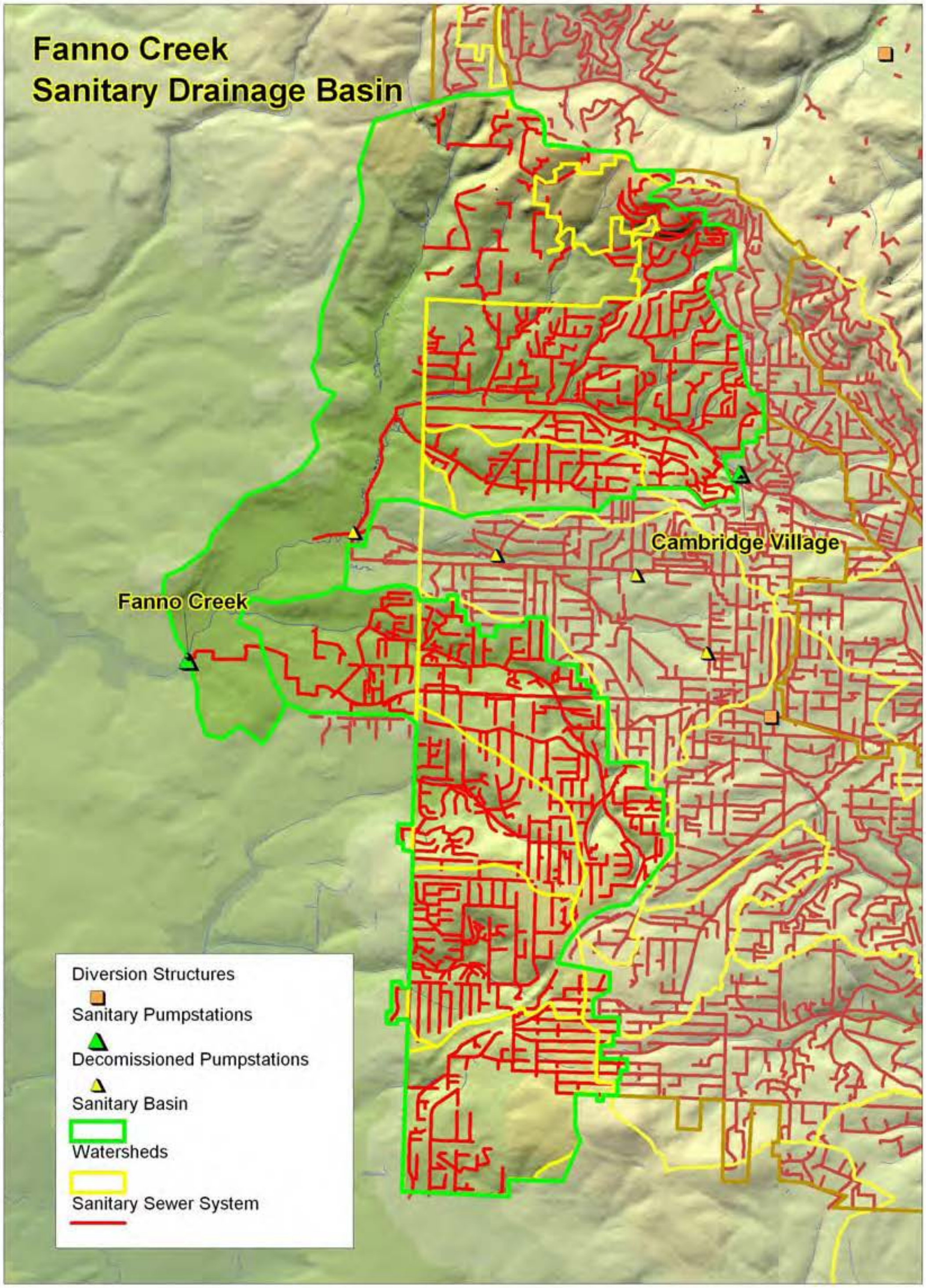
Sewage flows from the Tryon sanitary basin (primarily the Vermont subwatershed) are gravity fed to the TCWTP.

Sanitary flows from the Metzger sanitary basin (primarily the Woods, North Ash, South Ash, and Red Rock subwatersheds) are fed by gravity to Clean Water Services' wastewater treatment plant in Durham.

The sewerage system throughout the watershed is a gravity system constructed of concrete pipe, with an average age of 50 years. The system has extremely high infiltration and inflow (I/I) rates. Rates as high as 15,000 to 21,000 gallons per acre per day (gpad) were monitored during the winter of 1996/97. BES is currently conducting a project to address I/I problems within the Fanno basin (BES Project Number 7509).

Because of the operating requirements of the gravity sewerage system and the watershed topography, the sanitary sewer pipes are often located within stream corridors, with numerous stream crossings. (See Map 10-Fanno Creek Existing Sanitary System Maps by subwatershed in the Map Atlas) The proximity of the sanitary sewers to the streams can have potential impacts on the stream hydrology. Because of the I/I problems in the watershed, along with the soil characteristics and groundwater, any sewer breaks or imperfections usually result in groundwater flow into the sewer. However, major breaks or blockages can cause sewage to discharge directly to the streams.

The proximity of the sewers to the streams can also have impacts on the stream hydrology related to construction and maintenance. Studies have shown that installing sewers and other utilities in the riparian zone can alter groundwater flow patterns and the interaction of the stream with the saturated zone (ref). Required maintenance or reconstruction of these sewers can also impact hydrology without proper mitigation measures. This will be an increasingly important issue within the Fanno Creek Watershed, as the aging sewer infrastructure requires more frequent maintenance.



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GAGED STREAM FLOWS

Through a cooperative agreement with BES, the USGS has maintained a stream flow monitoring station on Fanno Creek at SW 56th Avenue since 1990.

Figure 3-8 shows the annual hydrograph for Fanno Creek at SW 56th Avenue for the 2000-2001 water year. The hydrograph shows the typical pattern for the streams in the Fanno Creek Watershed, with an extended wet period with frequent higher flows from October through the end of May, followed by a dry summer period of lower flows. It also shows the “flashy” response of the subwatershed to rainfall events, with rapid changes in flows. Winter season base flow is approximately five cubic feet per second (cfs), with peak storm event flows ranging from 30 to 160 cfs. Summer base flow is less than one cfs, with peak summer storm event peaks between 20 and 80 cfs.

Figure 3-8
Fanno Creek Water Year 2001-02
At SW 56th Avenue

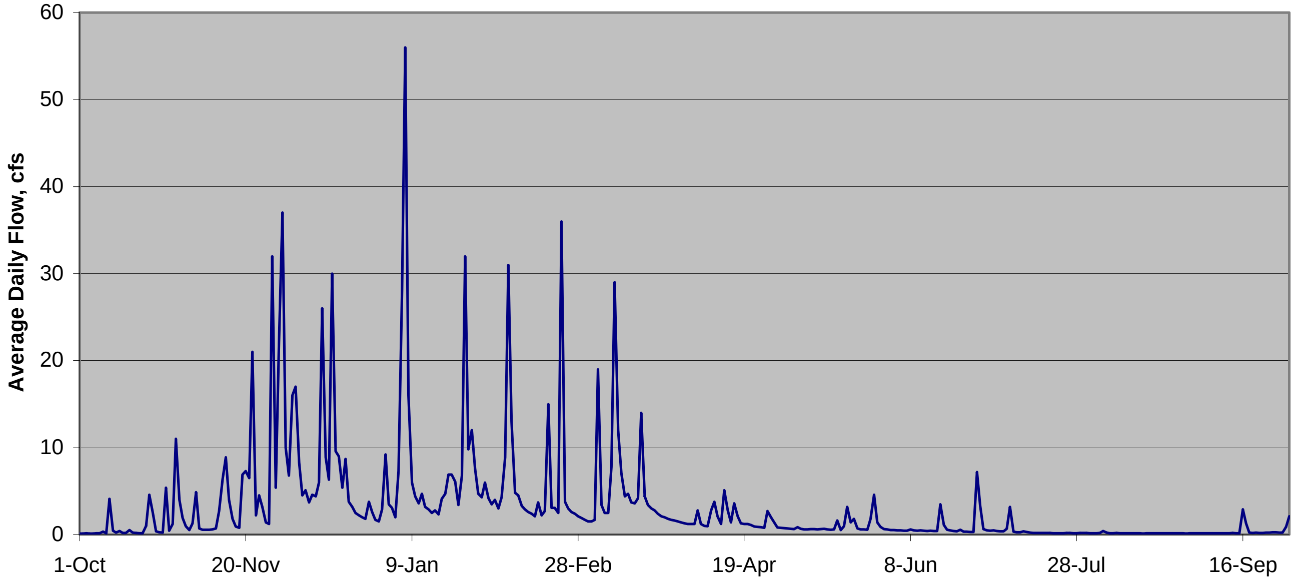


Figure 3-9 shows a flow duration curve for Fanno Creek (at SW 56th Avenue) based on continuous flow data collected at this site since 1990. The flow duration curve shows the probability of exceeding any given flow. The curve is further divided into five flow regions: high flows, wet conditions, transition flows, dry conditions, and low flows. As seen in the figure, low flows are dominant in Fanno Creek with base flow during wet periods (generally during the winter months) averaging approximately 3 cfs (cubic feet per second). Dry period base flows average less than 1 cfs. It also shows the relatively infrequent but very high flows resulting from rainfall during storm events. Low flows (primarily during late summer) show ten percent of the flows being less then 0.2 cfs.

The flow duration curve analysis when combined with associated water quality data can be very useful in understanding the relationship between stream flow and water quality. These relationships can be utilized to identify potential pollutant sources and the development of appropriate management strategies.

Figure 3-9
Flow Duration Curve for Fanno Creek at SW 56th Avenue
USGS Gage 14206900

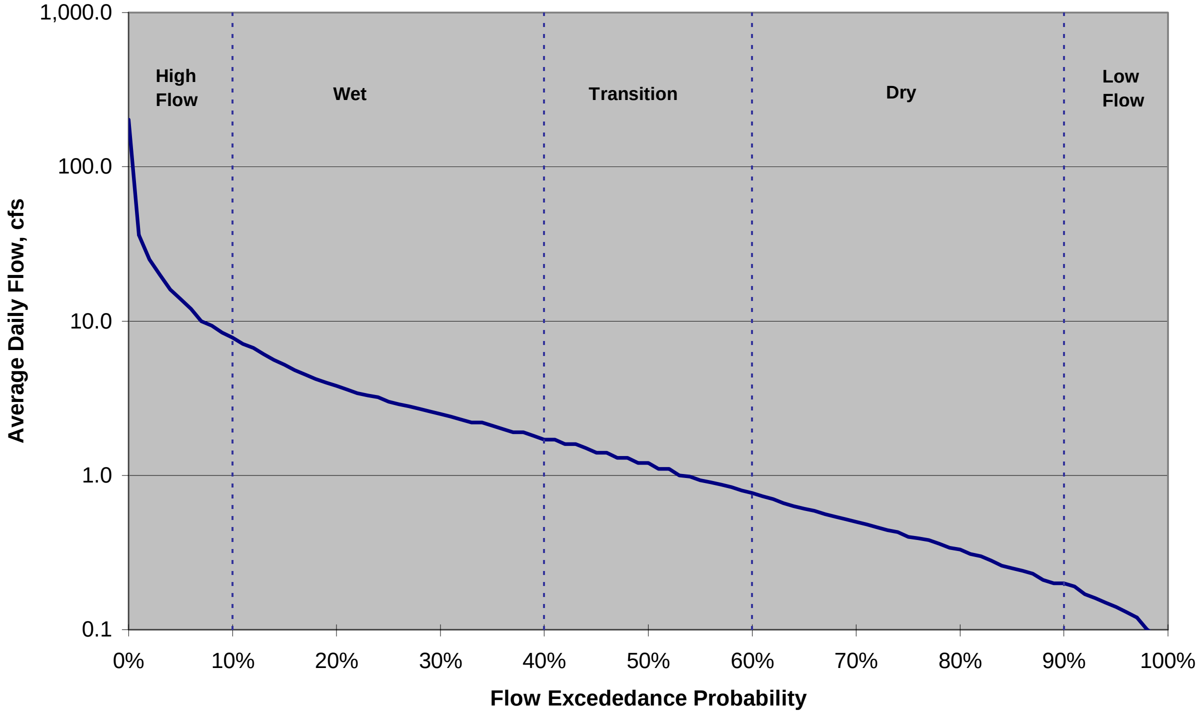
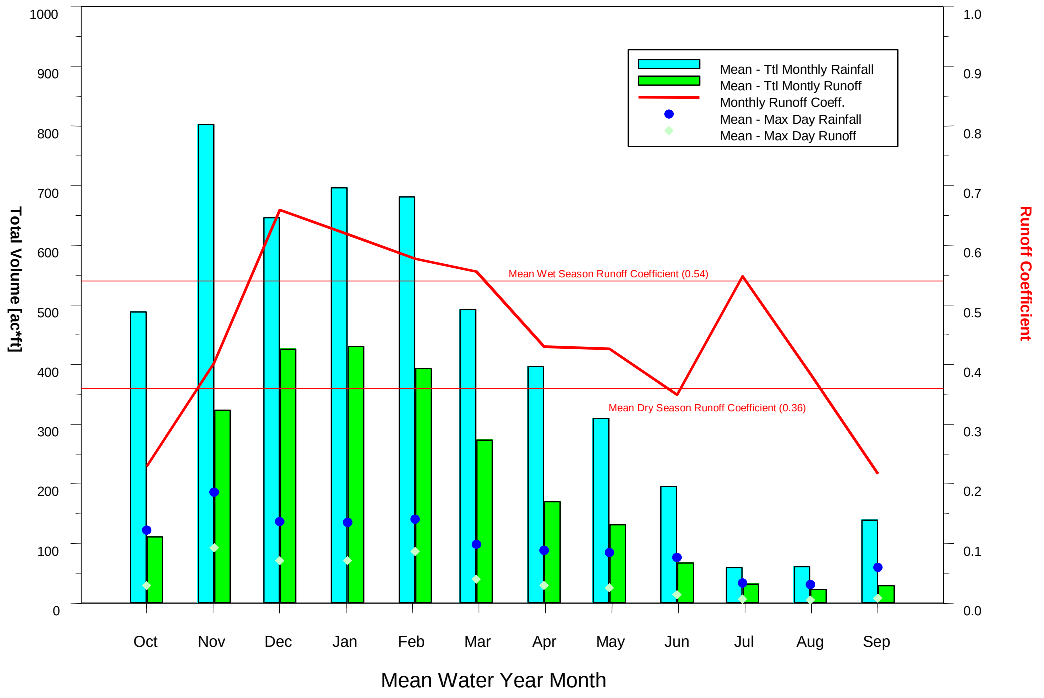


Figure 3-10 shows mean monthly rainfall and runoff volumes for the SW 56th Street gage location. The figure also shows the monthly runoff coefficient (runoff volume/rainfall volume). The mean monthly volumes for both rainfall and runoff show the same general annual pattern as described above. Based on the monthly runoff coefficient, however, there appear to be significant differences in hydrologic response during different periods of the year. During the early part of the wet season, starting in September, the runoff coefficient is low, with only about 20 percent of the rainfall recorded as runoff. The percentage of runoff then steadily increases during the wet season until about December. After that, the runoff coefficient remains constant at about 55 percent until the rainfall starts decreasing in the spring, followed by a decrease in the runoff coefficient. It is hypothesized that this lag in system response at the beginning of the wet season is caused by a recharge of the shallow groundwater (soil profile) until it reaches saturation, along with possible higher rates of interception by deciduous vegetation and trees prior to leaf fall.

The monthly runoff coefficient also shows a peak during the summer. Possible causes are a higher rate of runoff during short-duration summer storms after the soils have dried, resulting in decreased soil infiltration rates, along with a larger relative contribution of groundwater base flow during the summer.

Figure 3-10
Fanno Creek Watershed Drainage for USGW Stream Gage at SW 56th Avenue
Mean Water Year Based on Period of Record (1990-2002)



Stream gaging data are not available for other subwatersheds within the Fanno Creek Watershed. Based on modeling results and observations, however, yearly stream hydrograph patterns and response to storm events would be expected to be similar. Flow magnitudes would be different, based on the drainage areas of the other subwatersheds.

PREVIOUS HYDROLOGY STUDIES

Previous hydrologic studies of the Fanno Creek Watershed include BES's evaluation of the hydrologic impacts to stormwater facilities within the Fanno Creek Watershed basin. The most recent analysis was completed in 1998 as part of the Fanno Creek *Resource Management Plan/Public Facility Plan* (RMP/PFP). The RMP/PFP analysis was limited to a hydrologic assessment of subbasins/tributaries and did not account for the hydraulic impact of culverts and overbank flow events. The analysis involved a hydraulic review of selected locations on the main channel of Fanno Creek and major tributaries. The RMP/PFP used the HEC-1 model (Hydrologic Engineering Center, U.S. Army Corps of Engineers) to simulate a hydrologic response to designated rainfall events. (The HEC model is not suited for continuous simulation.) The analysis results showed potential areas where peak volume exceeded the carrying capacity of the system. The analysis recommended construction of a more detailed model to provide a more accurate assessment.

Another previous study was the *West Side Drainage Study* (BES 1982), which analyzed the watershed hydrology based on the rational method (an empirical method that relates peak flows to rainfall intensity, impervious area, and basin topography).

CURRENT HYDROLOGIC ASSESSMENT

To respond to the RMP\PFP recommendations and support development of the Fanno Creek Watershed Plan, BES selected the Danish Hydraulics Institute's MIKE SHE and MIKE 11 models to perform additional hydrologic and hydraulic modeling of the watershed. The MIKE SHE and MIKE 11 models are integrated surface and groundwater models that simulate hydrologic, hydraulic, upland pollutant loading, and instream processes within a watershed. The MIKE models can simulate continuous rainfall events to generate seasonal and annual flows, unlike the previously used HEC-1 event-based model.

The MIKE SHE model is a physically based, dynamic, fully distributed hydrologic model that simulates all major hydrological processes occurring in the land phase of the hydrologic cycle. Modeled hydrologic components include interception-evapotranspiration, infiltration, snowmelt, overland flow, subsurface flow, groundwater flow, and stream-aquifer exchange.

Runoff flows generated by the MIKE SHE model are input into the MIKE 11 model for routing through the modeled stormwater conveyance and stream system. The MIKE 11 model is a dynamic one-dimensional hydraulic model.

The MIKE SHE and MIKE 11 models are based on a grid system, where each model area is divided into a network of square grids. For the Fanno Creek Watershed, a constant 100-foot-square grid size was used, based on basin characteristics and computational constraints of the models. Separate MIKE SHE and MIKE 11 models were developed for the seven major drainage subwatersheds in the Fanno Creek Watershed:

- Fanno Creek Mainstem
- Pendleton Creek
- Vermont Creek
- Woods Creek

- North Ash Creek
- South Ash Creek
- Red Rock Creek

The models were calibrated and run for two basic model scenarios:

- An evaluation of subwatershed hydrology, using a continuous rainfall record developed for a "typical year," based on an analysis of actual rainfall recorded in the watershed.

- An evaluation of the capacity of the existing drainage system to convey stormwater, using design storms with recurrence intervals of 2, 10, 25, and 100 years.

The technical memoranda at the end of this report provide a detailed description of how the MIKE models were developed and used for this project.

Modeling Results

Table 3-6 shows design storm flows for the subwatersheds within the Fanno Creek Watershed.

Table 3-6
Design Storm Flow Results for Fanno Creek Basin Model

		Fanno Creek Gage at 56th Ave. (USGS #14206900) Modeled Basin Area = 1,517 acres					
Storm Event	**Rainfall (inches)**	**Peak Flow (cfs)**	**Rainfall Volume (10^6 gallon)**	**Flow Volume (10^6 gallon)**	**Flow Vol. Per Acre (10^6g/ac)**	**Runoff Coefficient**
2-yr	2.53	167	104.2	28.95	0.019	0.28
10-yr	3.36	347	138.4	49.9	0.033	0.36
25-yr	3.84	492	158.2	64.0	0.042	0.40
100-yr	4.49	720	185.0	98.8	0.065	0.53
		Pendleton Creek Modeled Basin Area = 240 acres				
2-yr	2.53	23.8	16.9	10.4	0.043	0.62
10-yr	3.36	41.7	22.4	14.2	0.059	0.63
25-yr	3.84	53.5	25.6	16.8	0.070	0.65
100-yr	4.49	70.3	29.9	20.4	0.085	0.68
		Vermont Creek Modeled Basin Area = 785 acres				
2-yr	2.53	59.0	53.9	18.5	0.024	0.34
10-yr	3.36	100.0	71.6	29.3	0.037	0.41
25-yr	3.84	128.0	81.9	36.4	0.046	0.44
100-yr	4.49	183.0	95.7	53.5	0.068	0.56
		Woods Creek Modeled Basin Area = 613 acres				
2-yr	2.53	73.0	42.1	18.9	0.031	0.45

10-yr	3.36	129.0	55.9	26.5	0.043	0.47
25-yr	3.84	154.0	63.9	31.4	0.051	0.49
100-yr	4.49	188.0	74.7	43.4	0.071	0.58
		North Ash Creek **Modeled Basin Area = 266 acres**				
2-yr	2.53	44.0	18.3	6.1	0.023	0.33
10-yr	3.36	83.0	24.3	9.5	0.036	0.39
25-yr	3.84	96.0	27.7	11.8	0.044	0.42
100-yr	4.49	111.0	32.4	16.7	0.063	0.51
		South Ash Creek **Modeled Basin Area = 188 acres**				
2-yr	2.53	31.4	12.9	5.5	0.029	0.43
10-yr	3.36	54.0	17.2	8.5	0.045	0.50
25-yr	3.84	62.0	19.6	10.4	0.055	0.53
100-yr	4.49	70.0	22.9	14.7	0.078	0.64
		Red Rock Creek **Modeled Basin Area = 811 acres**				
2-yr	2.53	116.4	55.5	27.4	0.034	0.49
10-yr	3.36	171.8	74.0	39.0	0.048	0.53
25-yr	3.84	197.8	84.6	46.0	0.057	0.54
100-yr	4.49	225.8	98.8	54.7	0.067	0.55

Source: Fanno Mainstem and Tributary Hydrodynamic and Water Quality Model Development , BES, 2004.)

The Mike SHE and MIKE 11 models were used to evaluate the capacity of the drainage system to convey stormwater under existing land use conditions. The evaluation was based on criteria in the City of Portland's Sewer Design Manual (BES 1991). A brief synopsis from the manual follows:

> All storm drainage facilities shall be designed to pass a 10-year storm without surcharge. Surcharging during a 25-year storm is permitted with a "stormwater only" system. Surcharged pipes and bankfull channels are acceptable for conveyance of the 100-year design storm provided that several health and safety conditions are met. The allowable headwater depth for culverts should be as great as practical, as long as it does not compromise safety, flood plain regulations, environmental considerations or property rights.

In general, the City designs a culvert or storm drainpipe to convey the 25-year flow without surcharge. In addition, within a FEMA regulated flood zone, the placement of a structure, such as a culvert, cannot increase the 100-year flood level. Culverts or storm drainpipes within a flood zone would therefore also need to convey the 100-year flow without surcharge. The only segment of Fanno Creek under FEMA floodplain jurisdiction is west of SW 56th.

Table 3-7 summarizes the capacity deficiencies identified by the modeling evaluation.

Table 3-7
Summary of Capacity Deficiencies

Subwatershed	**Number of Culverts Modeled**	**Number and Percentage of Culverts Surcharged under 2-yr & 10-yr Storm**	**Number and Percentage of Culverts Expected To Have Roadway Flooding Problems**	**Number of Storm Pipes Modeled**	**Number and Percentage of Storm Pipes Surcharged under 2-yr & 10-yr Storm**
Fanno Creek Mainstem	71	49 (69%)	34 (48%)	15	9 (60%)
Pendleton Creek	25	8 (32%)	4 (16%)	35	4 (11%)
Vermont Creek	24	9 (38%)	6 (25%)	54	27 (50%)
Woods Creek	76	43 (57%)	12 (16%)	37	19 (70%)
Ash Creek	79	42 (53%)	17 (22%)	52	32 (62%)
Red Rock Creek	27	21 (78%)	12 (44%)	47	36 (77%)

Source: Fanno Mainstem and Tributary Hydrodynamic and Water Quality Model Development, BES, 2004.

Fanno Creek Mainstem Subwatershed

DESCRIPTION

The Fanno Creek mainstem subwatershed is considered the headwaters of Fanno Creek. The subwatershed drains approximately 2,000 acres, of which 1,910 acres are within Portland’s jurisdiction. (See Map 1-Fanno Creek Aerial Map in the Map Atlas). Fanno Creek begins near the intersection of SW 25th Avenue and Beaverton-Hillsdale Highway. It flows west through West Portland along SW Beaverton-Hillsdale Highway before it leaves the City’s jurisdiction at SW Scholls Ferry Road. In addition to the west boundary described above, the subwatershed is bound on the east by the Willamette River Watershed and the southwest combined sewer basin; on the north by the Tanner Creek Watershed; and on the south by the Pendleton Creek and Vermont Creek subwatersheds. Pendleton Creek and Vermont Creek are tributary creeks that join Fanno Creek outside the City’s jurisdiction.

LANDSCAPE FACTORS

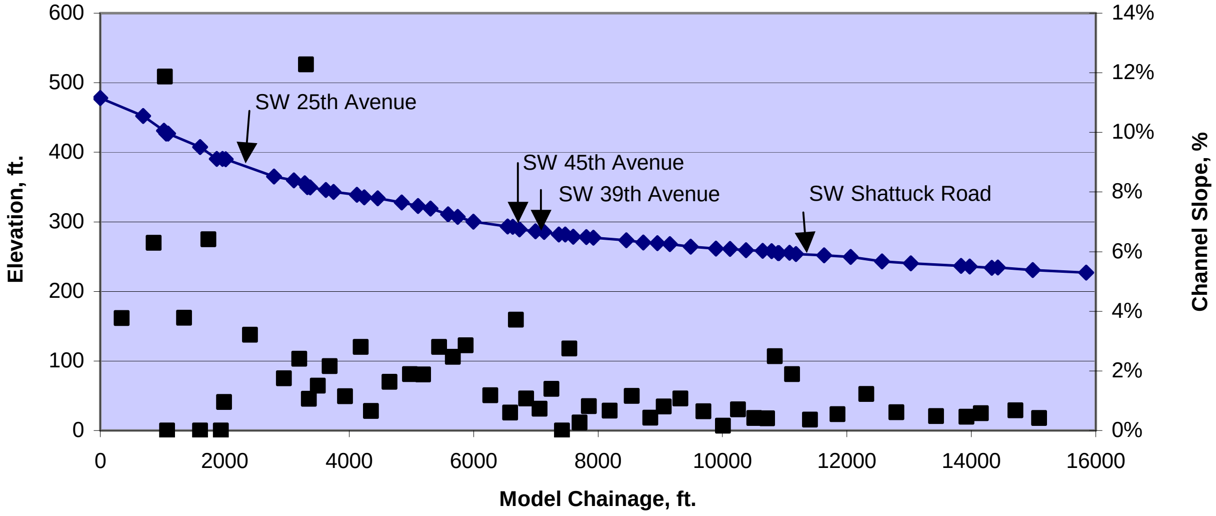
Topography

The Fanno Creek mainstem subwatershed ranges in elevation from a low of 200 feet above msl to the highest point in the Fanno Creek Watershed, Council Crest, approximately 1,070 feet above msl. The major contributing area to the subwatershed is the steep-sloping terrain on the north side of Fanno Creek, with slopes between 5 and 15 percent.

Stream Profile and Morphology

Figure 3-11 shows the modeled stream profile and channel slopes for Fanno Creek. Stream gradients range from moderate (4 percent average) upstream of SW 25th Avenue; low to moderate (2 percent average) from SW 25th Avenue to SW 45th Avenue; to low (less than 1 percent) downstream of SW 45th Avenue. Along the north side of Fanno Creek are small tributary subcatchments, including Columbia Creek, Ivey Creek, and several unnamed creeks. The grade of these tributaries drops more than 400 feet per mile, with stream gradients ranging from over 25 percent at their headwaters to 5 percent at their confluence with Fanno Creek.

Figure 3-11
Modeled Stream Profile and Channel Slopes for Fanno Creek



The *Fanno Creek Resource Management Plan* (BES and Brown & Caldwell 1998) included an extensive analysis of Fanno Creek's channel stability and geomorphic characteristics. In particular, a survey of bank erosion potential was conducted to identify components contributing to the erosion potential and affecting streambank stability. The survey identified and inventoried actively eroding streambanks. Based on this survey, three variables influence the stability of Fanno Creek:

- Oversteep bank angles (greater than 60 percent)
- Moderate to poor surface protection provided by vegetation

- Moderate root density

Of the 44 sampled sites, the survey found 25 sites with low bank erosion potential and 19 sites with moderate to high erosion potential. Three quarters of the 19 sites with moderate to high erosion potential were on the southern banks, adjacent to SW Beaverton-Hillsdale Highway.

The *Fanno Creek Resource Management Plan* also attempted to classify segments of Fanno Creek in accordance with the Rosgen stream classification method (Rosgen 1994). No set standard exists for classifying a stream and the physical variables that control the geomorphic process of a stream vary spatially and temporally. The Rosgen method, although it has some limitations in classifying urban streams, is the most commonly used procedure and has been widely adopted by state and federal agencies, such as the U.S. Forest Service's Stream System Technology Center. It is primarily a predictive tool that describes the degree to which a stream departs from an assumed stable stream.

The Rosgen method selects reference stream reaches from which stream attributes are measured. These attributes (including stream slope, bed material, width/depth ratio, sinuosity, and degree of confinement) determine the stream type from a hierarchical system that includes eight general stream types. Overall, Fanno Creek is classified primarily as a Type G and Type B stream.

Type G streams are described as entrenched gully, with step/pools and low width/depth ratio on a moderate grade. This type of channel signifies a degraded channel system. Extensive, consistent channel erosion, through either incision or lateral scour, is more typical than not. Exceptions occur where dense, woody vegetation helps stabilize the toe of the streambank slopes. The excessive erosion adversely affects water quality and aquatic habitat by contributing abundant silt and sand to the substrate.

Type B streams are described as moderately entrenched with a moderate gradient dominated by riffles and infrequent spaced pools. This type of channel is considered to have a very stable plan and profile, with stable banks

Type G was the dominant stream classification in the low-gradient reach of Fanno Creek downstream from SW 45th Avenue, signifying a degraded channel. Upstream from SW 45th Avenue, most reaches were classified as Type B, indicating a more stable stream channel.

Soils

Table 3-8 summarizes the distribution of soil types within the Fanno Creek mainstem subwatershed. The predominant soil type is Cascade (91.5 percent). Within the area of Cascade soils, 563 acres (30.7 percent) are subclassified as D and E series, occurring on slopes ranging from 15 to 60 percent. These areas, found primarily on the steep slopes along the crest of the West Hills, contribute to higher runoff volumes and have a high potential for soil erosion from exposed or disturbed areas. Areas of steep slopes are also found along many of the tributary stream corridors.

Delena soils are found mainly along the lower reaches of Fanno and Columbia Creeks. Cornelius soils are found at the extreme western boundary of the subwatershed.

Table 3-8
Soil Types in Fanno Creek Mainstem Subwatershed

Soil Type	Series	Slope (%)	Area (acres)	Percentage of Subwatershed
Cascade	7B/8B	3-8	442	24.1
	7C/8C	8-15	674	36.7
	7D/8D	15-30	405	22.1
	7E	30-60	158	8.6
Subtotal			***1,678***	***91.5***
Cornelius	11B/11C	3-15	89	4.8
Delena	14C	3-12	67	3.6
Total			**1,834**	**100.0**

HUMAN INFLUENCES

Land Use and Zoning

The predominant land use within the Fanno Creek mainstem subwatershed is single-family residential (84.7 percent). Multi-family residential (9.9 percent) and commercial development (1.3 percent) uses are concentrated in the Hillsdale area and along the SW Beaverton-Hillsdale Highway corridor.

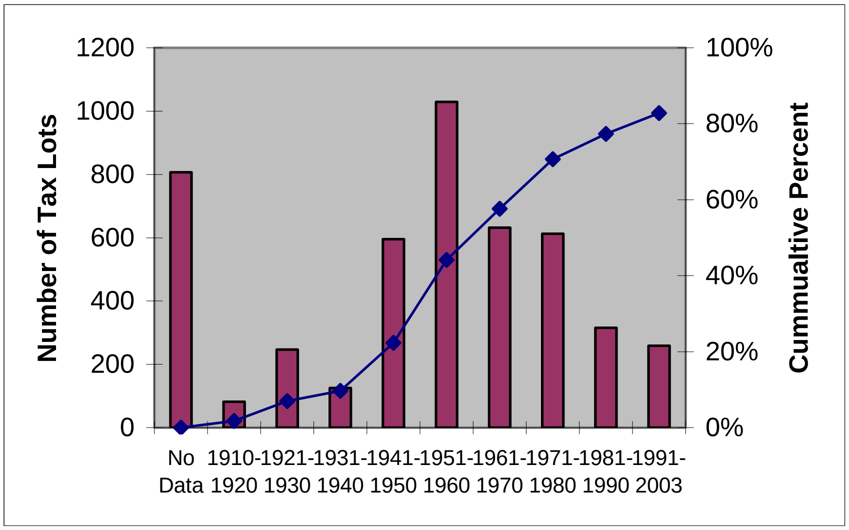
Table 3-9 summarizes the current zoning for the subwatershed, as adopted in the *Southwest Community Plan* (Bureau of Planning 2001). (See also Map 5-Fanno Creek Current Plan Maps by subwatershed in the Map Atlas). Figure 3-12 shows the percentage of tax lots built on between 1910 and 2003.

Table 3-9
Current Land Use Zoning
Fanno Creek Mainstem Subwatershed

Land Use Category	Area (acres)	Percentage
Single-Family Residential	1,617	84.7
Multi-Family Residential	189	9.9

Commercial	24	1.3
Parks & Open Space	80	4.1
Total	**1,910**	**100.0**

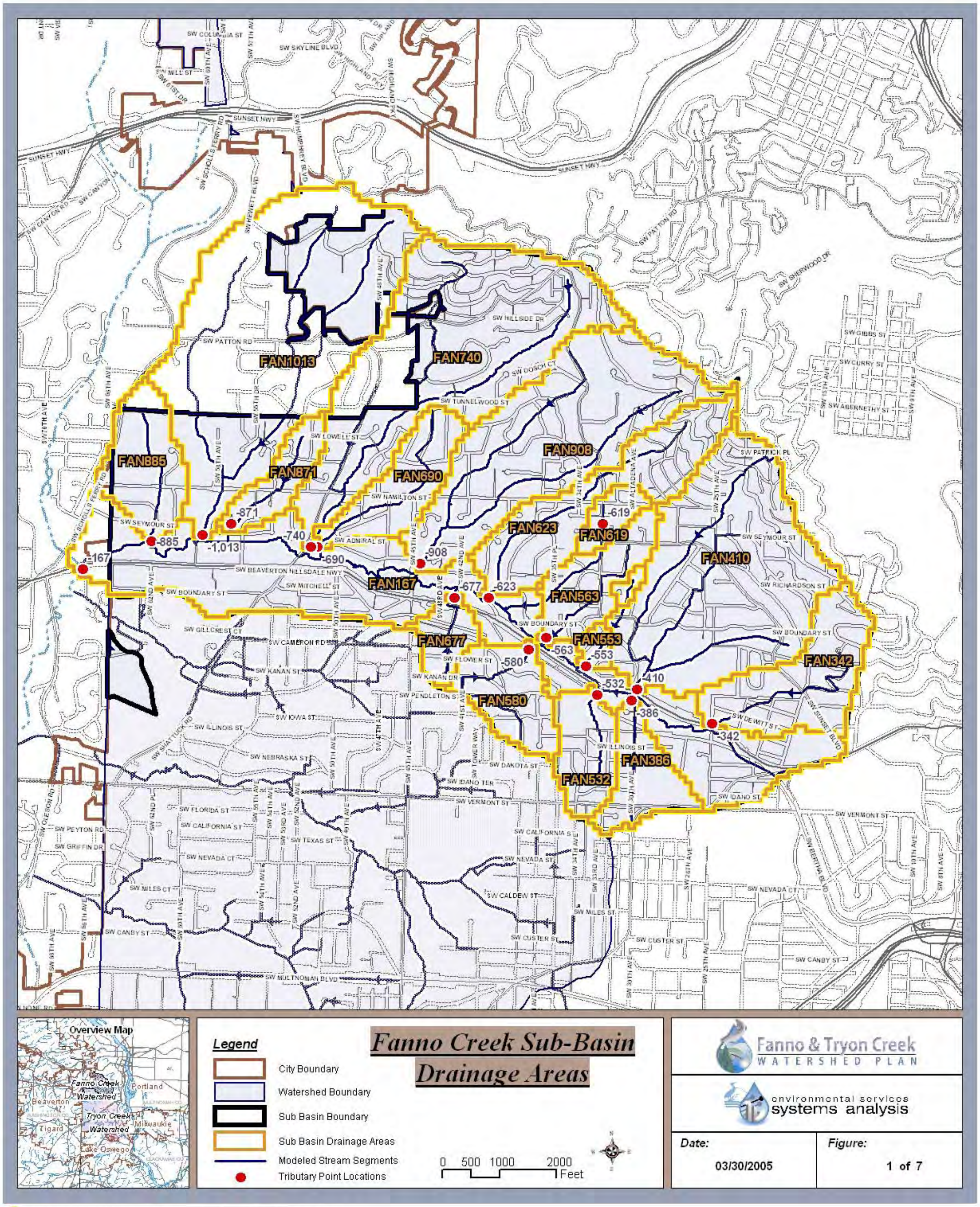
Figure 3-12
Tax Lots Built on in Fanno Creek Mainstem Subwatershed



GIS Analysis

A GIS analysis, using the 100-foot by 100-foot grid system established for the MIKE SHE/MIKE 11 modeling, was performed to evaluate three indicators of human influence on hydrology: impervious area, zoning, and the stormwater system (ratio of piped storm infrastructure to open channels). The area within the subwatershed was divided into modeled subcatchments for analysis, as shown on Figure 3-13.

Figure 3-13
Fanno Creek Sub-Basin Drainage Areas



Evaluation of the GIS results indicated that the subwatershed could be divided into three major subcatchments with distinctly different characteristics:

- Areas north of Fanno Creek: This subcatchment is characterized by single-family residential land use (96 percent), the least percentage of impervious area in the subwatershed (27 percent), and the fewest piped systems in the subwatershed (piped/channel ratio of 0.9)

- Areas south of Fanno Creek: This subcatchment is characterized by mixed single-family residential (90 percent) and multi-family residential (8 percent) land use, higher impervious area (35 percent), and more piped storm systems (piped/channel ratio of 1.8).

- Areas draining directly to Fanno Creek: This subcatchment includes the SW Beaverton-Hillsdale Highway corridor and is the most densely developed portion of the subwatershed. It is characterized by multi-family residential (35 percent) and commercial (14 percent) land uses, high impervious area (39 percent), and a piped/channel ratio of 1.1. The actual ratio of piped/channel for this area would be much higher if the private piped systems conveying runoff directly from private properties to the creek were included.

Results of the GIS analysis are summarized in Table 3-10.

Table 3-10
Results of GIS Analysis

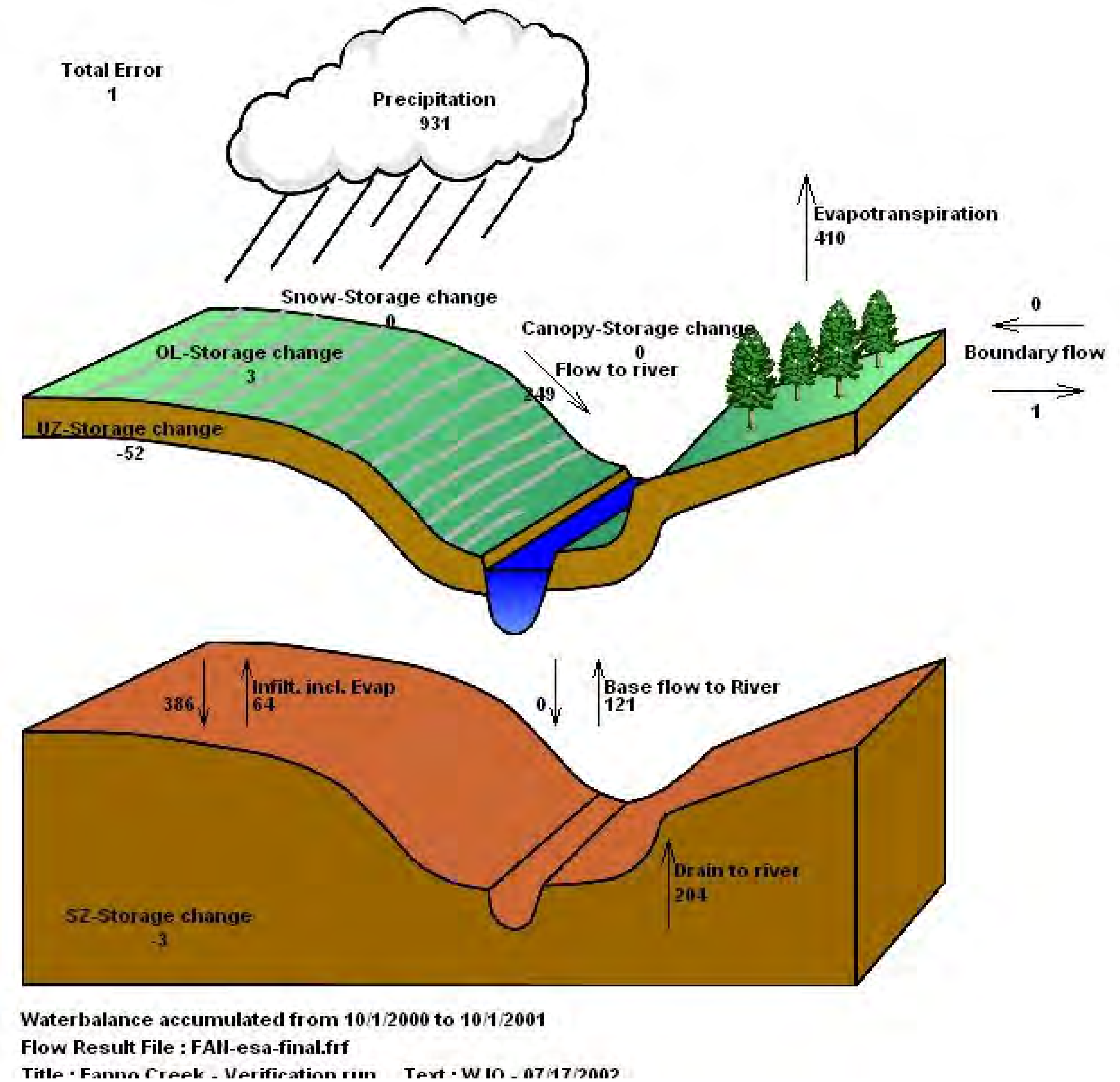
Fanno Creek Mainstem Subwatershed

Drainage Units	Area			ZONING				DRAINAGE SYSTEM		
	Total	IMPERVIOUS		SFR	MFR	COM	POS	CHNL_FT	PIP_FT	Ratio
	Acres	Acres	%	%	%	%	%	FT	FT	
Drainage Area 1: Subcatchments North of Fanno Creek										
FAN885	67	13	20	96	1	0	0	5,540	5,185	0.9
FAN1013	356	63	18	100	0	0	1	29,203	10,679	0.4
FAN871	35	12	34	100	0	0	0	1,371	2,898	2.1
FAN740	286	89	31	98	0	0	2	25,278	17,648	0.7
FAN690	62	21	34	88	0	0	12	3,637	6,982	1.9
FAN908	221	64	29	90	0	0	9	15,020	17,792	1.2
FAN623	109	40	36	98	1	0	2	5,535	9,227	1.7
FAN619	19	7	37	100	0	0	0	558	2,315	4.1
FAN563	55	16	29	83	3	0	14	2,981	7,382	2.5
Subtotal	1,211	325	27	96	<1	0	4	89,122	80,108	0.9
Drainage Area 2: Subcatchments South of Fanno Creek										
FAN553	14	5	32	100	0	0	0	1,151	1,500	1.3
FAN410	262	84	32	99	0	0	1	16,385	25,276	1.5
FAN677	26	11	43	74	15	11	0	3,091	2,805	0.9
FAN580	57	20	35	97	3	0	0	3,233	5,216	1.6
FAN532	47	16	34	87	13	0	0	1,323	8,229	6.2
FAN386	47	20	43	42	55	4	0	1,713	4,152	2.4
FAN342	95	36	38	93	4	1	2	3,675	8,527	2.3
Subtotal	548	192	35	90	8	1	1	30,572	55,704	1.8
Drainage Area 3: Direct Drainage										
FAN167	335	132	39	44	35	14	3	24,481	28,113	1.1
Totals	2,093	649	31	87	8	2	3	28,714	38,954	1.4

MODELING RESULTS

The Mike SHE/MIKE 11 model developed for the Fanno Creek mainstem subwatershed was run for the “typical year” rainfall record to evaluate hydrologic response in the subwatershed. Figures 3-14 through 3-17 show the modeling results.

Figure 3-14
Annual Water Balance
Fanno Creek Mainstem Subwatershed



Definition of the Terms in Water Balance Figure

Precipitation: Total precipitation falling in the watershed.
Canopy-storage change: Change in canopy interception storage, positive when increasing.
Evapotranspiration: Evaporation from canopy intercepted water (positive out) + evaporation from ponded water on ground + evaporation from oil (in unsaturated zone) + transpiration from root zone (in unsaturated zone) + evapotranspiration in saturated zone.
Snow-storage change: Not used in this study.
OL-storage change: Change in overland storage.
Overland boundary inflow: Potential flow into subcatchment or watershed.
Overland boundary outflow: Potential flow out of subcatchment + exchange from overland flooded areas to river outside the subcatchment.
Overland flow to river: Overland flow to river + overland flow directly to river (from paved areas) + exchange from overland flooded areas to river inside the subcatchment.
UZ-storage change: Unsaturated zone (UZ) and saturated zone (SZ) storage adjustment term (difference in unconfined storage capacity for UZ and SZ) + change in UZ deficit.
Infil. incl. Evap: Infiltration to SZ + UZ-SZ recharge – evapotranspiration from SZ (downwards arrow represents infiltration and other gains to SZ; upwards arrow represents loss from SZ).
Base flow to river: SZ aquifer inflow to river (upwards arrow) and river flow to SZ aquifer (downwards arrow).
Drain to river: SZ drainage flow (i.e., interflow) to river.
SZ-storage change: Change in SZ.

Figure 3-15
Annual Hydrograph
Fanno Creek Mainstem Subwatershed

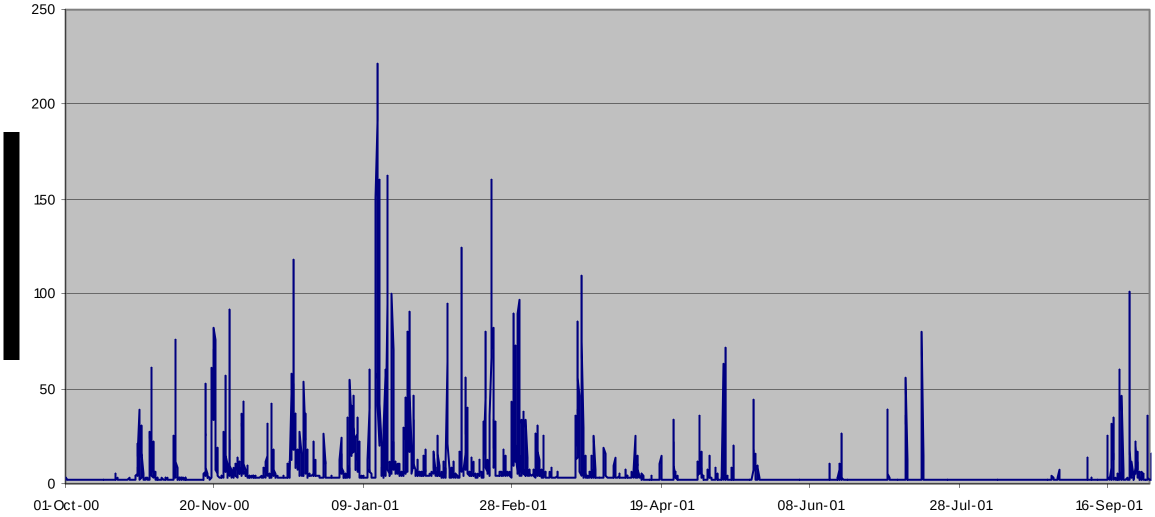


Figure 3-16
Average Monthly Flow
Fanno Creek Mainstem Subwatershed

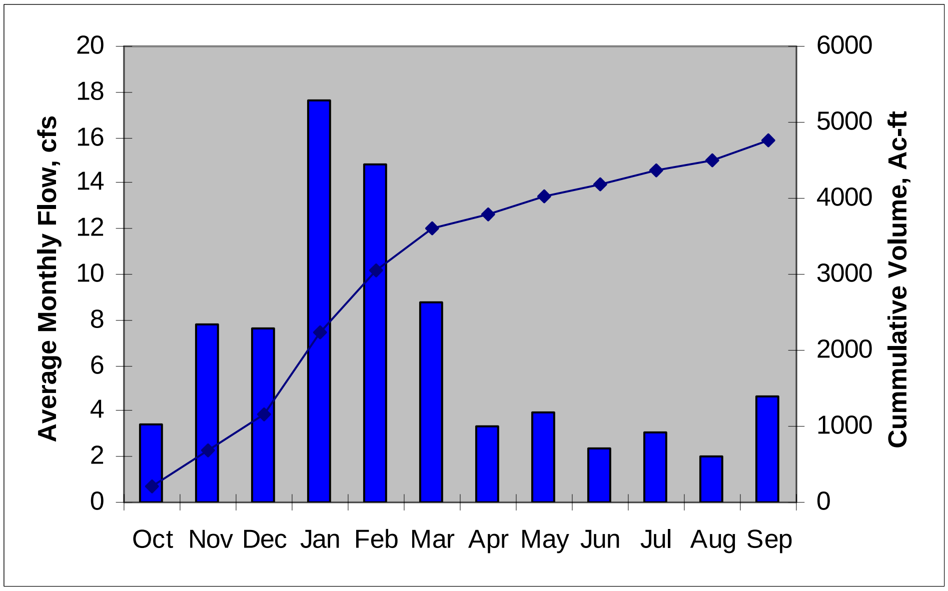
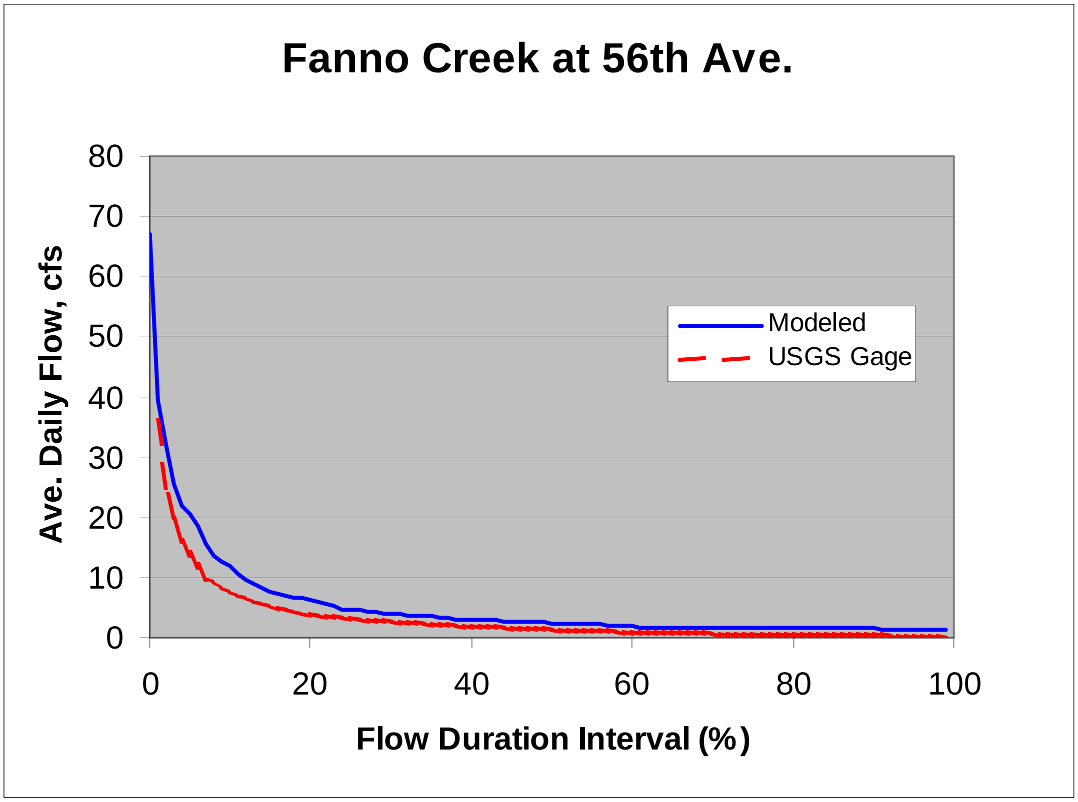
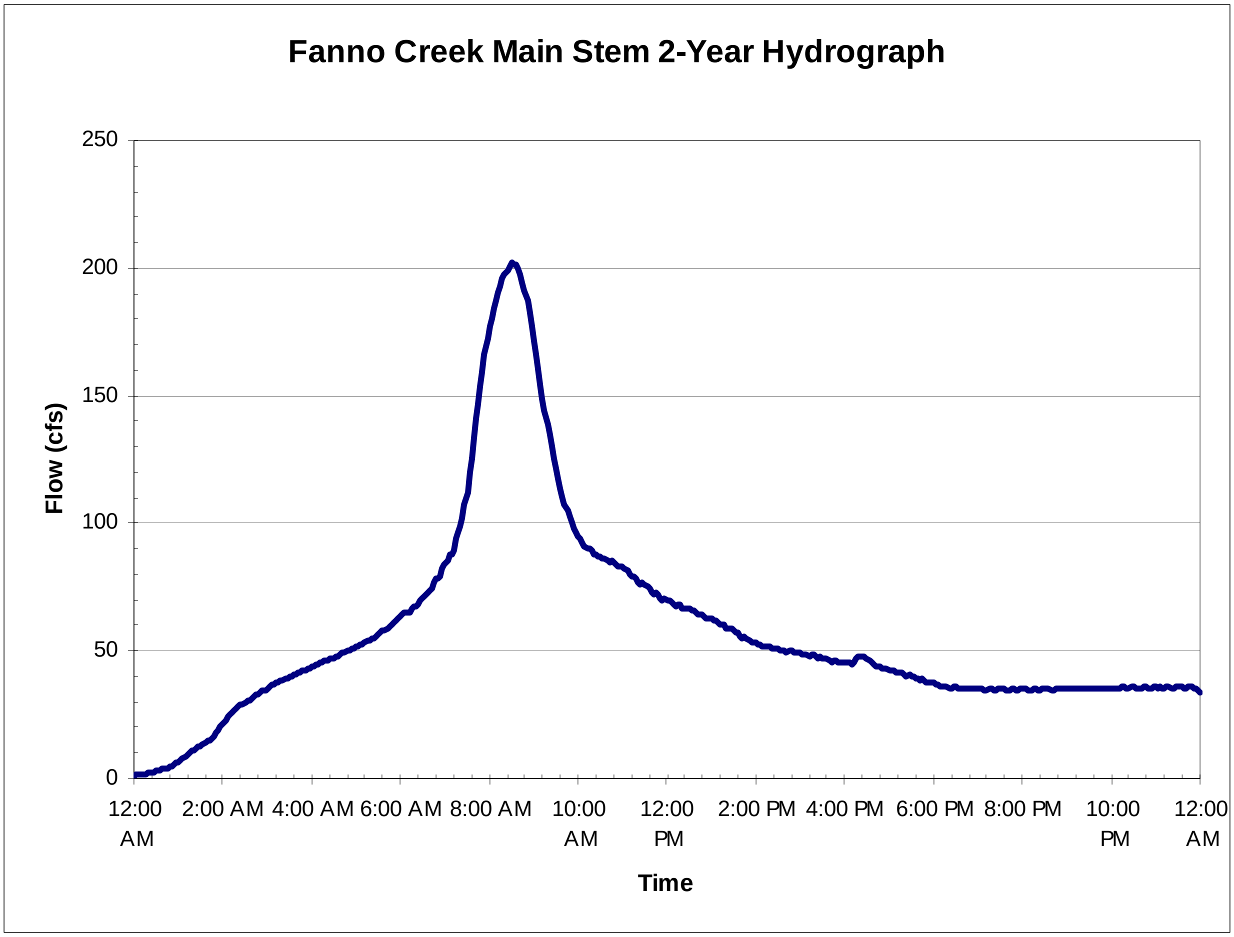


Figure 3-17
Flow Duration Interval
Fanno Creek Mainstem Subwatershed



The model was also run for design storms with return frequencies of 2, 10, 25, and 100 years. The technical memorandum in Appendix G provides the full modeling results.

Figure 3-18
Fanno Creek Mainstem
2-YR Design Storm
Hydrograph



Pendleton Creek Subwatershed

DESCRIPTION

The mainstem of Pendleton Creek originates near SW Fairvale Court and Kanan Street and drains approximately 230 acres within the City's jurisdiction. (See Map 1-Pendleton Creek Aerial Map in the Map Atlas) Pendleton Creek flows west for approximately 0.8 mile and exits the urban growth boundary south of SW Beaverton-Hillsdale Highway around SW 65th Avenue. Pendleton Creek then continues west until it joins the mainstem of Fanno Creek near the intersection of SW Beaverton-Hillsdale Highway and Oleson Road (BES 1999).

LANDSCAPE FACTORS

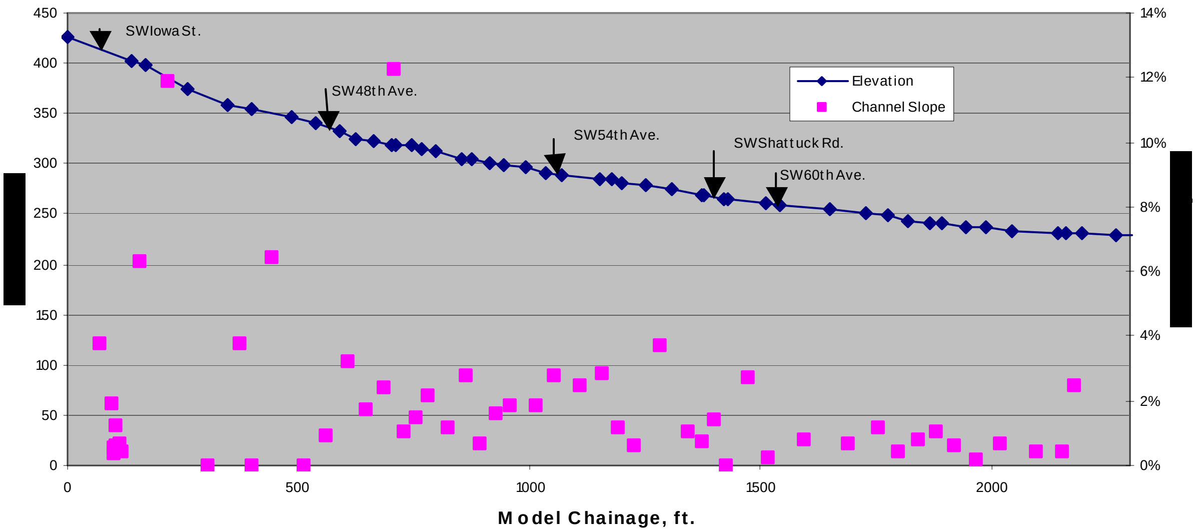
Topography

Land slopes in the Pendleton Creek subwatershed are generally flat (under 10 percent) to moderate (11-25 percent). The upper reaches of the creek east of SW Shattuck Road are flat or moderately sloped. West of Shattuck Road, the stream gradient increases, with steep slopes (over 25 percent) adjacent to the creek.

Stream Gradient and Morphology

Figure 3-18 shows the modeled stream profile and channel slopes for Pendleton Creek. Stream gradients range from steep (15 percent average) upstream from SW 48th Avenue; moderate to high (8.6 percent average) from SW 48th Avenue to SW 60th Avenue; to moderate (4 percent average) downstream of SW 60th Avenue.

Figure 3-19
Modeled Stream Profile and Channel Slopes for Pendleton Creek



Soils

Table 3-12 summarizes the distribution of soil types within the Pendleton Creek subwatershed. The predominant soil type is Cascade (81.9 percent). Cornelius soils (4.1 percent) are found mainly along the lower reaches of Pendleton Creek near the confluence with Fanno Creek. Delana soils (13.8 percent) form the stream corridor within the subwatershed.

Table 3-12
Soil Types in Pendleton Creek Subwatershed

Soil Type	**Series**	**Slope (%)**	**Area (acres)**	**Percentage of Subwatershed**
Cascade	7B/8B	3-8	134	58.2
	7C/8C	8-15	55	23.7
	7D/8D	15-30	0	0.0
	7E	30-60	0	0.0
Subtotal			***189***	***81.9***
Cornelius	11B	3-8	9	4.1
Delena	14C	3-12	32	13.8
Other			0	0.2
Total			**230**	**100.0**

HUMAN INFLUENCES

Land Use and Zoning

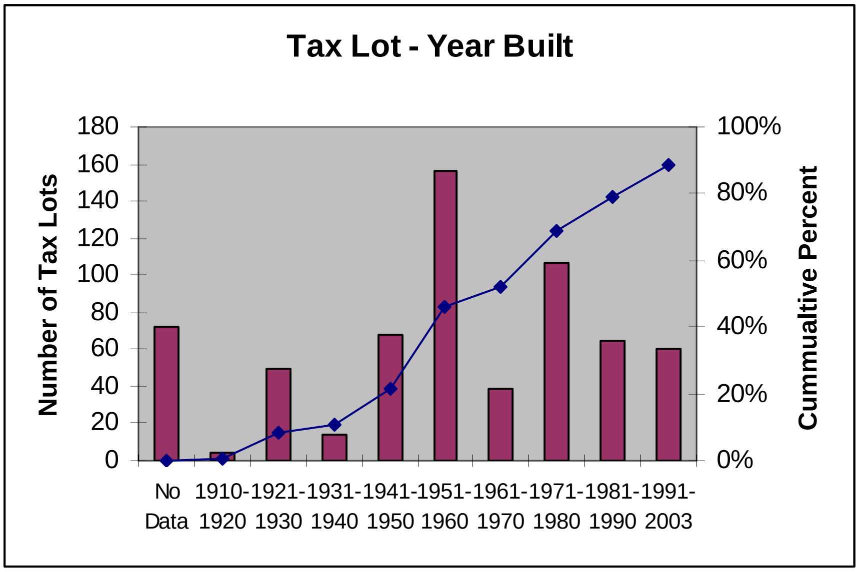
The predominant land use within the Pendleton Creek subwatershed is single-family residential (97.3 percent).

Table 3-13 summarizes the current zoning for the subwatershed, as adopted in the *Southwest Community Plan* (Bureau of Planning 2001). (See also Map 5-Pendleton Creek Current Plan in the Map Atlas). Figure 3-19 shows the percentage of tax lots built on between 1910 and 2003.

Table 3-13
Current Land Use Zoning
Pendleton Creek Subwatershed

Land Use Category	**Area (acres)**	**Percentage**
Single-Family Residential	224	97.3
Multi-Family Residential	0	0.0
Commercial	0	0.0
Parks & Open Space	6	2.7
Total	**230**	**100.0**

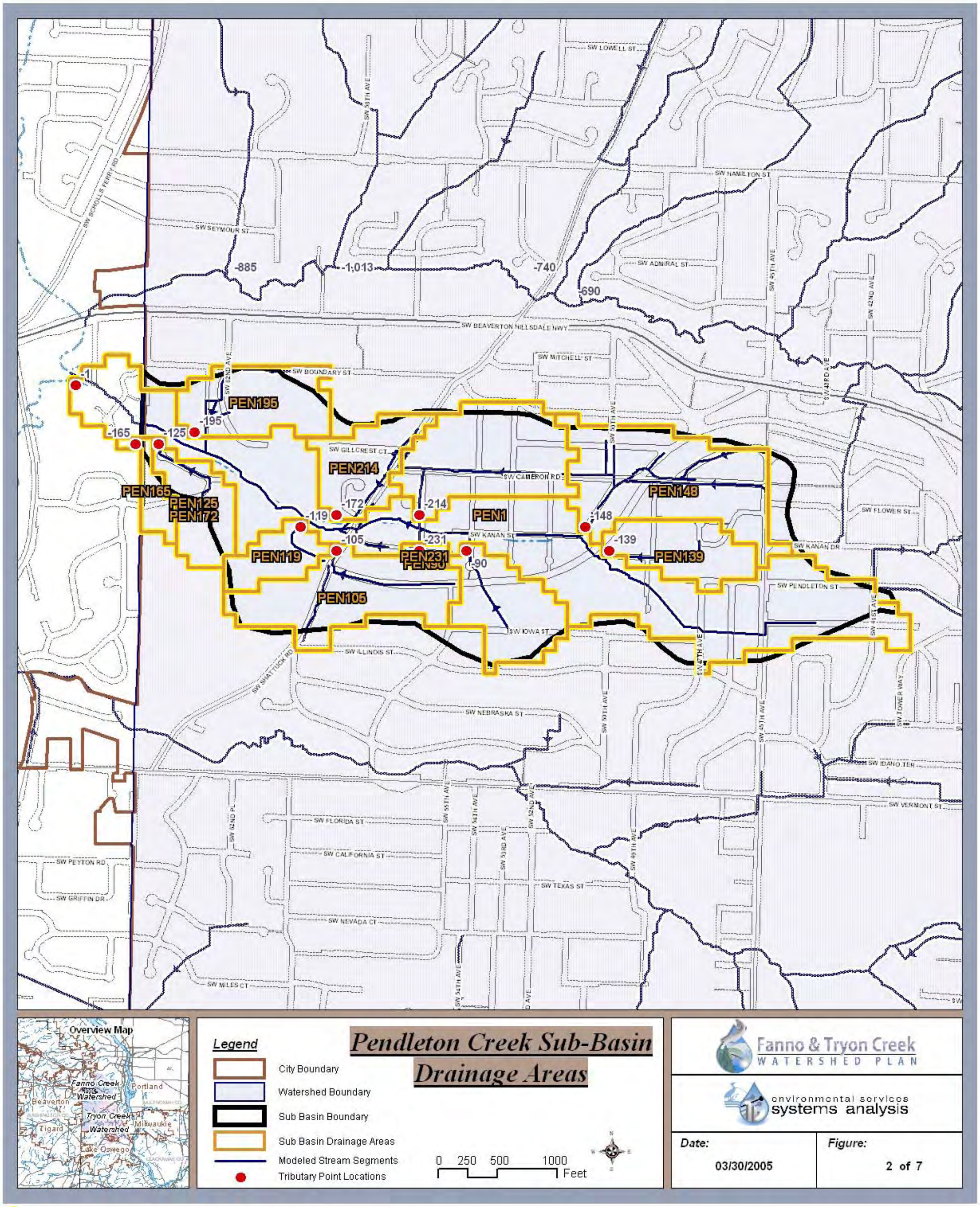
Figure 3-20
Tax Lots Built on in Pendleton Creek Subwatershed



GIS Analysis

A GIS analysis, using the 100-foot by 100-foot grid system established for the MIKE SHE/MIKE 11 modeling, was performed to evaluate three indicators of human influence on hydrology: impervious area, zoning, and the stormwater system (ratio of piped storm infrastructure to open channels). The area within the subwatershed was divided into modeled subcatchments for analysis, as shown on Figure 3-20.

Figure 3-21
Pendleton Creek Sub-Basin
Drainage Areas



Evaluation of the GIS results indicated that impervious areas were distributed throughout the subwatershed, with an overall average total impervious area of 26 percent. Areas draining directly to the stream had an overall lower total impervious area of 23 percent.

Table 3-14 summarizes the results of the GIS analysis.

Table 3-14
Results of GIS Analysis
Pendleton Creek Subwatershed

Drainage Units	Area			ZONING				DRAINAGE SYSTEM		
	Total	IMPERVIOUS		SFR	MFR	COM	POS	CHNL_FT	PIP_FT	Ratio
	Acres	Acres	%	%	%	%	%	FT	FT	
Drainage Area 1: All catchments except direct drainage										
PEN195	16	2	16	100	0	0	0	679	1,569	2.3
PEN165	4	1	14	90	0	0	0	0	618	Piped
PEN125	11	1	12	100	0	0	0	16	988	63.2
PEN172	13	4	35	100	0	0	0	656	563	0.9
PEN214	24	9	36	100	0	0	0	776	1,645	2.1
PEN119	7	0	3	100	0	0	0	442	51	0.1
PEN148	31	12	39	100	0	0	0	2,597	2,849	1.1
PEN105	22	5	23	99	0	0	2	2,045	622	0.3
PEN231	2	1	37	100	0	0	0	0	51	Piped
PEN90	15	3	22	63	0	0	38	0	400	Piped
PEN139	12	4	35	100	0	0	0	0	773	Piped
Subtotal	158	43	27					7,210	10,129	1.4
Drainage Area 2: Direct Drainage										
PEN1	88	20	23	91	0	0	0	5,586	5,881	1.1
Totals	246	63	26					12,796	16,010	1.3

MODELING RESULTS

The Mike SHE/MIKE 11 model developed for the Pendleton Creek subwatershed was run for the "typical year" rainfall record to evaluate hydrologic response in the subwatershed. Figures 3-21 through 3-24 show the modeling results.

Figure 3-22
Annual Water Balance
Pendleton Creek Subwatershed

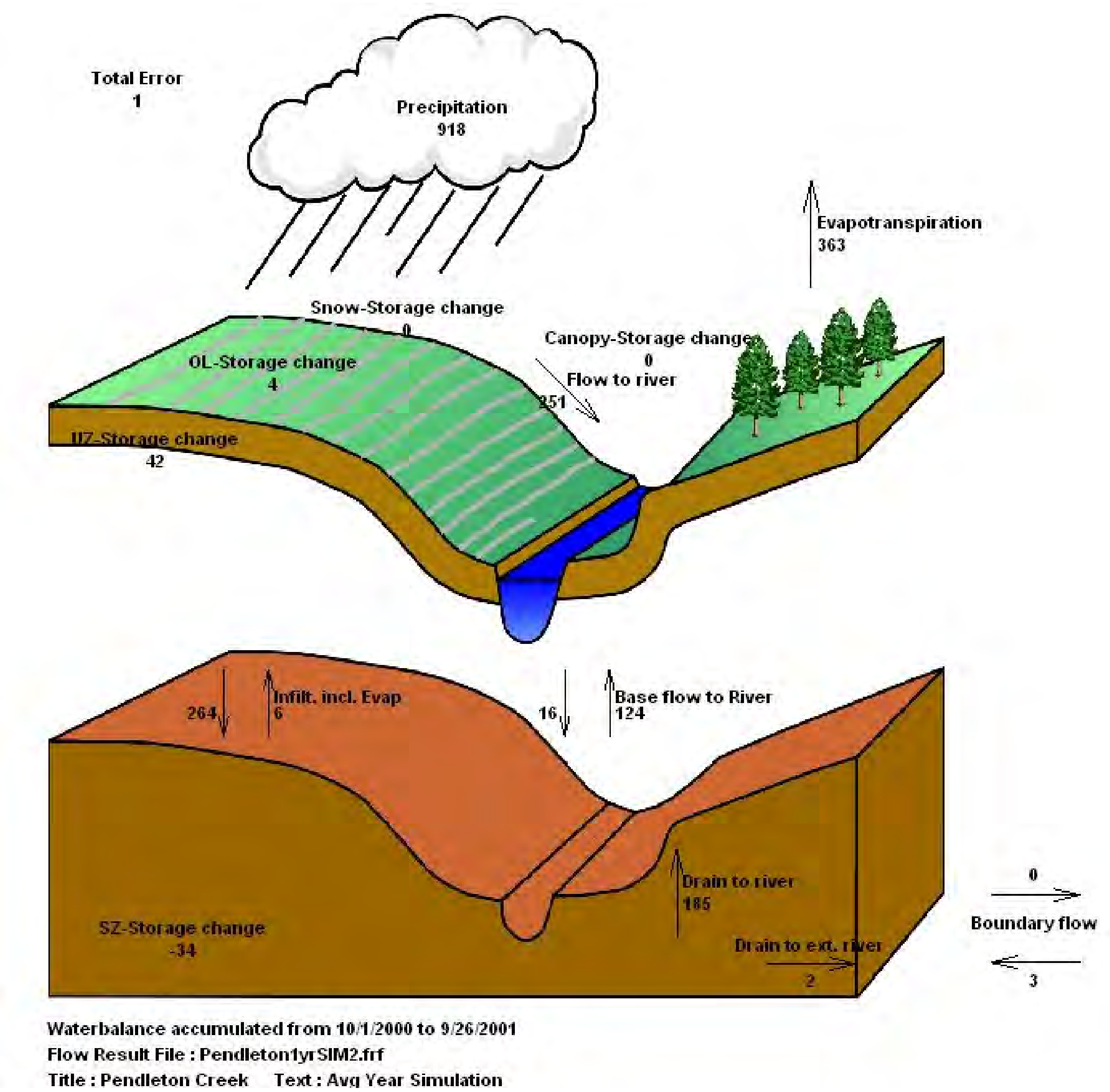


Figure 3-23
Annual Hydrograph
Pendleton Creek Subwatershed

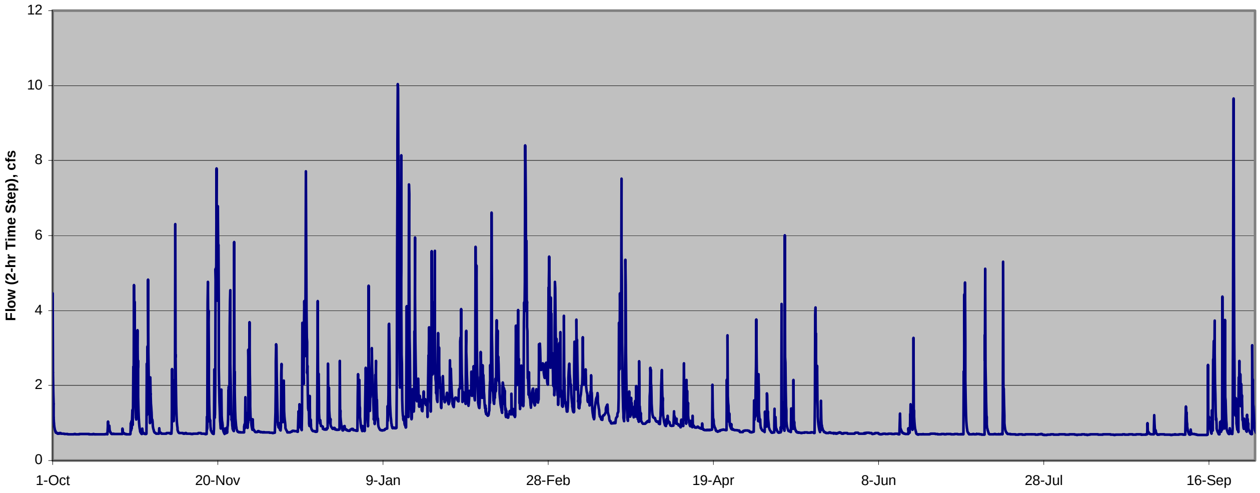
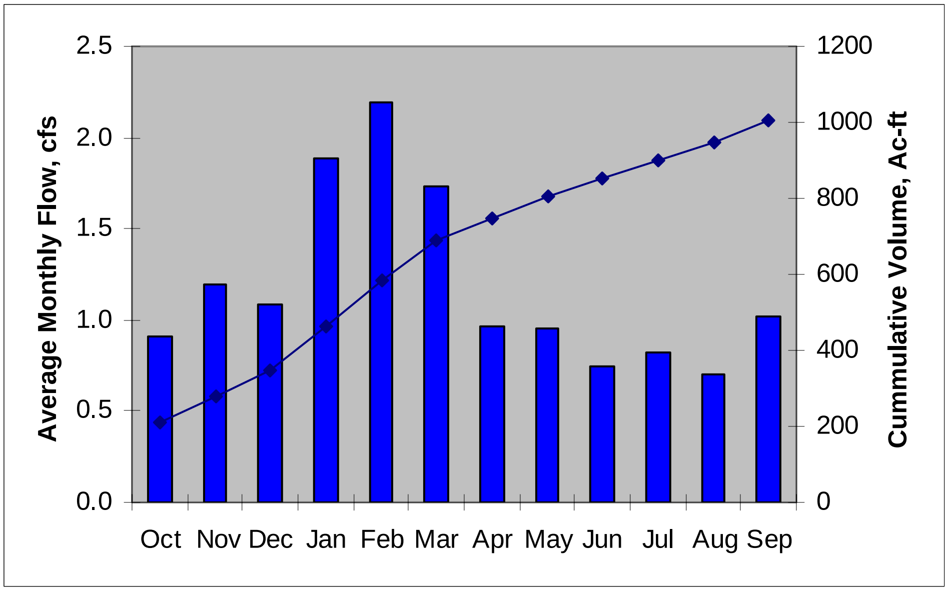
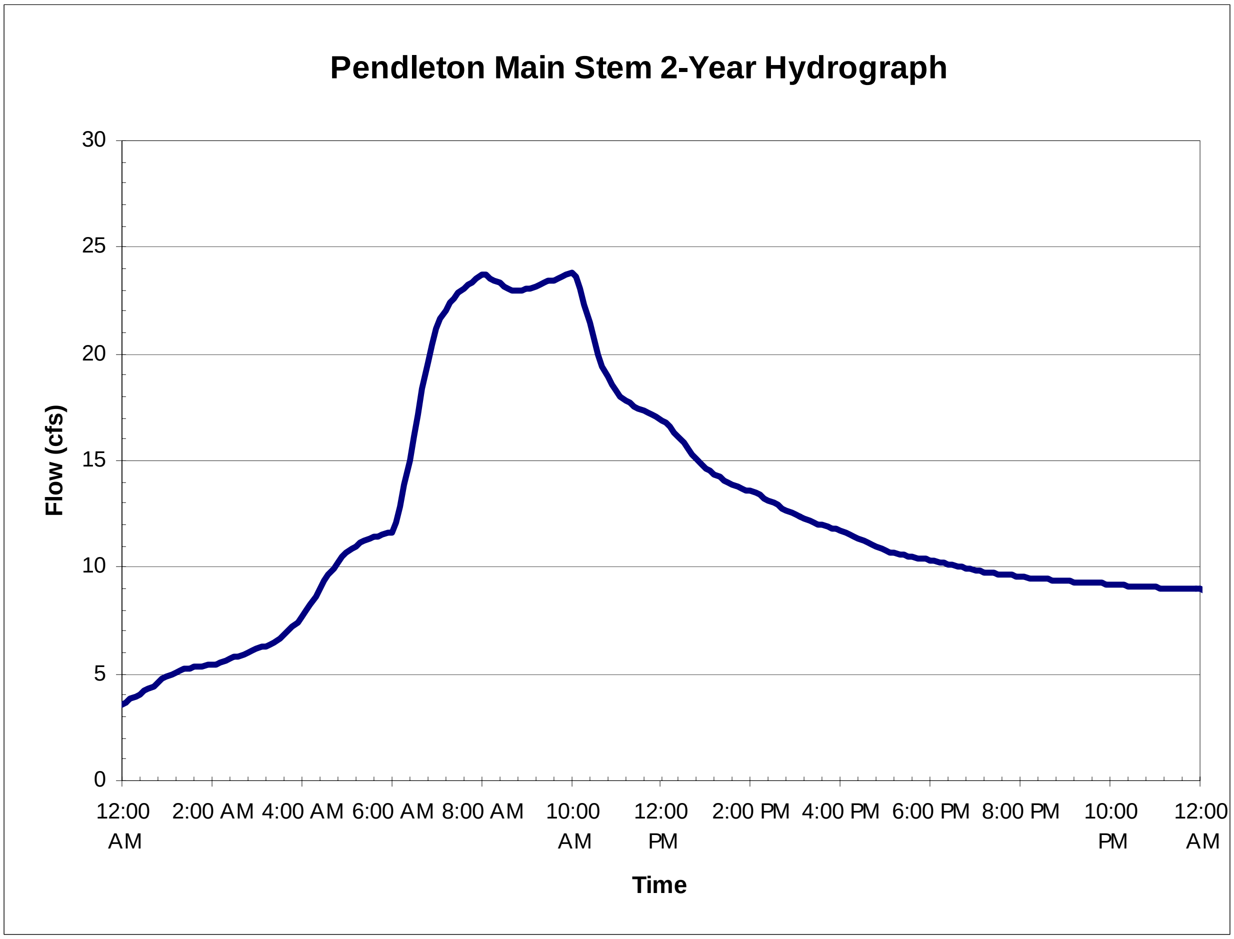


Figure 3-24
Average Monthly Flow
Pendleton Creek Subwatershed



The model was also run for design storms with return frequencies of 2, 10, 25, and 100 years. Figure 3-25 shows the hydrograph for the 2-year storm. The technical memorandum in Appendix G provides the full modeling results.

Figure 3-25
Pendleton Creek
2-YR Design Storm
Hydrograph



Vermont Creek Subwatershed

DESCRIPTION

Vermont Creek originates east of Gabriel Park and drains an area of approximately 758 acres within the City's jurisdiction. (See Map 1-Vermont Creek Aerial Map in the Map Atlas). A southern tributary originates just north of SW Multnomah Boulevard and flows north paralleling SW 45th Avenue, and joins the mainstem near SW 45th Avenue and SW Caldew Street. Vermont Creek flows west from this confluence for approximately 1.4 miles, exits the urban services boundary west of SW Shattuck Road north of SW Vermont Street, and continues west until it joins the mainstem of Fanno Creek west of Oleson Road.

LANDSCAPE FACTORS

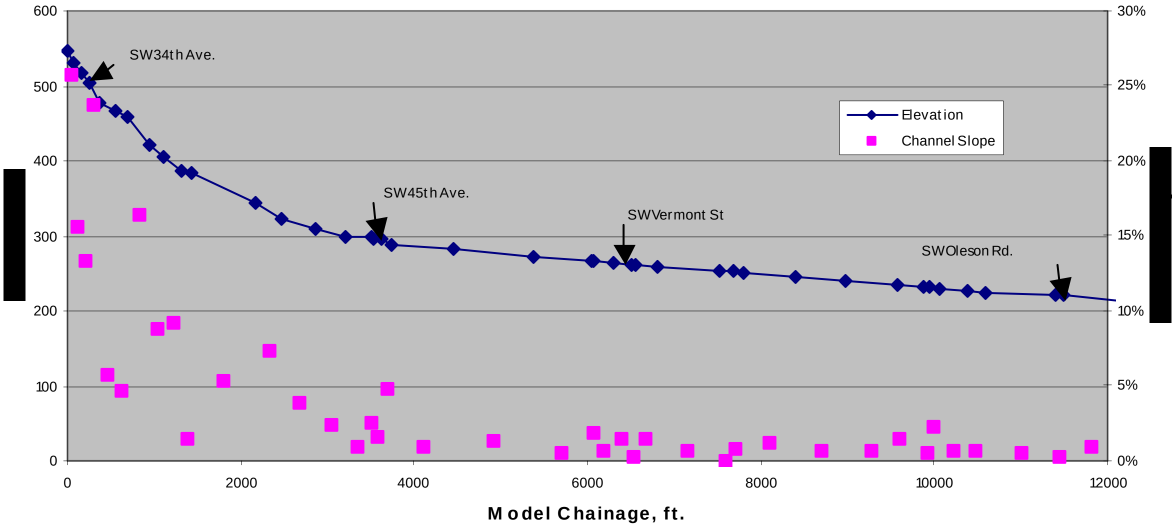
Topography

Land slopes in the upper part of the subwatershed east of SW 45th Avenue are moderate (11-25 percent) to steep (over 25 percent). The upper portion of the creek, in particular the wooded area of Gabriel Park, is characterized by a moderate to steep stream corridor (Map 9-Vermont Creek Contour Map in the Map Atlas) and unstable banks. From SW 37th almost to SW 45th, the creek has been stabilized as part of the Gabriel Park Wet Meadows Project (BES project number 5096). In general, stream segments in the lower portion of the creek below SW 45th are slightly to moderately entrenched and have low sinuosity.

Stream Gradient and Morphology

Figure 3-26 shows the modeled stream profile and channel slopes for Vermont Creek. Stream gradients range from steep (8.7 percent average) upstream from SW 45th Avenue to low (1.1 percent average) downstream of SW 45th Avenue.

Figure 3-26
Modeled Stream Profile and Channel Slopes for Vermont Creek



The *Fanno Creek Resource Management Plan* (BES and Brown & Caldwell 1998) included an extensive analysis of Vermont Creek's channel stability and geomorphic characteristics. In particular, a survey of bank erosion potential was conducted to identify components contributing to the erosion potential and affecting streambank stability. The survey identified and inventoried actively eroding streambanks. Based on this survey, three variables influence the stability of Vermont Creek:

- Overstep bank angles (greater than 60 percent)
- Moderate to poor surface protection provided by vegetation
- Moderate root density

Of 34 sampled sites, the survey found 24 sites with low bank erosion potential and 10 sites with moderate to high erosion potential. The survey indicated that the erosion was mainly the result of channel incision and lateral scour.

The *Fanno Creek Resource Management Plan* also attempted to classify segments of Vermont Creek in accordance with the Rosgen stream classification method (Rosgen 1994). No set standard exists for classifying a stream because the physical variables that control the geomorphic process of a stream vary spatially and temporally. The Rosgen method is the most commonly used procedure and has been widely adopted by state and federal agencies, such as the U.S. Forest Service's Stream System Technology Center. It is primarily a predictive tool that describes the degree to which a stream departs from an assumed stable stream.

The Rosgen method selects reference stream reaches from which stream attributes are measured. These attributes (including stream slope, bed material, width/depth ratio, sinuosity, and degree of confinement) determine the stream type from a hierarchical system that includes eight general stream types. Overall, Vermont Creek is classified primarily as a Type B and Type E stream.

Type B streams are described as moderately entrenched, with a moderate gradient dominated by riffles and infrequent spaced pools. This type of channel is considered to have a very stable plan and profile, with stable banks

Type E streams are described as low gradient, meandering riffle/pool streams with low width/depth ratio and little deposition. This type of channel is considered to be very stable.

Type E was the dominant stream classification in the low-gradient reach of the stream downstream from SW 45th Avenue. Upstream, most reaches were classified as Type B, indicating a stable, moderately entrenched stream channel.

Soils

Table 3-16 summarizes the distribution of soil types within the Vermont Creek subwatershed. The predominant soil type is Cascade silt loam (96 percent). Within the area of Cascade soils, 45 acres (6 percent) are subclassified as D and E series, occurring on slopes ranging from 15 to 60 percent. These areas are found primarily in the upper subwatershed along the steep stream corridor slopes and also in upland areas north of SW Vermont Street. They have a high potential for soil erosion from exposed or disturbed areas. Delana soils (4 percent) form the stream corridor west of SW 45th Avenue.

Table 3-16
Soil Types in Vermont Creek Subwatershed

Soil Type	Series	Slope (%)	Area (acres)	Percentage of Subwatershed
Cascade	7B/8B	3-8	274	58
	7C/8C	8-15	406	23
	7D/8D	15-30	26	3
	7E	30-60	19	3
Subtotal			***726***	***96***
Cornelius	11B	3-8	1	0
Delena	14C	3-12	33	4
	16C		0	0
Total			**760**	**100.0**

HUMAN INFLUENCES

Land Use/Zoning

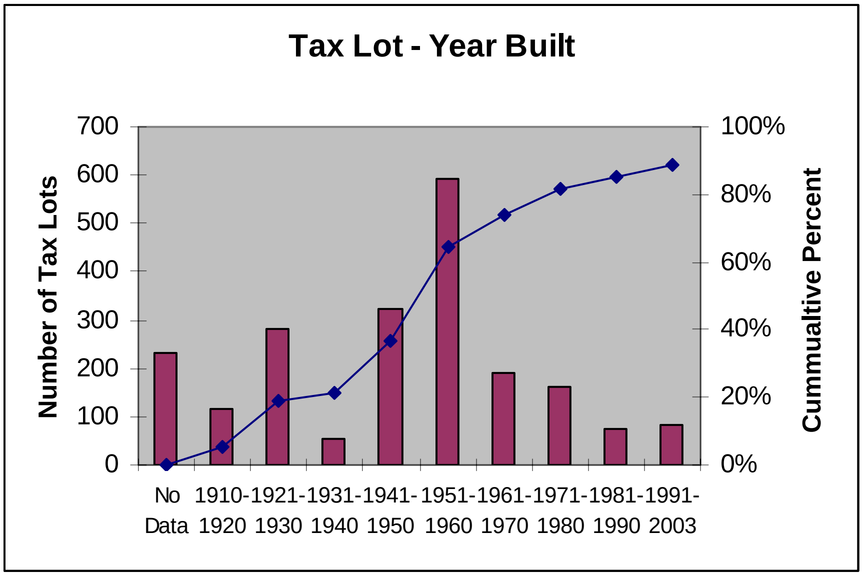
The predominant land use in the Vermont Creek subwatershed is single-family residential (78.9 percent). Parks and open space areas, primarily Gabriel Park, total 97 acres (12.8 percent). The remaining land uses are commercial and multi-family development along SW Multnomah Boulevard east of SW 45th Avenue.

Table 3-17 summarizes the current zoning for the subwatershed, as adopted in the Southwest Community Plan (Bureau of Planning 2001). (See also Map 5-Vermont Creek Current Plan Map, Map Atlas). Figure 3-27 shows the percentage of tax lots built on between 1910 and 2003.

Table 3-17
Current Land Use Zoning
Vermont Creek Subwatershed

Land Use Category	Area (acres)	Percentage
Single-Family Residential	598	78.9
Multi-Family Residential	54	7.1
Commercial	9	1.2
Parks & Open Space	97	12.8
Total	**758**	**100.0**

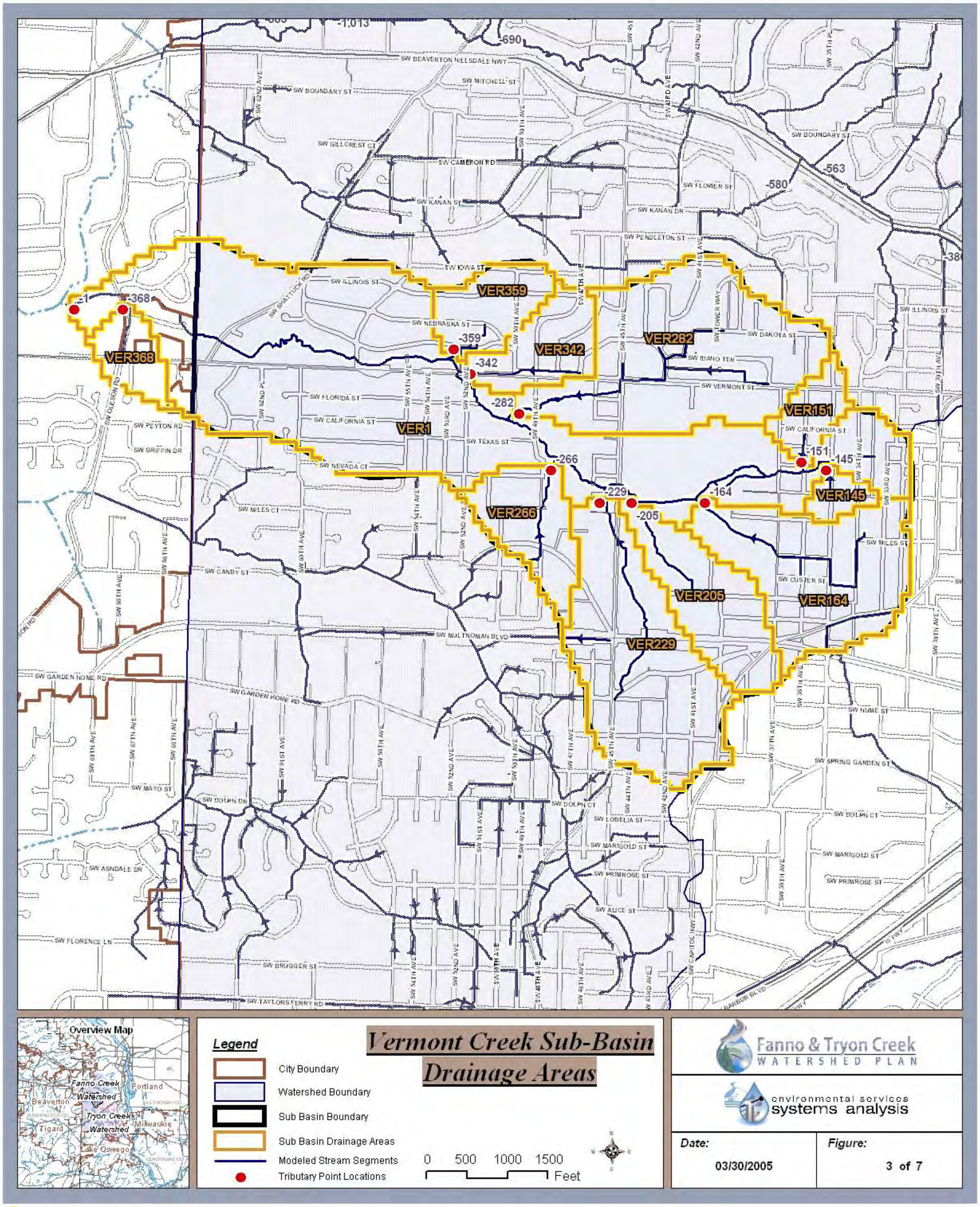
Figure 3-27
Tax Lots Built on in Vermont Creek Subwatershed



GIS Analysis

A GIS analysis, using the 100-foot by 100-foot grid system established for the MIKE SHE/MIKE 11 modeling, was performed to evaluate three indicators of human influence on hydrology: impervious area, zoning, and the stormwater system (ratio of piped storm infrastructure to open channels). The area within the subwatershed was divided into modeled subcatchments for analysis, as shown on Figure 3-28.

Figure 3-28
Vermont Creek Sub-Basin Drainage Areas



Produced in MapInfo: \\CASSIO\GIS2\Projects\Fanno_Tryon\Report_Figs\Misc\Eugene\Ver_Dr.Wor (JDP) May, 2004

Evaluation of the GIS results indicated that impervious areas were distributed throughout the subwatershed, with an overall average total impervious area of 33 percent. Areas draining directly to the stream had an overall lower total impervious area of 23 percent. Table 3-18 summarizes the results of the GIS analysis.

Table 3-18
Results of GIS Analysis
Vermont Creek Subwatershed

Drainage Units	Area			ZONING				DRAINAGE SYSTEM		
	Total	IMPERVIOUS		SFR	MFR	COM	POS	CHNL_FT	PIP_FT	Ratio
	Acres	Acres	%	%	%	%	%	FT	FT	
Drainage Area 1:										
VER145	9	3	37	100	0	0	0	524	1,153	2.2
VER151	17	6	38	94	0	0	6	791	1,103	1.4
VER164	83	33	39	69	5	20	7	1,971	7,921	4.0
VER205	48	15	32	46	7	18	29	3,879	4,090	1.1
VER229	101	35	35	70	17	5	7	11,154	7,576	0.7
VER266	35	9	26	100	0	0	0	2,465	2,430	1.0
VER282	121	40	33	75	2	4	20	2,224	9,324	4.2
VER342	30	12	39	100	0	0	0	0	2,206	Piped
VER359	28	10	35	100	0	0	0	0	3,697	Piped
VER368	18	0	0	7	20	0	0	709	826	1.2
Subtotal	490	164	33					23,717	40,326	1.7
Drainage Area 2: Direct Drainage										
VER1	318	74	23	76	2	0	14	23,205	19,133	0.8
Totals	809	237	29					46,922	59,460	1.3

MODELING RESULTS

The Mike SHE/MIKE 11 model developed for the Vermont Creek subwatershed was run for the “typical year” rainfall record to evaluate hydrologic response in the subwatershed. Figures 3-29 through 3-32 show the modeling results.

Figure 3-29
Annual Water Balance
Vermont Creek Subwatershed

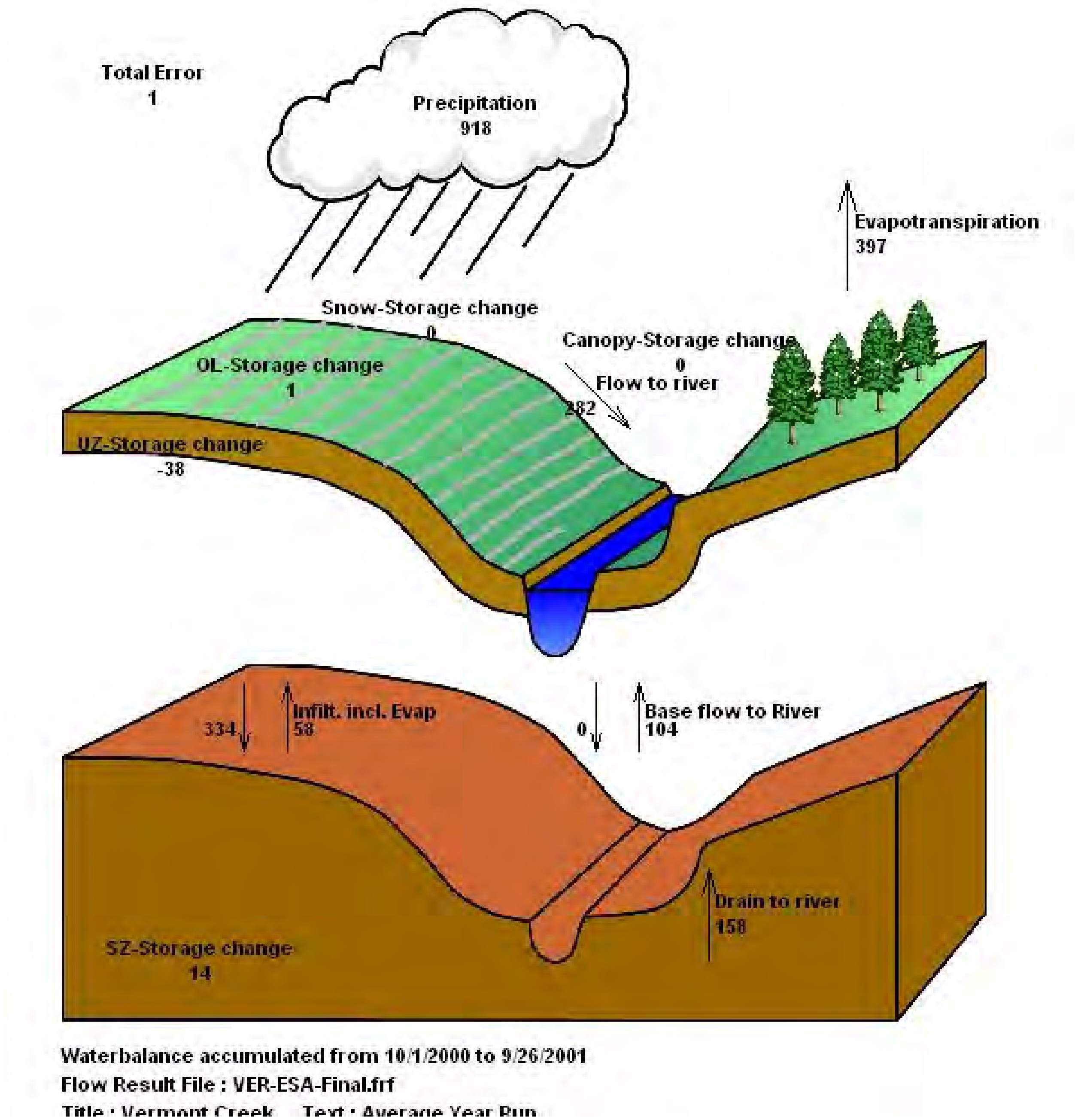


Figure 3-30
Annual Hydrograph
Vermont Creek Subwatershed

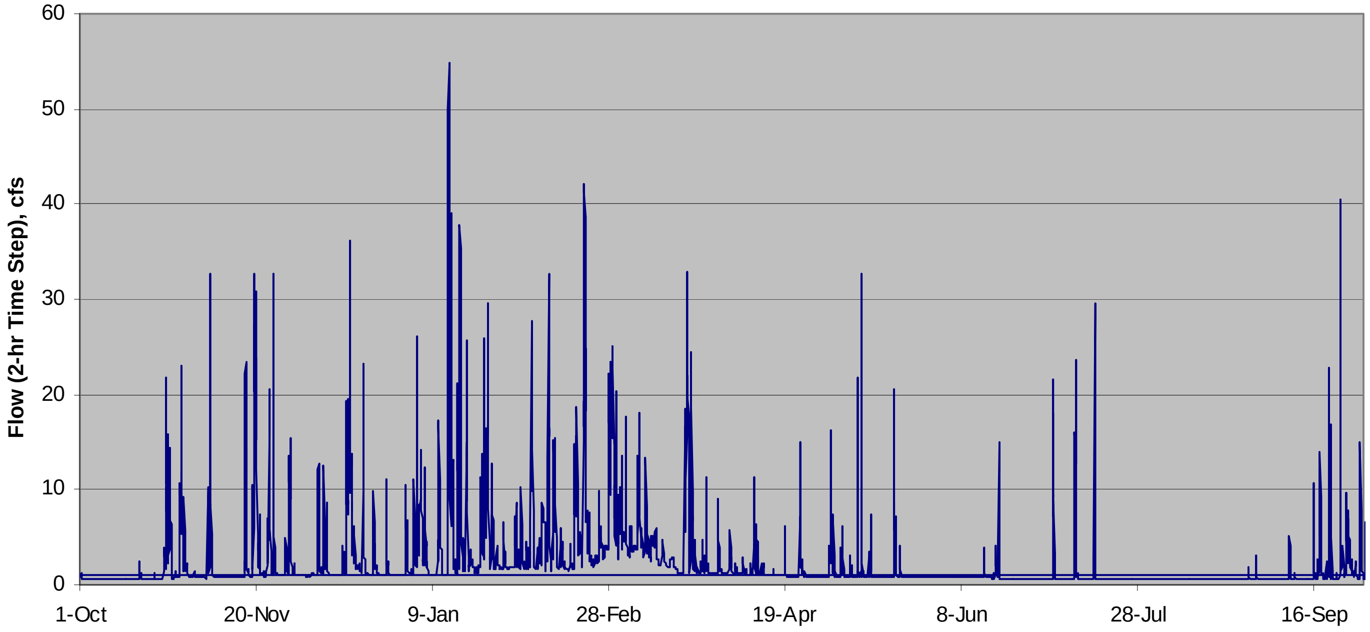
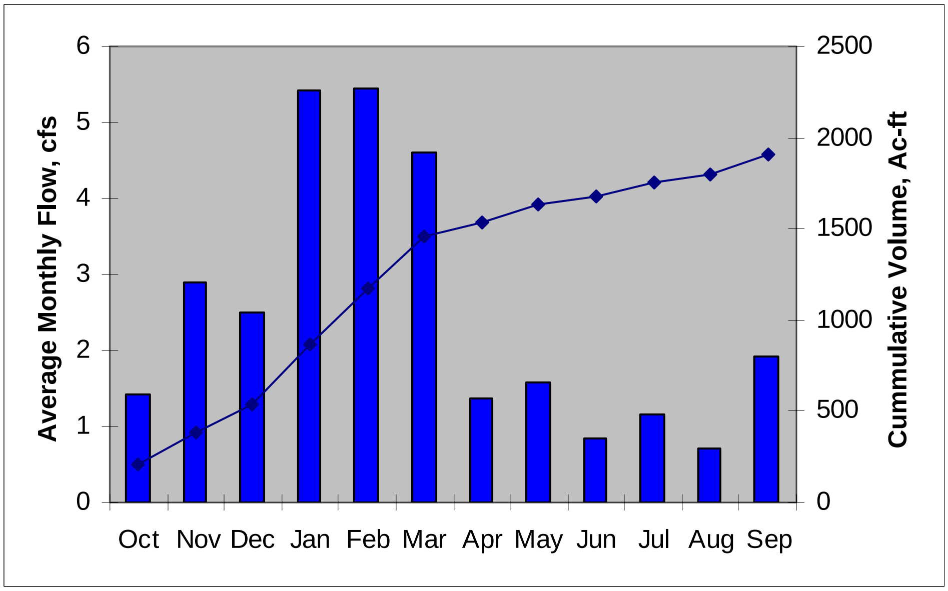
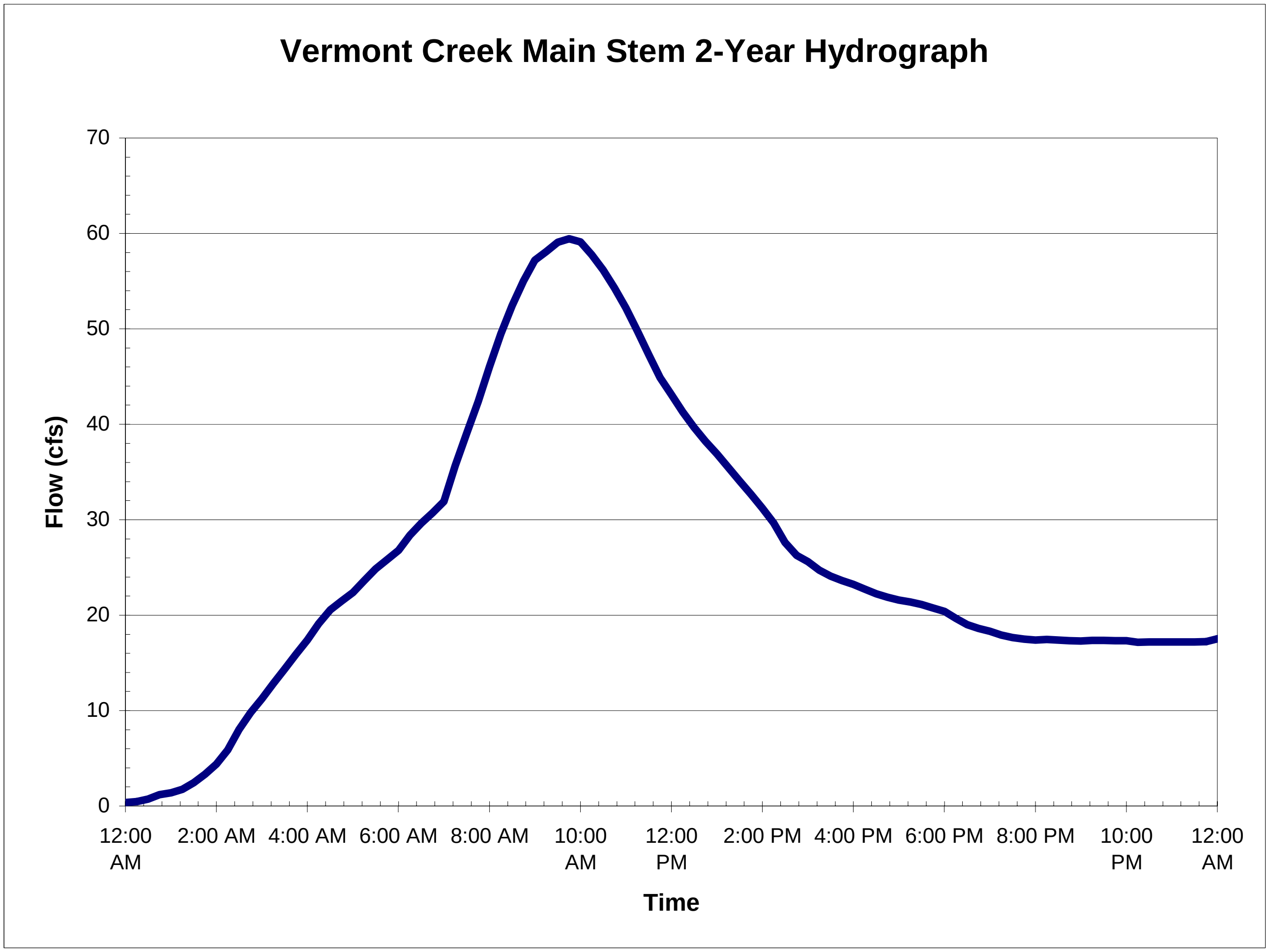


Figure 3-31
Average Monthly Flow
Vermont Creek Subwatershed



The model was also run for design storms with return frequencies of 2, 10, 25, and 100 years. Figure 3-32 shows the hydrograph for the 2-year storm. The technical memorandum in Appendix G provides the full modeling results.

Figure 3-32
Vermont Creek
2-Yr Design Storm Hydrograph



Woods Creek Subwatershed

DESCRIPTION

Woods Creek originates near SW Taylors Ferry Road and Capitol Highway and drains an area of approximately 575 acres with the City's jurisdiction (784 acres total). (See Map 1-Woods Creek Aerial Map, Map Atlas). The creek flows northwest for approximately 1.8 miles, crossing SW Multnomah Boulevard near SW 51st Avenue. It then flows west, exiting Portland approximately 350 feet north of SW Canby Street near 64th Place. Woods Creek continues west until it joins the mainstem of Fanno Creek west of Oleson Road near Oregon Episcopal School.

LANDSCAPE FACTORS

Topography

The Woods Creek subwatershed has extensive areas of steep slopes (over 25 percent), particularly along a broad stream corridor upstream of SW Multnomah Boulevard. (See Map 9-Woods Creek Contour Map, Map Atlas).

Stream Gradient and Morphology

Figure 3-33 shows the modeled stream profile and channel slopes for Woods Creek. Stream gradients range from moderate (5.37 percent average) upstream from SW Garden Home Road to low (1.4 percent average) downstream of SW Garden Home Road.

The *Fanno Creek Resource Management Plan* (BES and Brown & Caldwell 1998) included an extensive analysis of Woods Creek's channel stability and geomorphic characteristics. In particular, a survey of bank erosion potential was conducted to identify components contributing to the erosion potential and affecting streambank stability. The survey identified and inventoried actively eroding streambanks. Based on this survey, three variables influence the stability of Woods Creek:

- Overstep bank angles (greater than 60 percent)
- Moderate to poor surface protection provided by vegetation
- Moderate root density

Of the 35 sampled sites, the survey found 14 sites with low bank erosion potential and 21 sites with moderate to high erosion potential. The survey indicated that the erosion was mainly the result of channel incision and lateral scour.

The *Fanno Creek Resource Management Plan* also attempted to classify segments of Woods Creek in accordance with as the Rosgen stream classification method. No set standard exists for classifying a stream because the physical variables that control the geomorphic process of a stream vary spatially and temporally. The science of stream dynamics is not yet able to relate the physical variables of one stream's dynamics to another stream. The Rosgen method is the most commonly used procedure and has been widely adopted by state and federal agencies, such as the U.S. Forest Service's Stream System Technology Center. It is primarily a predictive tool that describes the degree to which a stream departs from an assumed stable stream.

The Rosgen method selects reference stream reaches from which stream attributes are measured. These attributes (including stream slope, bed material, width/depth ratio, sinuosity, and degree of confinement) determine the stream type from a hierarchical system that includes eight general stream types. Overall, Woods Creek is primarily classified as a Type B and Type E stream.

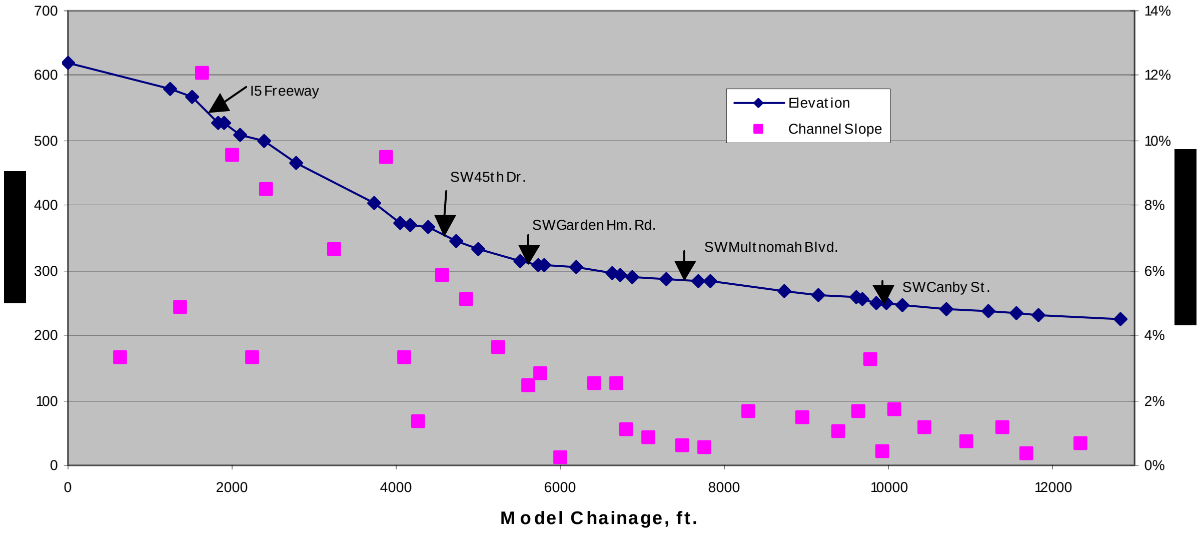
Type B streams are described as moderately entrenched, with a moderate gradient dominated by riffles and infrequent spaced pools. This type of channel is considered to have a very stable plan and profile, with stable banks

Type E streams are described as low gradient, meandering riffle/pool streams with low width/depth ratio and little deposition. This type of channel is considered to be very stable.

Type E was the dominant stream type in the low-gradient reach of the stream downstream from SW Garden Home Road. Upstream, most reaches were classified as Type B, indicating a stable, moderately entrenched stream channel.

The morphology of the stream varies from steep, highly entrenched channels in the upper reaches to moderately entrenched channels with moderate –to low gradients in the lower segments.

Figure 3-33
Modeled Stream Profile and Channel Slopes for Woods Creek



Soils

Table 3-20 summarizes the distribution of soil types within the Woods Creek subwatershed. The predominant soil type is Cascade silt loam (97.9 percent). Within the area of Cascade soils, 78 acres (6 percent) are subclassified as D and E series, occurring on slopes ranging from 15 to 60 percent. These areas are found primarily in the upper subwatershed along the steep stream corridor slopes. They have a high potential for soil erosion from exposed or disturbed areas, and they have increased runoff volumes.

Table 3-20
Soil Types in Woods Creek Subwatershed

Soil Type	Series	Slope (%)	Area (acres)	Percentage of Subwatershed
Cascade	7B/8B	3-8	168	29.1
	7C/8C	8-15	319	55.3
	7D/8D	15-30	20	3.5
	7E	30-60	58	10.1
Subtotal			***565***	***97.9***
Cornelius	11B/11C	3-15	9	1.5
Delena	14C	3-12	3	0.6
Total			**577**	**100.0**

HUMAN INFLUENCES

Land Use and Zoning

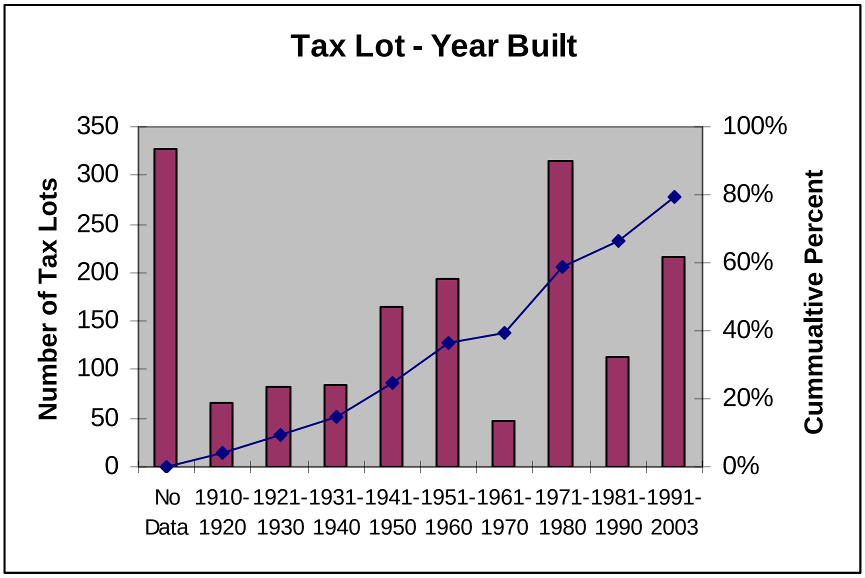
The predominant land use in the Woods Creek subwatershed is single-family residential (84.3 percent). Woods Memorial Park provides 42.8 acres (8.1 percent) of open space. The remaining land uses are 44 acres (7.5%) of multi-family residential and commercial areas, primarily in the upper part of the subwatershed along I-5, SW Barbur Boulevard, and SW Capitol Highway.

Table 3-21 summarizes the current zoning for the subwatershed, as adopted in the *Southwest Community Plan* (Bureau of Planning 2001). (See also Map 5-Woods Creek Current Plan Map, Map Atlas). Figure 3-34 shows the percentage of tax lots built on between 1910 and 2003.

Table 3-21
Current Land Use Zoning
Woods Creek Subwatershed

and Use Category	Area (acres)	Percentage
Single-Family Residential	485	84.3
Multi-Family Residential	15	2.5
Commercial	29	5.0
Parks & Open Space	47	8.1
Total	**575**	**100.0**

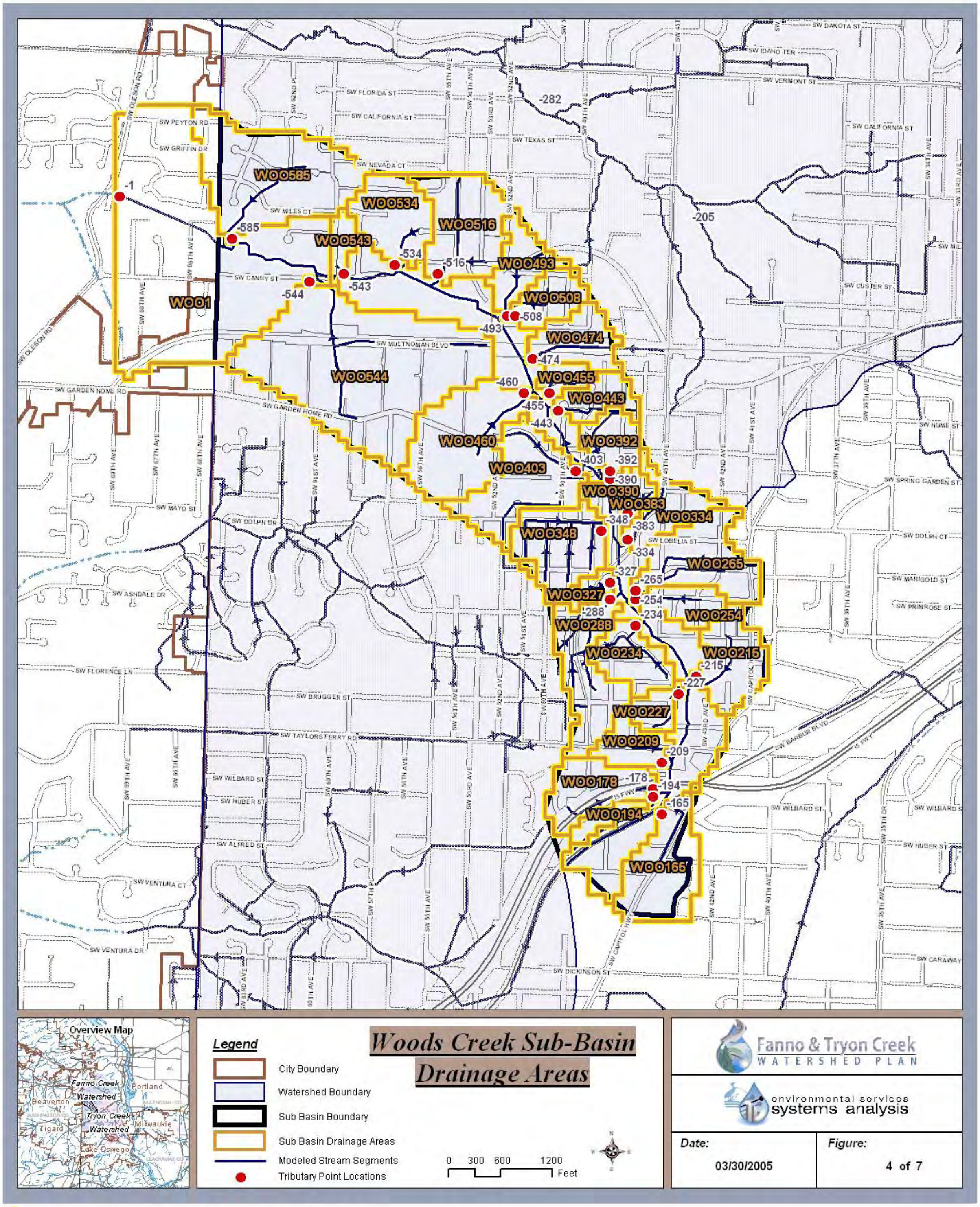
Figure 3-34
Tax Lots Built on in Woods Creek Subwatershed



GIS Analysis

A GIS analysis, using the 100-foot by 100-foot grid system established for the MIKE SHE/MIKE 11 modeling, was performed to evaluate three indicators of human influence on hydrology: impervious area, zoning, and the stormwater system (ratio of piped storm infrastructure to open channels). The area within the subwatershed was divided into modeled subcatchments for analysis, as shown on Figure 3-35.

Figure 3-35
Woods Creek Sub-Basin Drainage Areas



Produced in MapInfo: \\CASSIO\GIS2\Projects\Fanno_Tryon\Report_Figs\Misc\Eugene\Woo_Dr.Wor (HDR) May, 2004

Evaluation of the GIS results indicated that impervious areas were concentrated in the upper part of the subwatershed. The subwatershed was divided into three subcatchments for analysis. Impervious areas ranged from 47.8 percent in the upper subcatchment (including the I-5-Barbur Boulevard corridor), 37.8 percent in the mid-subcatchment, to 27.8 percent in the lower subcatchment. Areas draining directly to the stream had an overall lower total impervious area of 29.8 percent. The overall total impervious area in the subwatershed was 29.8 percent. Table 3-22 summarizes the results of the GIS analysis.

Table 3-22
Results of GIS Analysis
Woods Creek Subwatershed

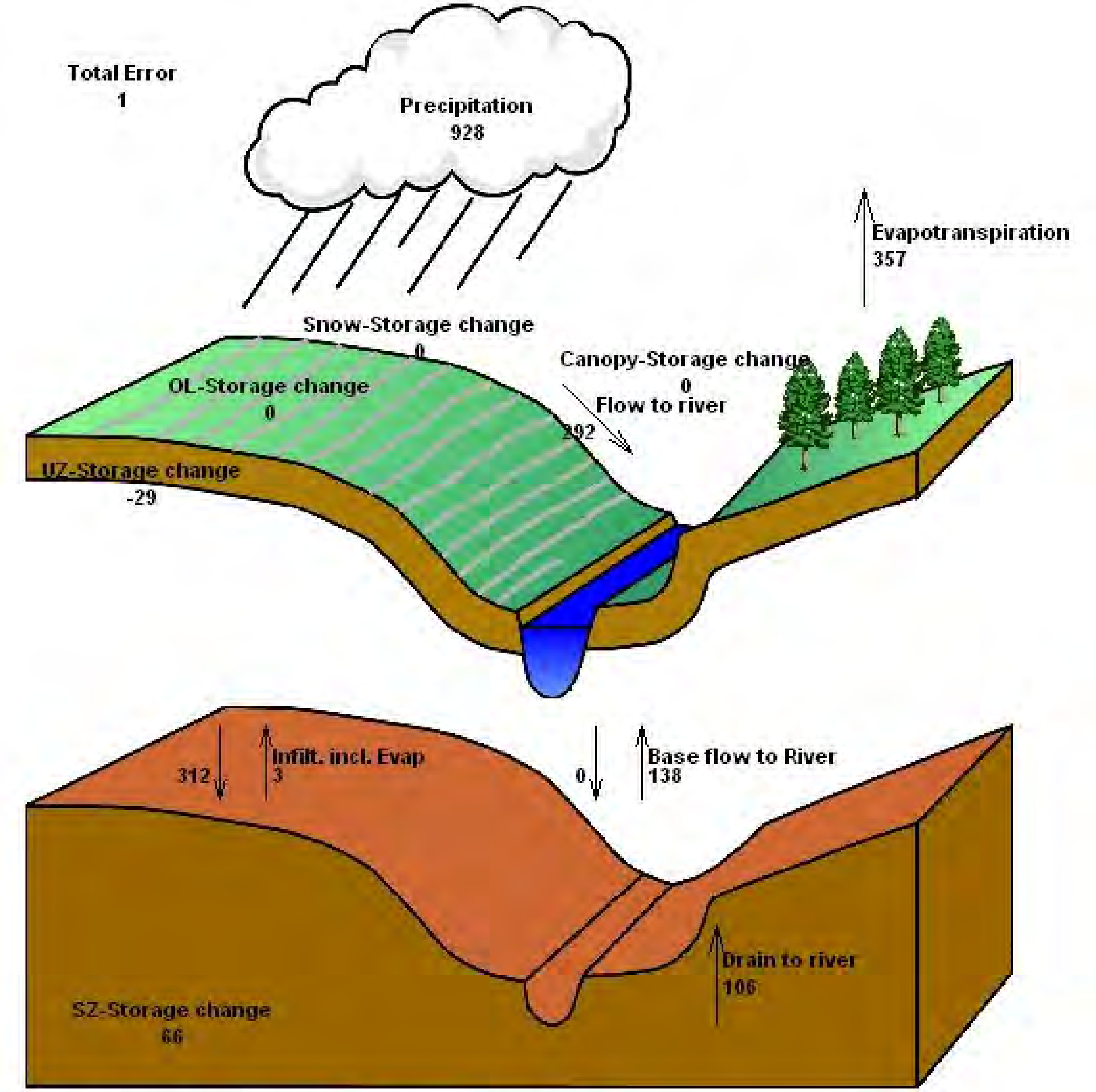
Drainage Units	Area			ZONING				DRAINAGE SYSTEM		
	Total	IMPERVIOUS		SFR	MFR	COM	POS	CHNL_FT	PIP_FT	Ratio
	Acres	Acres	%	%	%	%	%	FT	FT	
Drainage Area 1:										
WOO165	23	12	52	28	48	25	0	0	3,414	Piped
WOO194	4	3	82	0	0	100	0	0	444	Piped
WOO178	16	10	61	75	0	25	0	639	1,803	2.8
WOO209	8	3	33	100	0	0	0	465	610	1.3
WOO227	6	2	40	77	0	0	23	1,256	154	0.1
WOO215	16	5	30	81	0	0	19	1,405	259	0.2
Subtotal	74	35	48					3,765	6,685	1.8
Drainage Area 2:										
WOO254	9	3	35	82	0	0	19	1,152	983	0.9
WOO265	22	8	35	97	0	0	4	2,829	2,234	0.8
WOO288	22	9	41	78	0	0	23	4,429	1,880	0.4
WOO234	13	4	33	46	0	0	55	1,277	657	0.5
WOO327	3	1	34	45	0	0	55	2,597	64	0.0
WOO334	12	4	33	84	0	0	16	3,351	880	0.3
WOO348	20	8	41	100	0	0	0	124	3,492	28.2
WOO383	4	1	35	100	0	0	0	920	247	0.3
WOO390	2	1	37	100	0	0	0	273	307	1.1
WOO392	9	4	42	100	0	0	0	645	943	1.5
WOO403	27	10	37	100	0	0	0	1,430	4,109	2.9
WOO443	9	4	44	100	0	0	0	511	1,568	3.1
WOO455	4	1	29	100	0	0	0	0	1,008	piped
Subtotal	155	58	37					19,538	18,374	0.9

Drainage Area 3:													
WOO585		44	11	26		86	0	0	0		3,896	3,410	0.9
WOO544		82	22	27		100	0	0	0		5,463	2,607	0.5
WOO543		5	2	36		100	0	0	0		545	692	1.3
WOO534		18	3	19		66	0	0	34		1,307	817	0.6
WOO516		24	8	34		100	0	1	0		1,038	2,789	2.7
WOO493		12	3	29		98	0	2	0		796	1,845	2.3
WOO508		9	3	33		100	0	0	0		979	574	0.6
WOO474		13	7	53		100	0	0	0		3,018	810	0.3
WOO460		31	6	19		100	0	0	0		2,290	989	0.4
Subtotal		237	66	28							19,332	14,533	0.8
Drainage Area 4: Direct Drainage													
WOO1		199	39	19		47	4	8	9		20,458	10,600	0.5
Totals		665	198	30							63,094	50,191	0.8

MODELING RESULTS

The Mike SHE / MIKE 11 model developed for the Woods Creek subwatershed was run for the “typical year” rainfall record to evaluate hydrologic response in the subwatershed. Figures 3-36 through 3-39 show the modeling results.

Figure 3-36
Annual Water Balance
Woods Creek Subwatershed



Waterbalance accumulated from 10/1/2000 to 9/30/2001

Flow Result File : Woods_esa-final.frf

Title : Woods Creek Annual Hydrograph Run   Text : BW - 01/28/04

Figure 3-37
Annual Hydrograph
Woods Creek Subwatershed

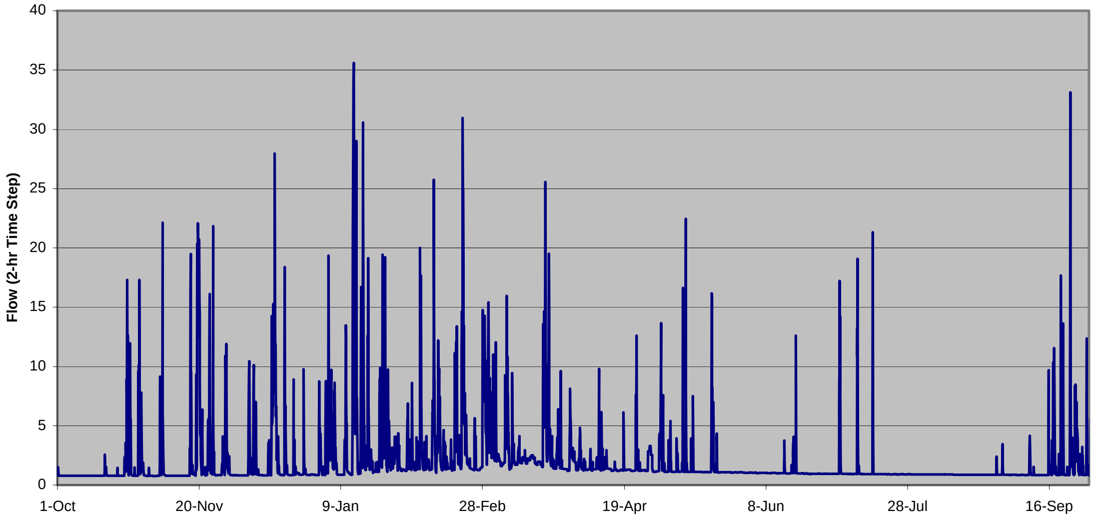
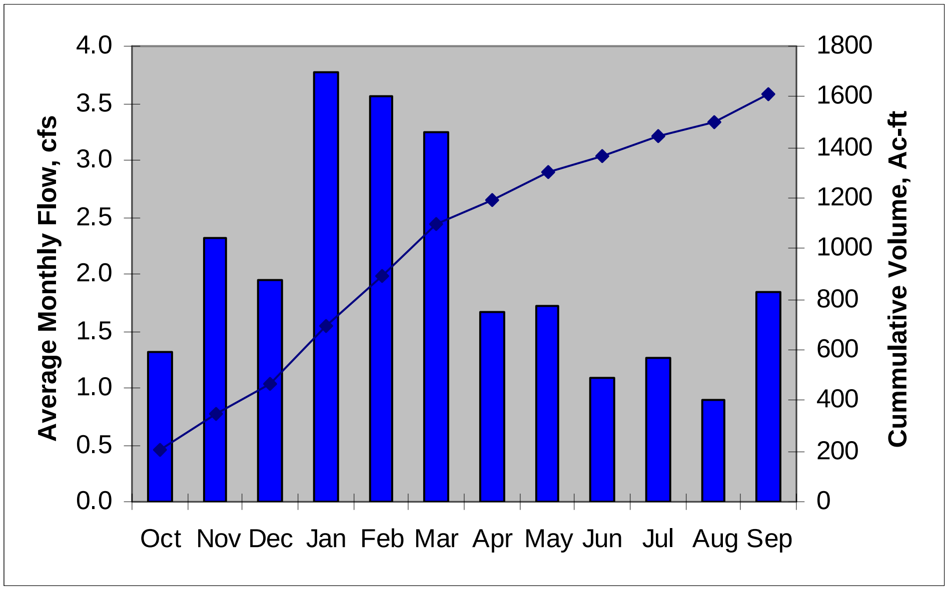
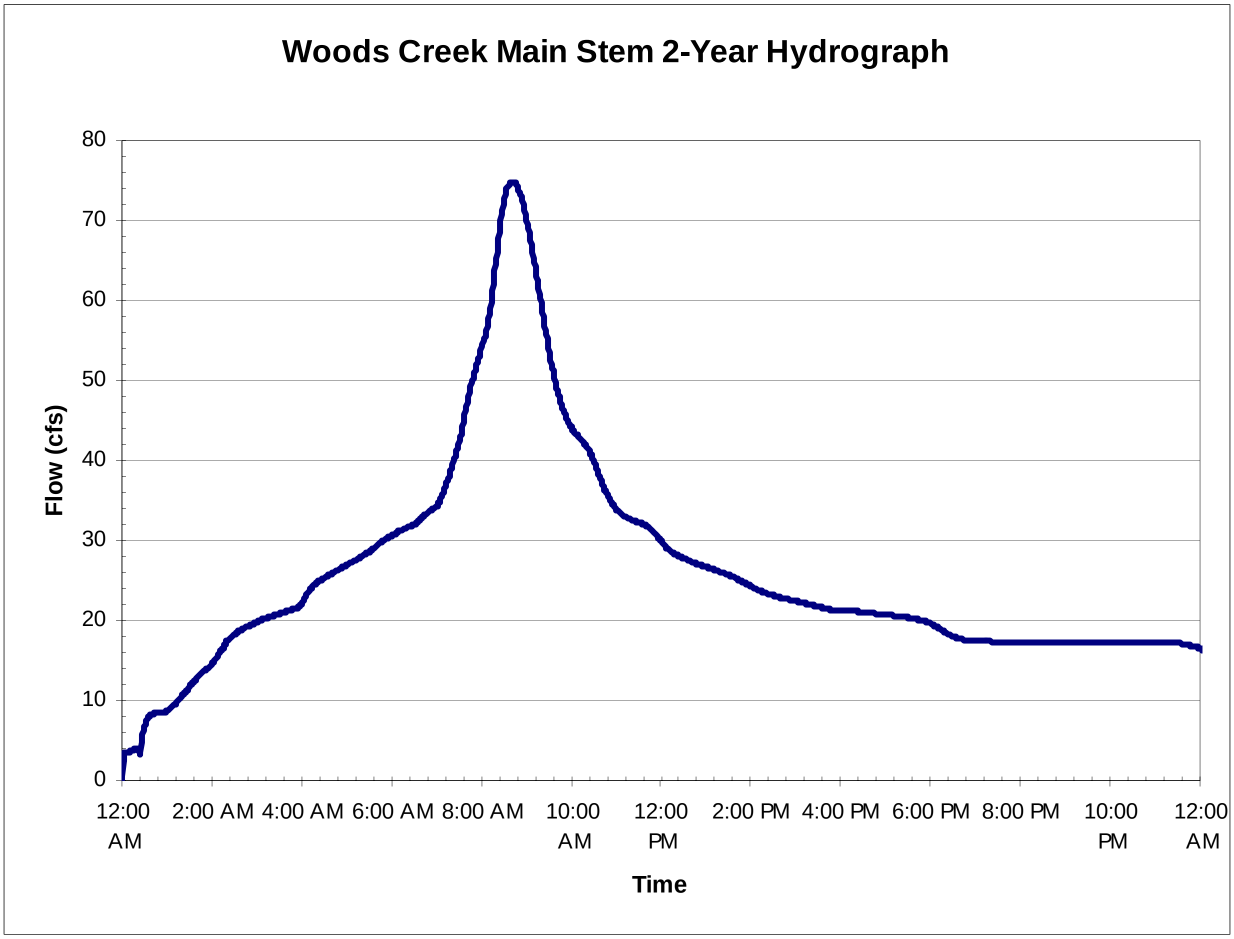


Figure 3-38
Average Monthly Flow
Woods Creek Subwatershed



The model was also run for design storms with return frequencies of 2, 10, 25, and 100 years. Figure 3-39 shows the hydrograph for the 2-year storm. The technical memorandum in Appendix G provides the full modeling results.

Figure 3-39
Woods Creek
2-YR Design Storm Hydrograph



North Ash Creek Subwatershed

DESCRIPTION

North Ash Creek originates near SW Bruegger Street and SW 50th Avenue and drains an area of approximately 282 acres within the City's jurisdiction. (See Map 1-North Ash Creek Aerial Map, Map Atlas) The creek flows west for approximately 0.8 mile until it exits the urban services boundary at SW Dolph Road (BES 1999).

LANDSCAPE FACTORS

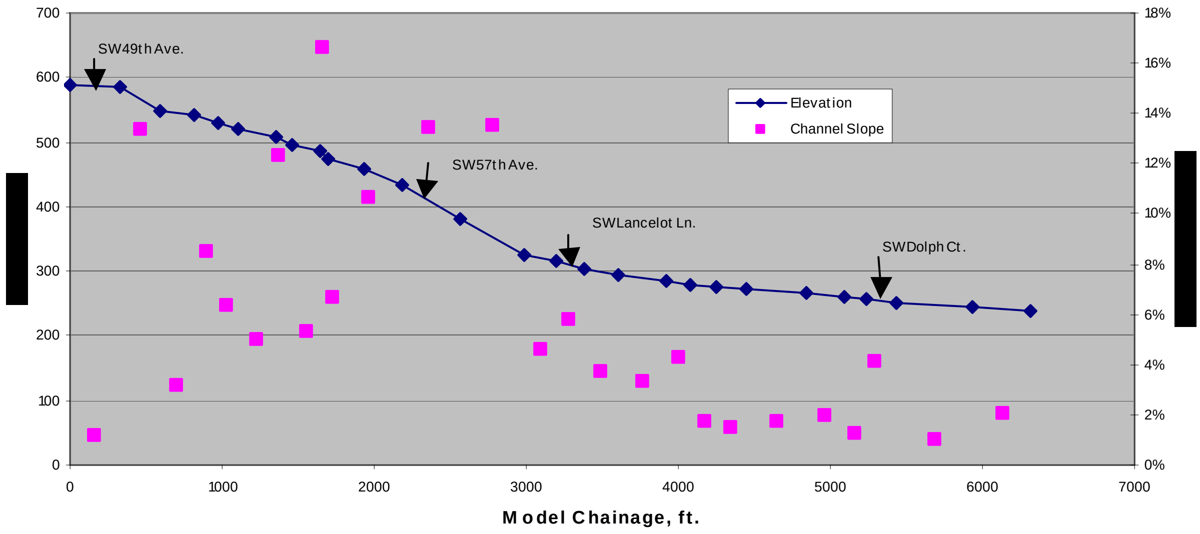
Topography

Steep (over 25 percent) or moderate (11 to 25 percent) slopes characterize much of the subwatershed. (See Map 9-North Ash Creek Contour Map, Map Atlas)

Stream Gradient and Morphology

Figure 3-40 shows the modeled stream profile and channel slopes for North Ash Creek. Stream gradients range from steep (8.4 percent average) upstream from SW Lancelot Lane to moderate (2.7 percent average) downstream of SW Lancelot Lane.

Figure 3-40
Modeled Stream Profile and Channel Slopes for North Ash Creek



Soils

Table 3-24 summarizes the distribution of soil types within the North Ash Creek subwatershed. The predominant soil type is Cascade silt loam (99.5 percent). Within the area of Cascade soils, 45 acres (15.9 percent) are subclassified as D and E series, occurring on slopes ranging from 15 to 60 percent. These areas are found primarily along the stream corridor. They have a high potential for soil erosion from exposed or disturbed areas and increased runoff volumes.

Table 3-24
Soil Types in North Ash Creek Subwatershed

Soil Type	Series	Slope (%)	Area (acres)	Percentage of Subwatershed
Cascade	7B/8B	3-8	110	38.9
	7C/8C	8-15	126	44.7
	7D/8D	15-30	13	4.8
	7E	30-60	32	11.1
Subtotal			***282***	***99.5***
Cornelius	11B	3-8	0	0.1
Other			1	0.4
Total			**283**	**100.0**

HUMAN INFLUENCES

Land Use and Zoning

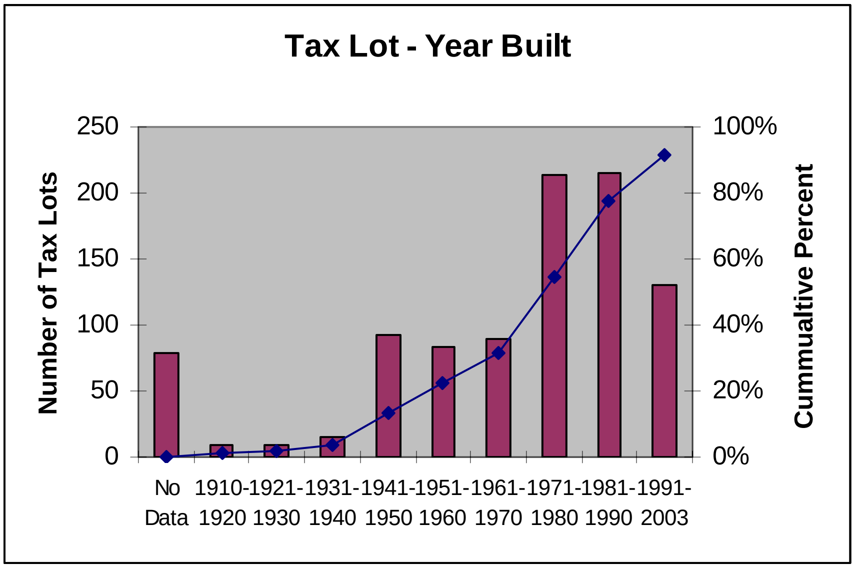
The North Ash Creek subwatershed in currently zoned as single family residential (100 percent).

Table 3-25 summarizes the current zoning for the subwatershed, as adopted in the *Southwest Community Plan* (Bureau of Planning 2001). (See also Map 5-North Ash Creek Current Plan Map, Map Atlas). Figure 3-41 shows the percentage of tax lots built on between 1910 and 2003.

Table 3-25
Current Land Use Zoning North Ash Creek Subwatershed

Land Use Category	Area (acres)	Percentage
Single-Family Residential	282	100.0
Multi-Family Residential	0	0.0
Commercial	0	0.0
Parks & Open Space	0	0.0
Total	**282**	**100.0**

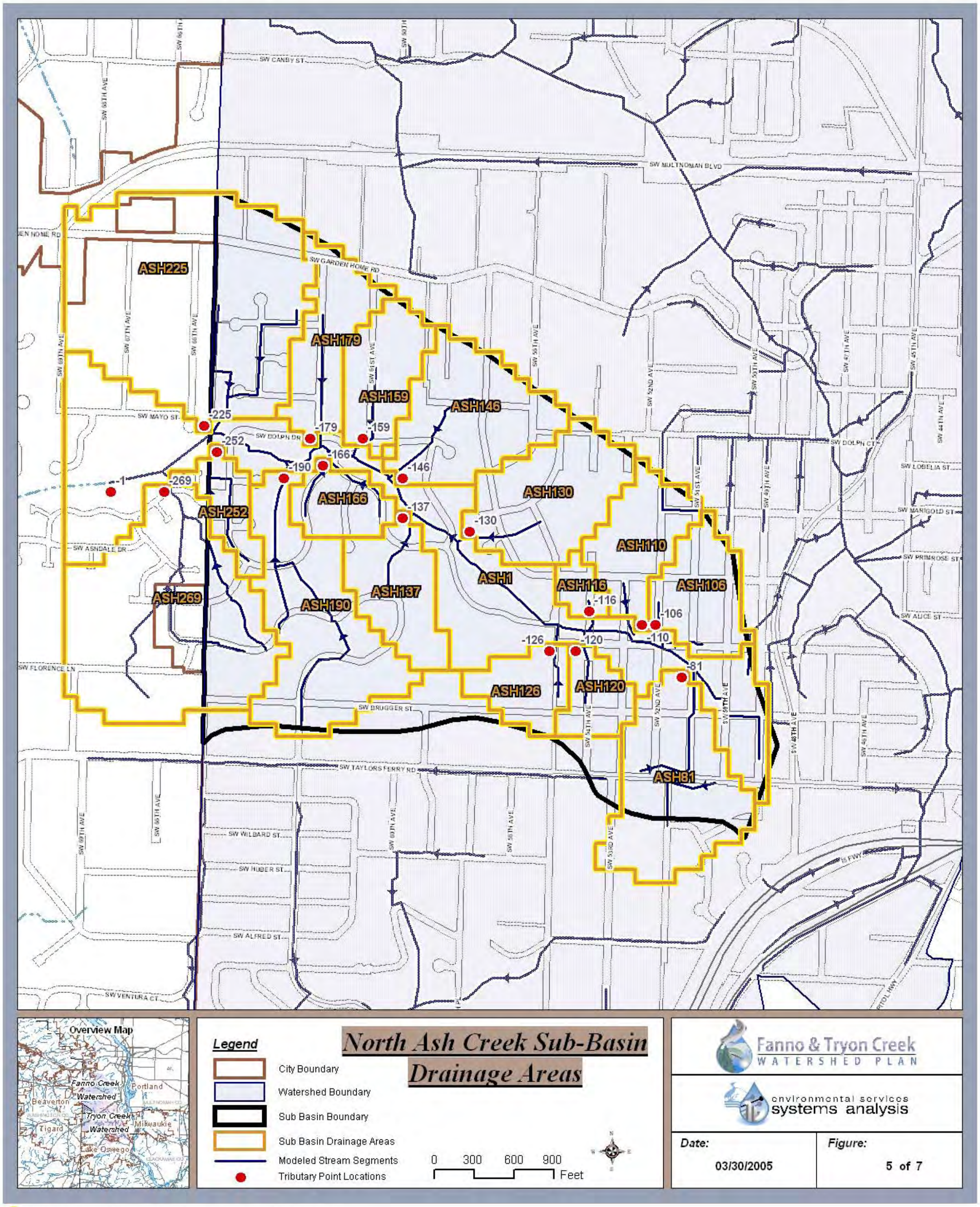
Figure 3-41
Tax Lots Built on in North Ash Creek Subwatershed



GIS Analysis

A GIS analysis, using the 100-foot by 100-foot grid system established for the MIKE SHE/MIKE 11 modeling, was performed to evaluate three indicators of human influence on hydrology: impervious area, zoning, and the stormwater system (ratio of piped storm infrastructure to open channels). The area within the subwatershed was divided into modeled subcatchments for analysis, as shown on Figure 3-42.

Figure 3-42
North Ash Creek Sub-Basin
Drainage Areas



Evaluation of the GIS results indicated that impervious areas were concentrated in the upper part of the subwatershed. The subwatershed was divided into two subcatchments for analysis. Impervious areas ranged from 43.7 percent in the upper subcatchment compared to 22 percent in the lower subcatchment. Areas draining directly to the stream had an overall lower total impervious area of 25.5 percent. The overall total impervious area was 25.5 percent. Table 3-26 summarizes the results of the GIS analysis.

Table 3-26
Results of GIS Analysis
North Ash Creek Subwatershed

Drainage Units	Area			ZONING				DRAINAGE SYSTEM		
	Total	IMPERVIOUS		SFR	MFR	COM	POS	CHNL_FT	PIP_FT	Ratio
	Acres	Acres	%	%	%	%	%	FT	FT	
Drainage Area 1:										
ASH81	27	11	41	100	0	0	0	1,451	3,478	2.4
ASH106	13	7	53	100	0	0	0	498	480	1.0
ASH110	14	5	37	100	0	0	0	30	1,612	53.8
ASH116	3	2	47	100	0	0	0	503	318	0.6
ASH120	7	3	48	100	0	0	0	198	485	2.5
Subtotal	63	28	44					2,680	6,372	2.4
Drainage Area 2:										
ASH126	8	2	20	100	0	0	0	581	424	0.7
ASH130	21	6	31	100	0	0	0	643	860	1.3
ASH137	14	3	19	100	0	0	0	491	715	1.5
ASH146	23	7	30	100	0	0	0	1,351	358	0.3
ASH159	13	3	24	100	0	0	0	0	1,082	Piped
ASH166	8	4	44	100	0	0	0	0	1,447	Piped
ASH179	14	5	32	100	0	0	0	630	1,411	2.2
ASH190	30	7	24	100	0	0	0	2,904	2,278	0.8
ASH225	61	10	16	48	7	0	0	1,870	4,925	2.6
ASH252	7	3	51	87	0	0	0	0	1,628	Piped
ASH269	48	5	11	36	0	0	0	1,245	1,500	1.2
Subtotal	246	54	22					9,716	16,628	1.7
Drainage Area 3: Direct Drainage										
ASH1	71	15	21	66	0	0	0	6,562	6,779	1.0
Totals	381	97	25					18,958	29,779	1.0

MODELING RESULTS

The Mike SHE/MIKE 11 model developed for the North Ash Creek subwatershed was run for the “typical year” rainfall record to evaluate hydrologic response in the subwatershed. Figures 3-43 through 3-46 show the modeling results.

Figure 3-43
Annual Water Balance
North Ash Creek Subwatershed

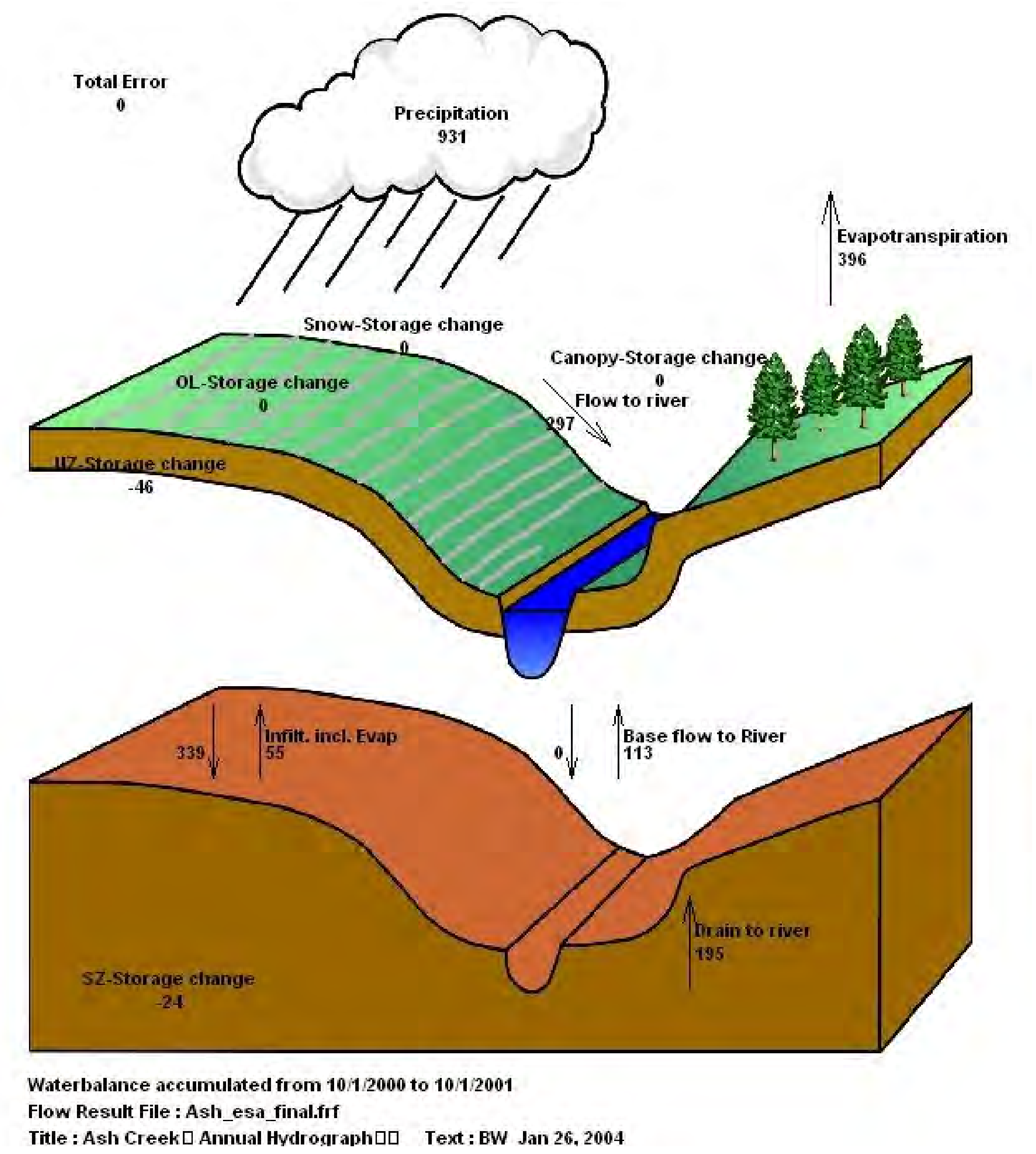


Figure 3-44
Annual Hydrograph
North Ash Creek Subwatershed

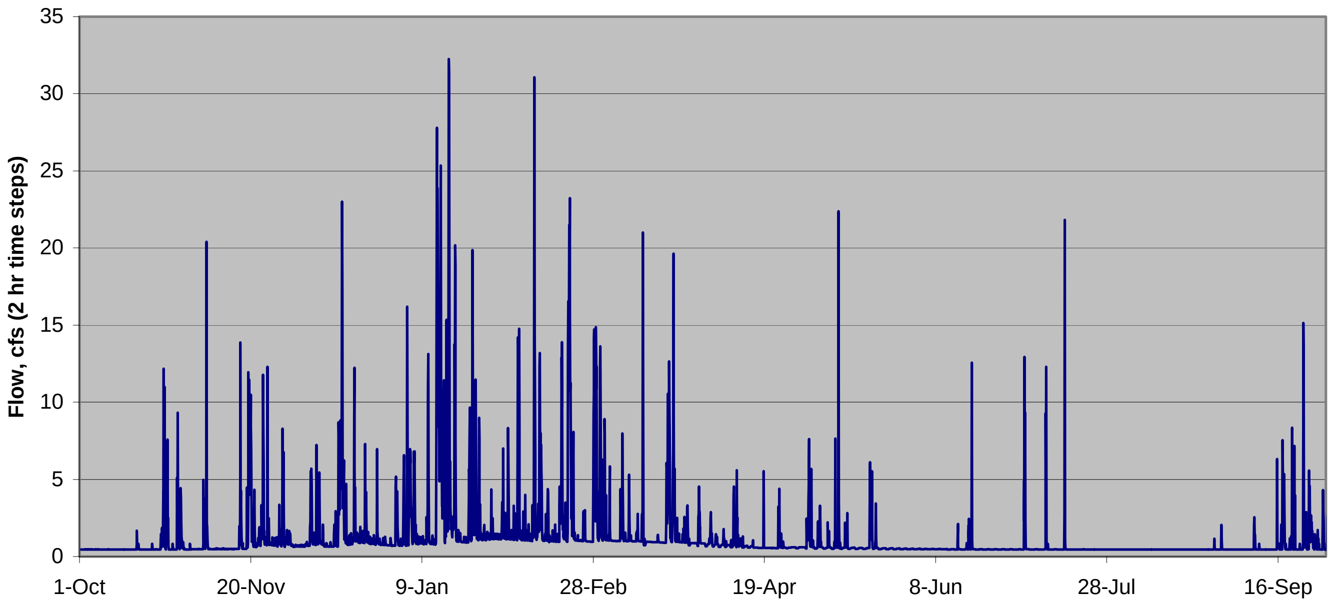
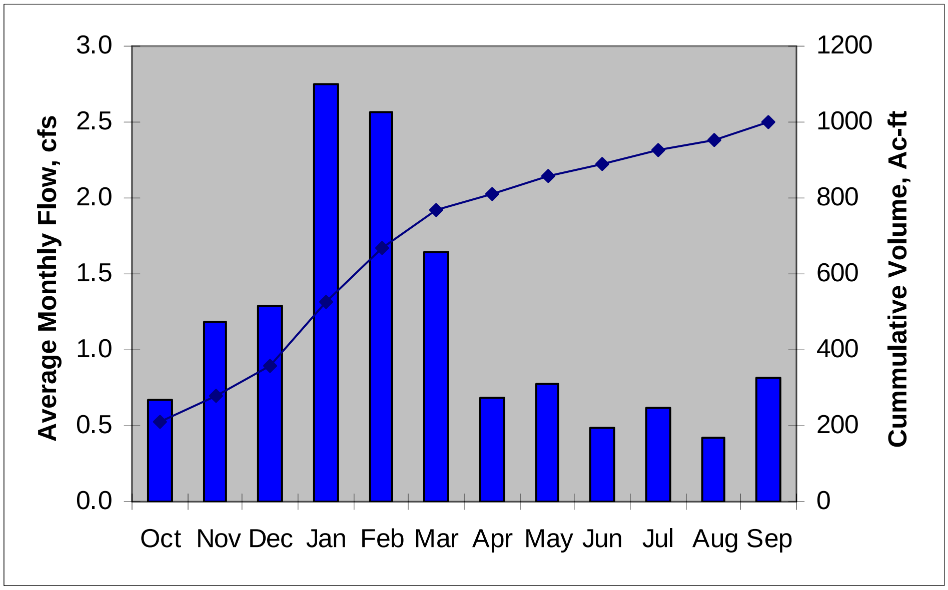
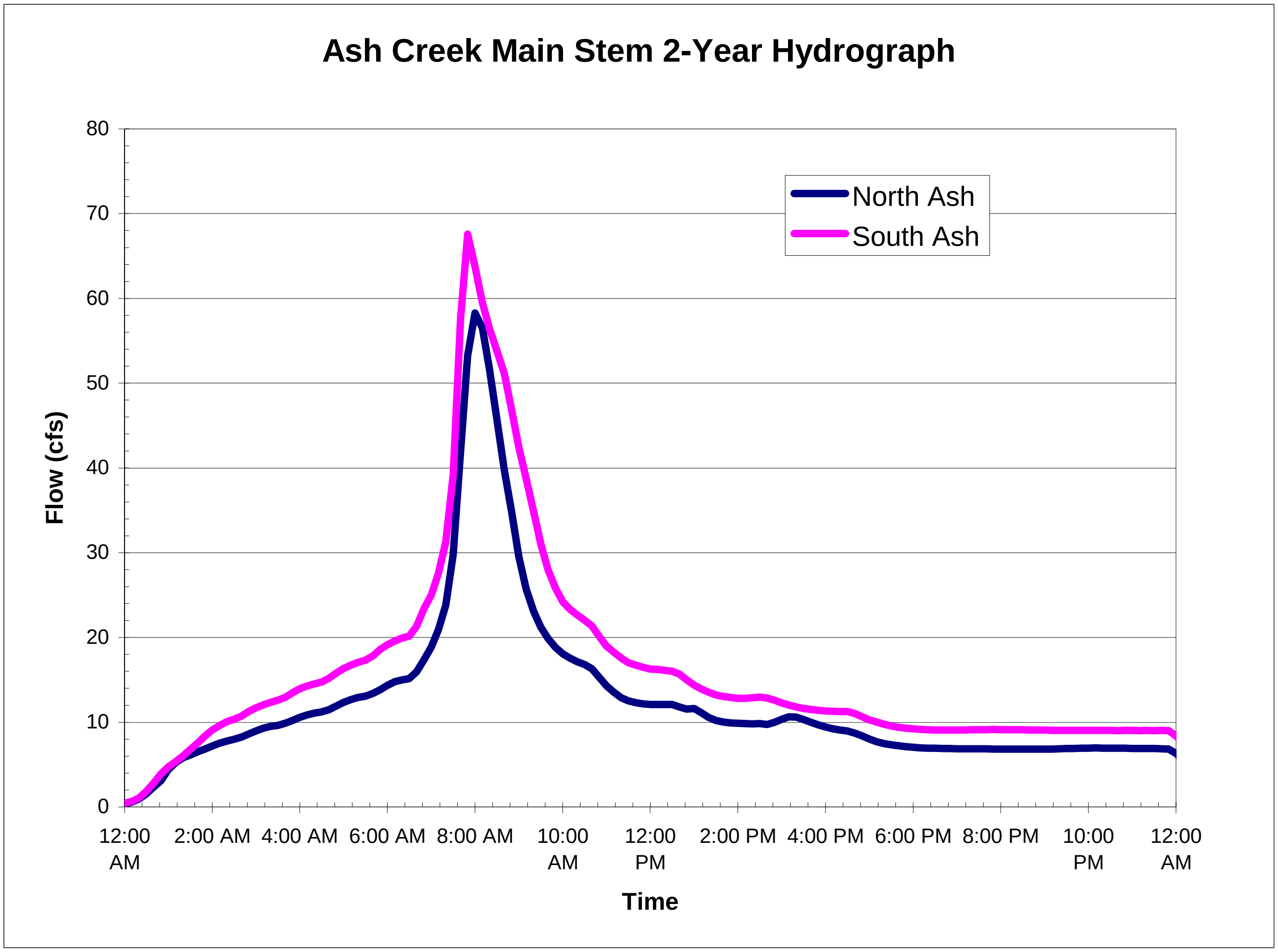


Figure 3-45
Average Monthly Flow
North Ash Creek Subwatershed



The model was also run for design storms with return frequencies of 2, 10, 25, and 100 years. Figure 3-46 shows the hydrograph for the 2-year storm. The technical memorandum in Appendix G provides the full modeling results.

Figure 3-46
North Ash Creek
2-YR Design Storm Hydrograph



South Ash Creek Subwatershed

DESCRIPTION

South Ash Creek originates just west of I-5 near SW 52nd Avenue and drains an area of approximately 360 acres within the City's jurisdiction (Map 1-South Ash Creek Aerial, Map Atlas). Stormwater from sections of I-5 drains into South Ash Creek. The creek flows in a westerly direction and exits the USB north of SW Dickson Place prior to joining Fanno Creek (BES, 1999).

LANDSCAPE FACTORS

Topography

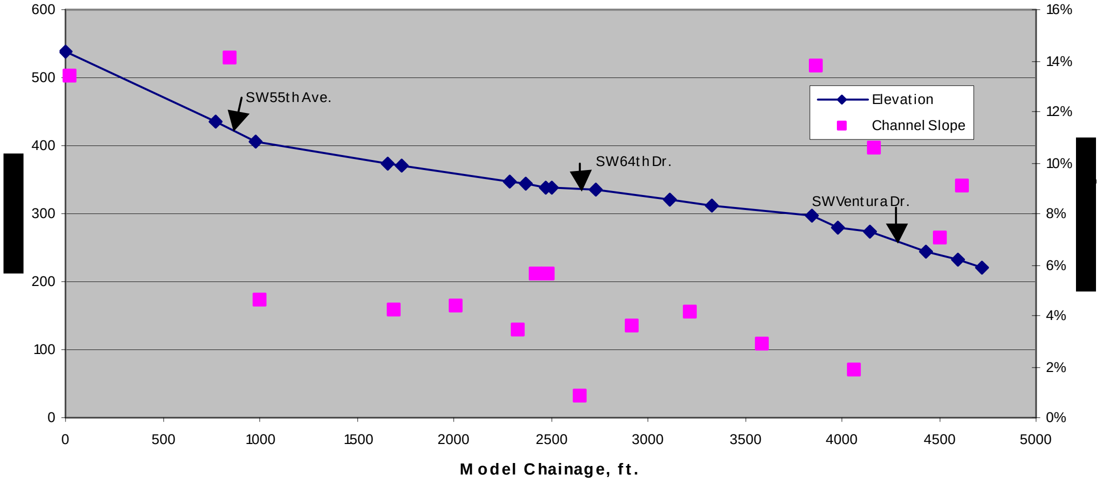
Steep (>25 percent) slopes (Map 9- South Ash Creek Contour Map, Map Atlas) characterize much of the upper reaches of the subwatershed, especially areas near mainstem tributaries.

Stream Gradient and Morphology

The modeled stream profile and channel slopes for South Ash Creek is shown in Figure 3-47. As shown stream gradients for South Ash Creek are moderate (6.4 percent average) throughout this reach.

Figure 3-47

Modeled Stream Profile and Channel Slopes for North Ash Creek



Soils

The predominant soil type within the subwatershed is Cascade silt loam (99.5 percent). Included within the area of Cascade soils are 87 acres (24 percent) subclassified as D and E series occurring on slopes ranging from 15 to 60 percent. These areas, are found primarily along the stream corridor have a high potential for soil erosion from exposed or disturbed areas and along with increased runoff volumes.

The distribution of soil types within the subwatershed is summarized in Table 3-28.

Table 3-28
Soil Types in South Ash Creek Subwatershed

Soil Type	**Series**	**Slope (%)**	**Area (acres)**	**Percentage of Subwatershed**
Cascade	7B/8B	3-8	198	55.1
	7C/8C	8-15	68	19.0
	7D/8D	15-30	87	24.0
	7E	30-60	0	0.0
Subtotal			***353***	***98.1***
Delena	14C	3-12%	6	1.6
Helvetia	21B	3-8%	1	0.3
Total			**360**	**100.0**

HUMAN INFLUENCES

Land Use and Zoning

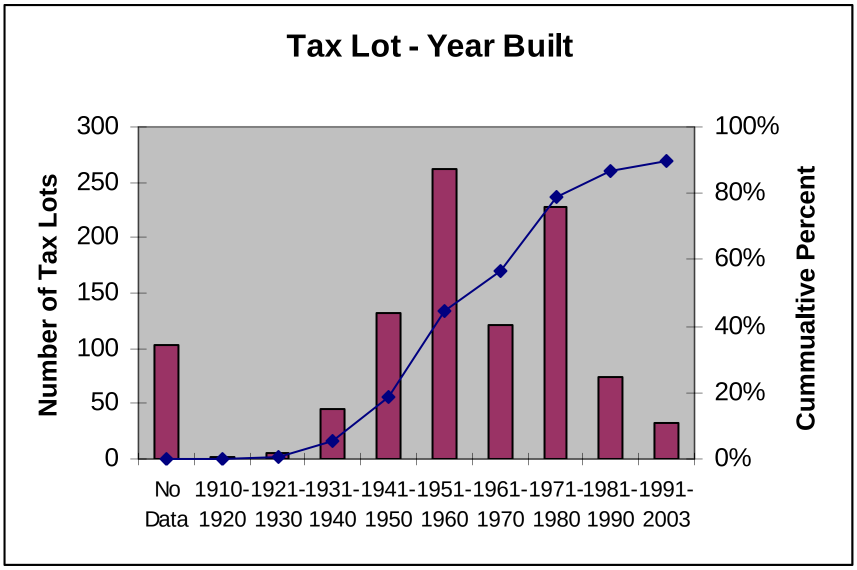
The predominant land use within the Woods Creek subwatershed is single family residential (79.6 percent). Also included in the subwatershed are 51 acres (14.1 percent) of multi-family residential and commercial areas primarily along the I-5- Barbur Boulevard corridor in the upper subwatershed and 23 acres (6.3 percent) zoned as Parks and Open Space.

The current zoning for the subwatershed as adopted in the Southwest Community Plan is summarized in Table 3-29. (Also refer to Map 5-South Ash Creek Current Plan, Map Atlas).

Table 3-29
Current Land Use Zoning South Ash Creek Subwatershed

Land Use Category	Area (acres)	Percentage
Single-Family Residential	286	79.6
Multi-Family Residential	26	7.1
Commercial	25	7.0
Parks & Open Space	23	6.3
Total	**359**	**100.0**

Figure 3-48
Tax Lots Built on in South Ash Creek Subwatershed

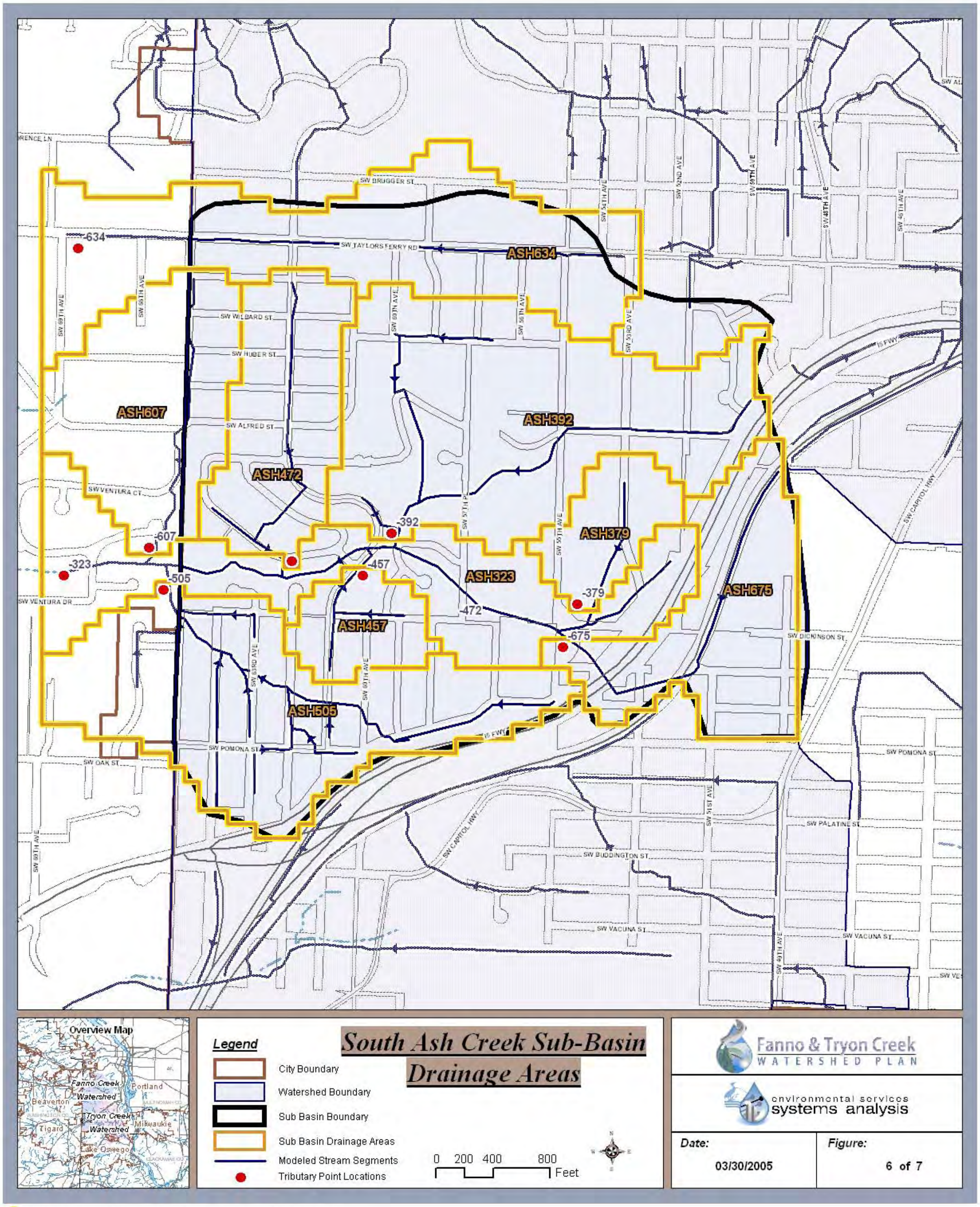


GIS Analysis

A GIS analysis, using the 100-foot by 100-foot grid system established for the MIKE SHE/MIKE 11 modeling, was performed to evaluate three indicators of human influence on hydrology: impervious area, zoning, and the stormwater system (ratio of piped storm infrastructure to open channels). The area within the subwatershed was divided into modeled subcatchments for analysis, as shown on Figure 3-49.

Figure 3-49

South Ash Creek Sub-BasinDraiange Areas



Evaluation of the GIS results indicated that impervious areas were concentrated in the upper part of the subwatershed. For analysis the subwatershed was divided into two subcatchments. Impervious areas ranged from 45.0 percent in the upper subcatchment (including the I-5-Barbur Blvd corridor) to 24.9 percent in the lower subcatchment. Areas draining directly to the stream had an overall lower total impervious area of 24.91 percent. The overall total impervious area was 32.1 percent.

Table 3-30 summarizes the results of the GIS analysis.

Table 3-30
Results of GIS Analysis
South Ash Creek Subwatershed

Drainage Units	Area			ZONING				DRAINAGE SYSTEM		
	Total	IMPERVIOUS		SFR	MFR	COM	POS	CHNL_FT	PIP_FT	Ratio
	Acres	Acres	%	%	%	%	%	FT	FT	
Drainage Area 1:										
ASH379	16	3	19	79	0	0	22	1,425	1,011	0.7
ASH392	87	26	30	90	0	1	10	8,618	8,231	1.0
ASH472	35	15	42	100	0	0	0	2,452	5,921	2.4
ASH607	44	6	14	28	0	0	0	1,712	1,990	1.2
ASH634	74	19	26	72	0	0	0	3,833	5,276	1.4
Subtotal	257	69	27					18,040	22,430	1.2
Drainage Area 2:										
ASH457	14	6	43	98	0	0	3	844	2,368	2.8
ASH505	74	29	39	68	17	2	0	7,659	9,021	1.2
ASH675	43	24	56	27	26	47	0	2,319	2,923	1.3
Subtotal	130	59	45					10,822	14,312	1.3
Drainage Area 3: Direct Drainage										
ASH323	57	14	25	51	0	2	18	4,807	3,233	0.7
Totals	444	142	32					33,669	39,975	1.2

MODELING RESULTS

The Mike SHE/MIKE 11 model developed for the South Ash Creek subwatershed was run for the “typical year” rainfall record to evaluate hydrologic response in the subwatershed. Figures 3-50 through 3-53 show the modeling results.

Figure 3-50
Annual Water Balance
South Ash Creek Subwatershed

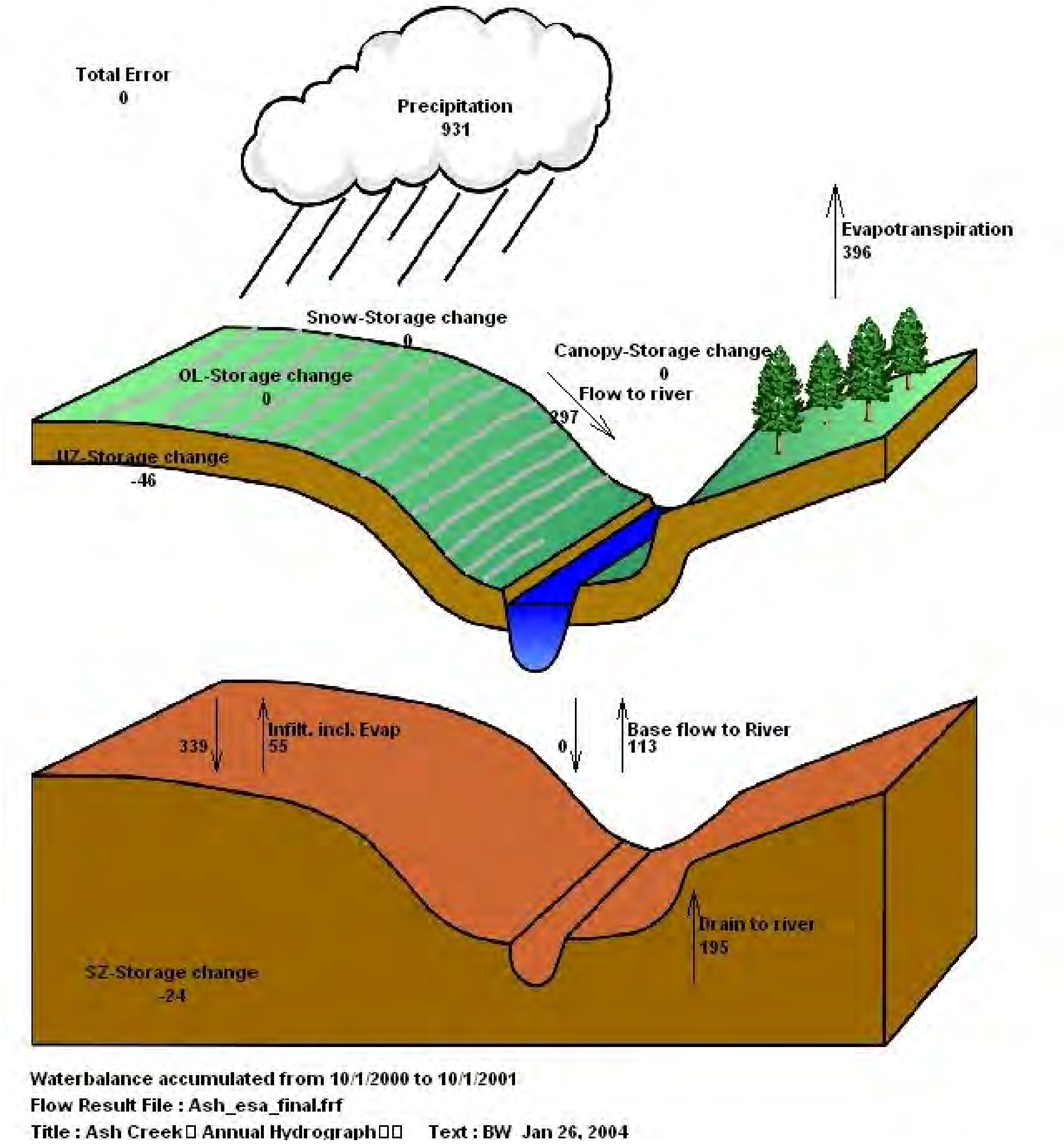


Figure 3-51
Annual Hydrograph
South Ash Creek Subwatershed

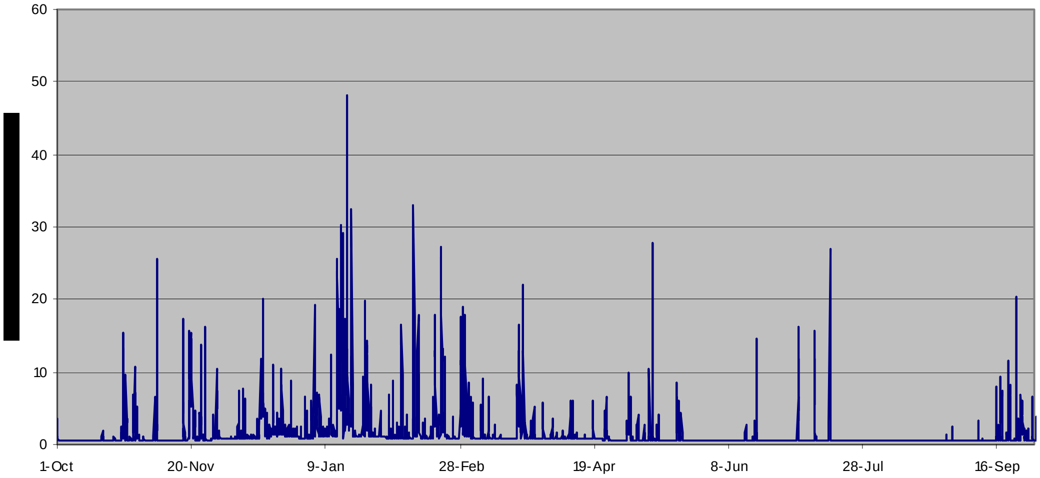
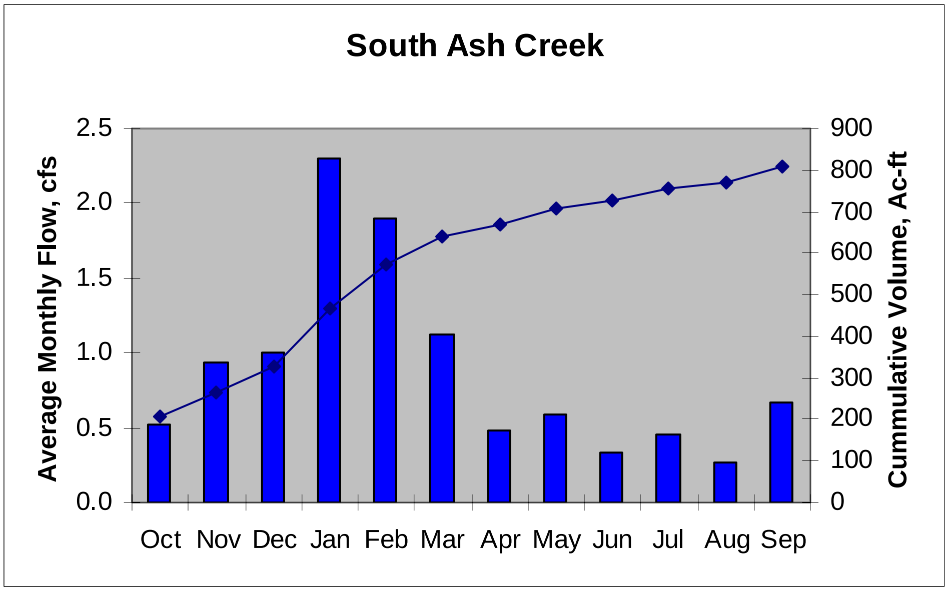
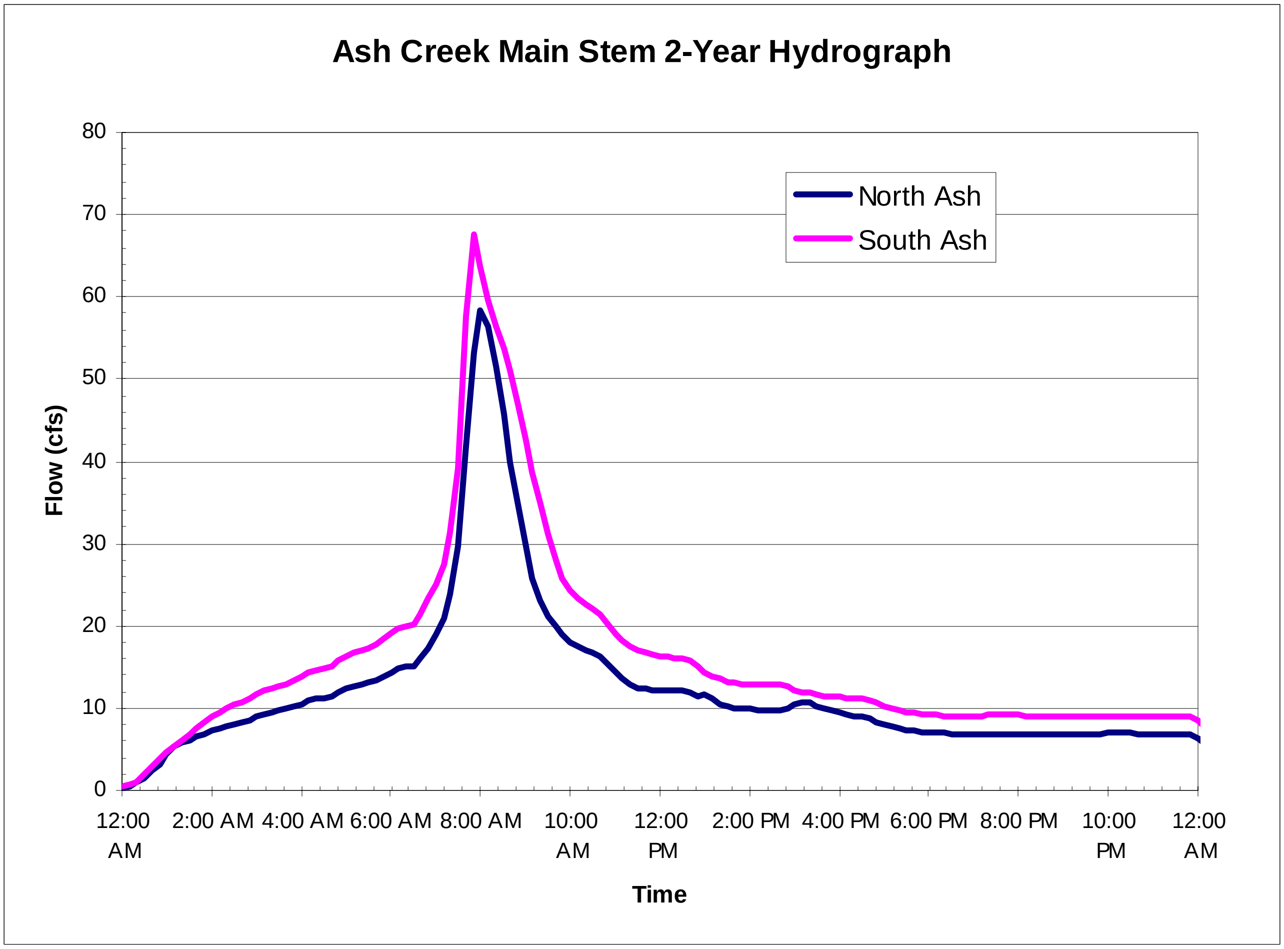


Figure 3-52
Average Monthly Flow
South Ash Creek Subwatershed



The model was also run for design storms with return frequencies of 2, 10, 25, and 100 years. Figure 3-53 shows the hydrograph for the 2-year storm. The technical memorandum in Appendix G provides the full modeling results.

Figure 3-53
South Ash Creek
2-YR Design Storm Hydrograph



Red Rock Creek Subwatershed

DESCRIPTION

Red Rock Creek originates just south of I-5 near SW Capitol Highway and drains approximately 413 acres within the City's jurisdiction. (See Map 1-Red Rock Creek Aerial, Map Atlas). Stormwater from sections of I-5 drains into Red Rock Creek. The creek flows west and exits the urban services boundary near SW 64th Avenue before it joins Fanno Creek (BES 1999).

LANDSCAPE FACTORS

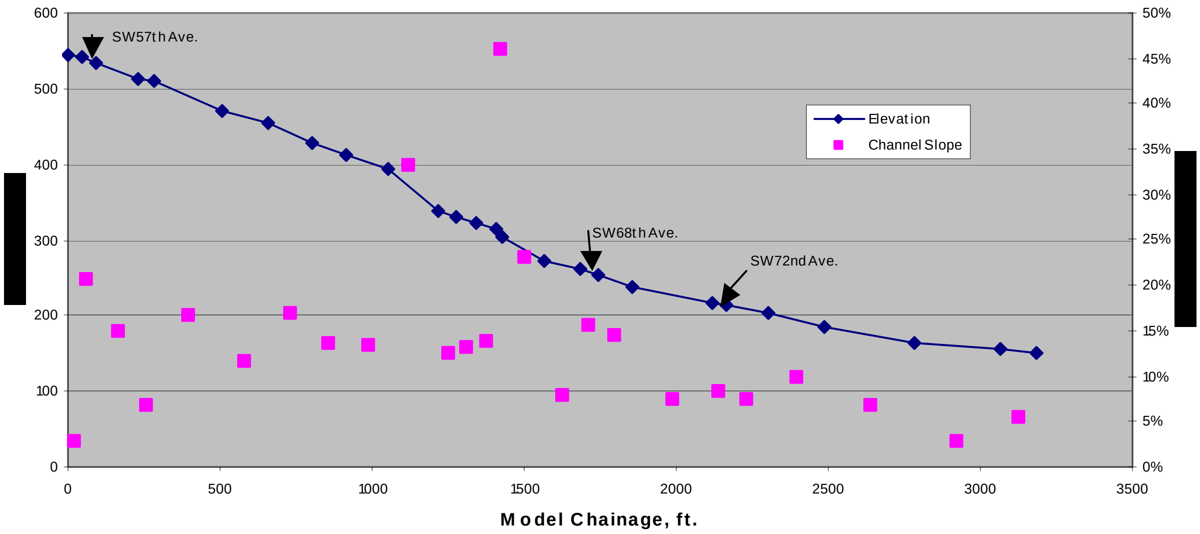
Topography

Overall, the subwatershed is relatively flat. (See Map 9-Red Rock Creek Contour Map, Map Atlas). However, steep and moderate slopes dominate the western portion around Red Rock Creek and its tributaries.

Stream Gradient and Morphology

Figure 3-54 shows the modeled stream profile and channel slopes for Red Rock Creek. Stream gradients are steep (13.9 percent average) throughout this reach.

Figure 3-54
Modeled Stream Profile and Channel Slopes for Red Rock Creek



Soils

Table 3-32 summarizes the distribution of soils within the Red Rock Creek subwatershed. The predominant soil types are Cascade silt loam (70.3 percent) and Cornelius silt loam (27.6 percent). The Cornelius soils are predominant in the southern portion of the subwatershed.

Table 3-32
Soil Types in Red Rock Creek Subwatershed

Soil Type	Series	Slope (%)	Area (acres)	Percentage of Subwatershed
Cascade	7B/8B	3-8	188	45.5
	7C/8C	8-15	84	20.4
	7D/8D	15-30	18	4.5
	7E	30-60	0	0.0
Subtotal			***291***	***70.3***
Cornelius	11B/11C	3-15	109	26.2
	10D	15-30	6	1.4
Subtotal			***114***	***27.6***
Delena	14C	3-12	3	0.7
Quantama	37B/37C	3-15	6	1.4
Total			**415**	**100.0**

HUMAN INFLUENCES

Land Use and Zoning

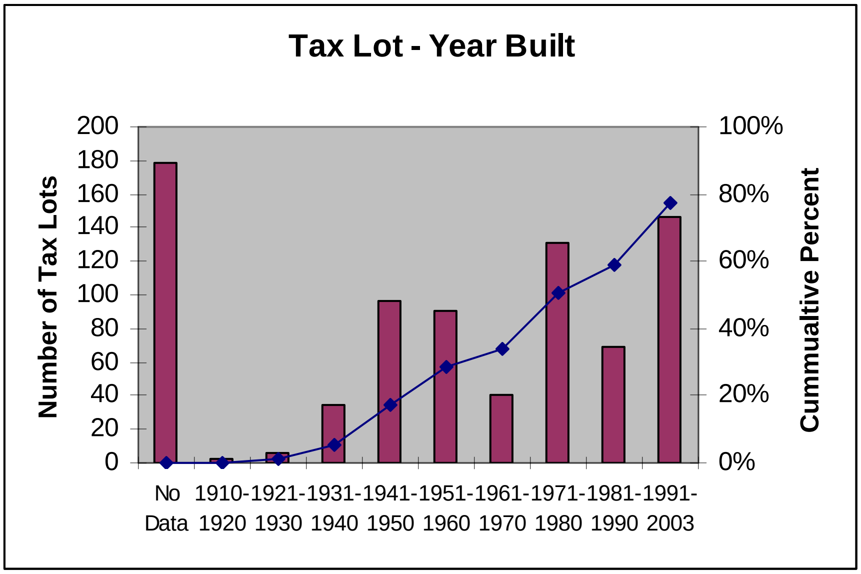
The predominant land use in the Red Rock Creek subwatershed is single-family residential (60.4 percent). The subwatershed has 128 acres (31 percent) designated as multi-family residential, which includes the Portland Community College Sylvania campus. Twenty-seven acres of commercial zoning is located primarily along the I-5 - SW Barbur Boulevard corridor in the upper subwatershed.

Table 3-33 summarizes the current zoning for the subwatershed, as adopted in the *Southwest Community Plan* (Bureau of Planning 2001). (See also Map 5-Red Rock Creek Current Plan, Map Atlas). Figure 3-55 shows the percentage of tax lots built on between 1910 and 2003.

Table 3-33
Current Land Use Zoning Red Rock Creek Subwatershed

Land Use Category	Area (acres)	Percentage
Single-Family Residential	249	60.4
Multi-Family Residential	128	31.0
Commercial	27	6.4
Parks & Open Space	9	2.2
Total	**413**	**100.0**

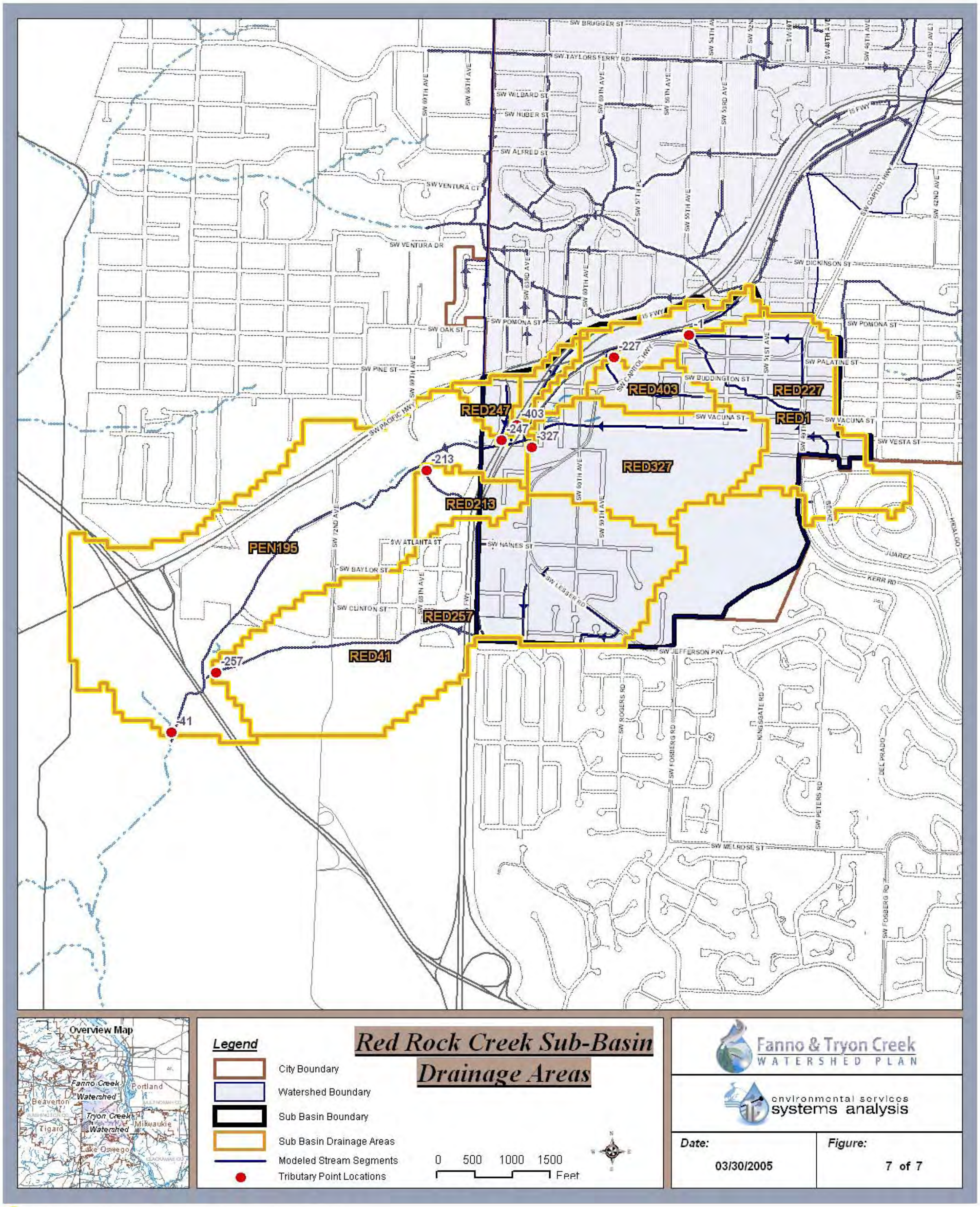
Figure 3-55
Tax Lots Built on in Red Rock Creek Subwatershed



GIS Analysis

A GIS analysis, using the 100-foot by 100-foot grid system established for the MIKE SHE/MIKE 11 modeling, was performed to evaluate three indicators of human influence on hydrology: impervious area, zoning, and the stormwater system (ratio of piped storm infrastructure to open channels). The area within the subwatershed was divided into modeled subcatchments for analysis, as shown on Figure 3-56.

Figure 3-56
Red Rock Creek Sub-Basin
Drainage Areas

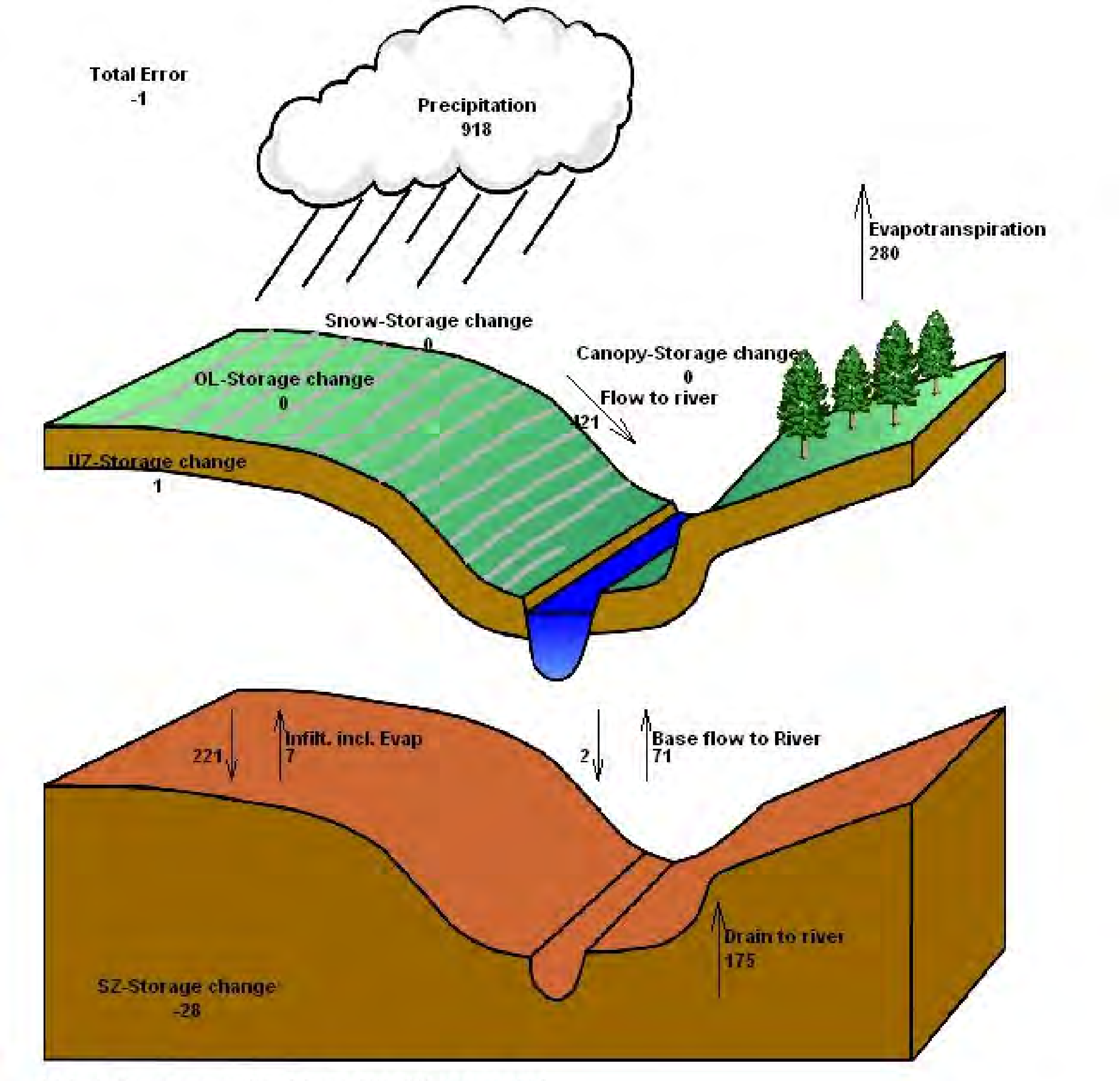


Produced in MapInfo: \CASSIO\GIS2\Projects\Fanno_Tryon\Report_Figs\Misc\Eugene\Roc_Dr.Wor (HDR) May, 2004

MODELING RESULTS

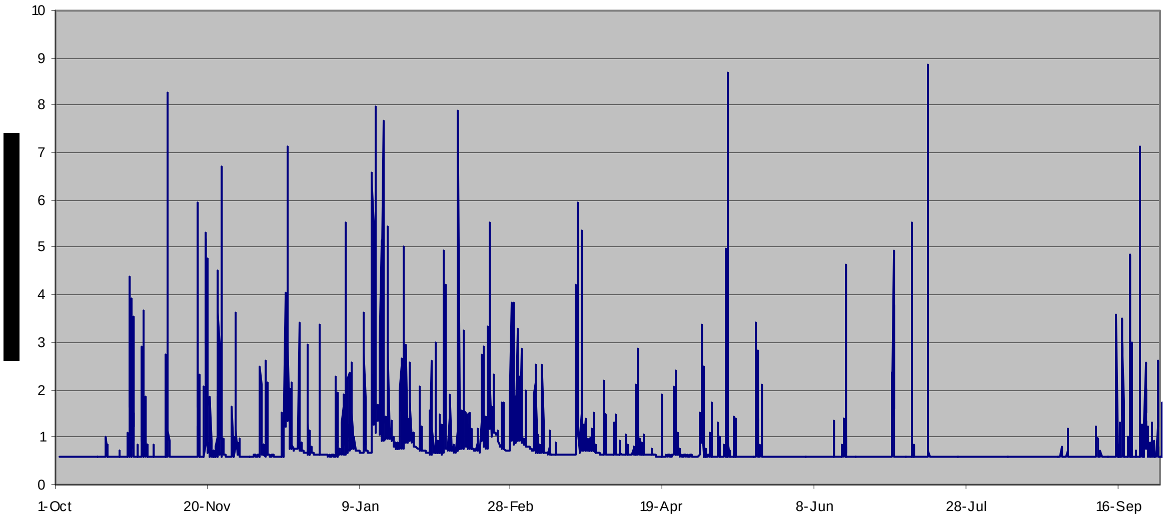
The Mike SHE/MIKE 11 model developed for the Red Rock Creek subwatershed was run for the "typical year" rainfall record to evaluate hydrologic response in the subwatershed. Figures 3-57 through 3-58 show the modeling results.

Figure 3-57
Annual Water Balance
Red Rock Creek Subwatershed



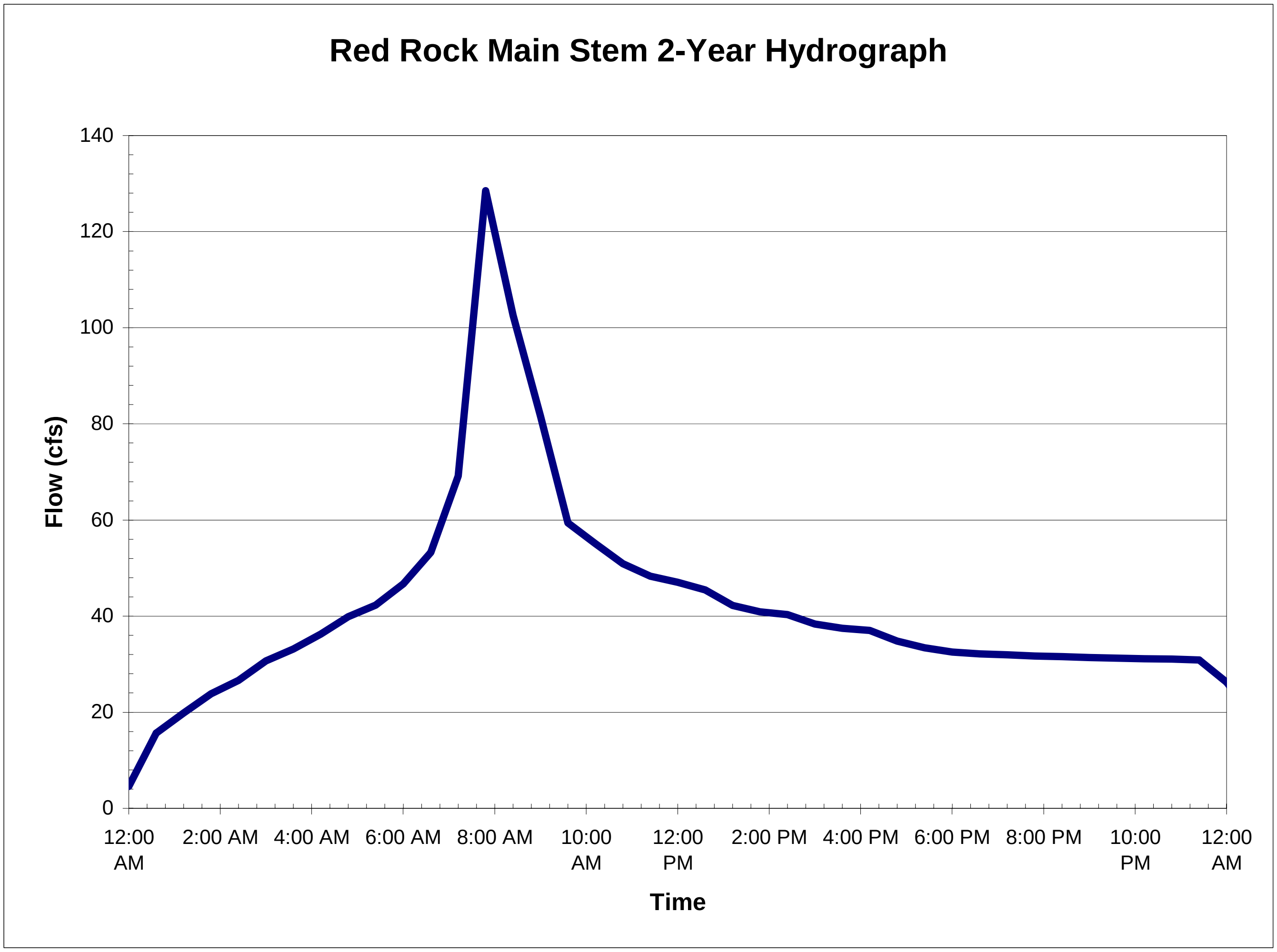
Waterbalance accumulated from 10/1/2000 to 9/26/2001
Flow Result File : redrock_1yrSIM2.frf
Title : Red Rock Creek 1-yr Simulation   Text : Model Run

Figure 3-58
Annual Hydrograph
Red Rock Creek Subwatershed



The model was also run for design storms with return frequencies of 2, 10, 25, and 100 years. Figure 3-59 shows the hydrograph for the 2-year storm. The technical memorandum in Appendix G provides the full modeling results.

Figure 3-59
Red Rock Creek
2-YR Design Storm Hydrograph



SUMMARY OF FINDINGS

The hydrology of Fanno Creek and its tributaries is typical of low to moderate gradient Willamette Valley headwater streams. The hydrologic response of the watershed has modified by the effects of development and urbanization with major factors including the following:

- Loss of native vegetation including mature forest cover.
- Increase of impervious surfaces.
- Construction of roads and streets including the Beaverton Hillsdale Highway.
- Construction of stormwater conveyance systems including storm sewer systems and culverts.

The effects of development in the Fanno Creek Watershed are particularly concentrated along the mainstem of Fanno Creek along the Beaverton Hillsdale Highway corridor.

The annual hydrograph for Fanno Creek reflects the climatic precipitation pattern, with higher flows and frequent storm flow events during the wet period from approximately October through May, followed by lower flows during the summer dry period from June through September. Winter base flows average approximately 3 cfs with summer base flows extremely low with flows less than 0.5 cfs common. The watershed also shows very quick, “flashy” response to storm events.

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CHAPTER 4

Hydrology: Tryon Creek Watershed

This chapter characterizes the hydrology of the Tryon Creek Watershed. It includes:

- Watershed Description
- Historic Conditions
- Landscape Factors
- Human Influences
- Gaged Stream Flows
- Current Hydrologic Assessment

WATERSHED DESCRIPTION*

The Tryon Creek Watershed in southwest Portland covers an area of approximately 4,142 acres, or 6.5 square miles. Approximately 3,058 acres (nearly 80 percent of the watershed) is within Portland's city limits. The remaining watershed area is within the jurisdictions of Multnomah County, Clackamas County, and the City of Lake Oswego.

The Tryon Creek Watershed is divided into three subwatersheds: Tryon Creek mainstem, Arnold Creek, and Falling Creek:

- The **Tryon Creek mainstem** is about seven miles long and flows southeast from its headwaters near Multnomah Village (just north of Interstate 5 and Highway 99) to its confluence with the Willamette River in Lake Oswego at the Highway 43 crossing. The Tryon Creek mainstem subwatershed comprises about 3,083 acres.

- Arnold Creek joins Tryon Creek at the SW Boones Ferry Road crossing. The Arnold Creek subwatershed comprises about 775 acres.

- Falling Creek joins Tryon Creek at SW 26th Avenue and Taylors Ferry Road. The Falling Creek subwatershed comprises about 283 acres.

Other smaller tributaries flow into Tryon Creek both within and outside Portland's city limits.

HISTORIC CONDITIONS

The historic hydrology of Tryon Creek and its tributaries was typical of low to moderate gradient Willamette Valley headwater streams with steep landscape slopes. The annual hydrograph reflected the climatic precipitation pattern, with an extended wet period exhibiting higher flows and frequent storm flow events from approximately October through May, followed by a dry summer season with low flows from June through September. Stream flows during the summer low-flow period were dominated by groundwater recharge to the streams. The topography,

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* Refer to Chapter 2: Tryon Creek Watershed Overview, for additional description and maps.

including steep slopes, and the native soil characteristics, which limited infiltration, contributed to a rapid response of flows to storm events and moderate runoff volume. This response was moderated by the native vegetation, including a mature forest with a surficial forest duff layer, that provided precipitation storage (May et al. 1997). Topographic features confined many of the headwater tributary stream channels, with lower reaches of the streams exhibiting more meandering and interaction with the floodplain (e.g., lower Tryon Creek mainstem within Tryon Creek State Natural Area).

LANDSCAPE FACTORS

Landscape factors are broad-scale influences such as climate, rainfall/precipitation, topography, geology, and soils that play a major role in determining the structure, dynamics, and function of a watershed. Landscape factors set constraints on, and can be a determining factor in, the form and function of a watershed (City of Portland 2004).

Climate

The climate in the Tryon Creek Watershed is classified as Mediterranean, characterized by mild winters with prolonged winter rainfall and cool, dry summers. Temperatures range from 25 to 45 degrees Fahrenheit (^{o} F) in the winter and from 70 to 90 degrees Fahrenheit (^{o} F) in the summer (Johnson 1987).

Rainfall/Precipitation

Rainfall data are available from the Bureau of Environmental Services' (BES) Hydrologic Data and Acquisition (HYDRA) system, which collects five-minute rainfall data from rain gages located throughout the City of Portland, including the Tryon Creek Watershed. Table 4-1 summarizes the seasonal frequency of rainfall events. Table 4-2 shows the average seasonal and annual rainfall amounts for the three operational rainfall gages in or near the Tryon Creek Watershed. Figure 4-1 shows the average annual precipitation by month.

Table 4-1
Annual Average Rainfall at PCC Sylvania Campus (PCC)[1] and Portland International Airport (PDX)[2]

Characteristic	**Winter (November through May)**		**Summer (June through October)**		**Annual**	
Station	***PCC***	***PDX***	***PCC***	***PDX***	***PCC***	***PDX***
Rainfall, days per season or year	98	101	42	48	140	149
Rainfall depth, inches per season or year	**25.7**	**27.7**	**9.5**	**9.7**	**35.2**	**37.4**
Rain events per season or year	36	37	24	25	60	62
Volume per event, inches	0.74	0.75	0.38	0.39	0.59	0.61
Peak intensity, inches per hour	0.094	0.095	0.091	0.092	0.093	0.094
Duration per event, hours	40	45	20	24	34	36
Dry time between storms, hours	75	74	155	154	107	106

[1] PCC period of record, 1976-1998; Source: HYDRA system data compiled by the BES Modeling Group.

[2] PDX period of record, 1946-1991; Source: Combined Sewer Overflow Management Plan; Characterization Report; CH2M Hill, December 1992;

TABLE 4-2

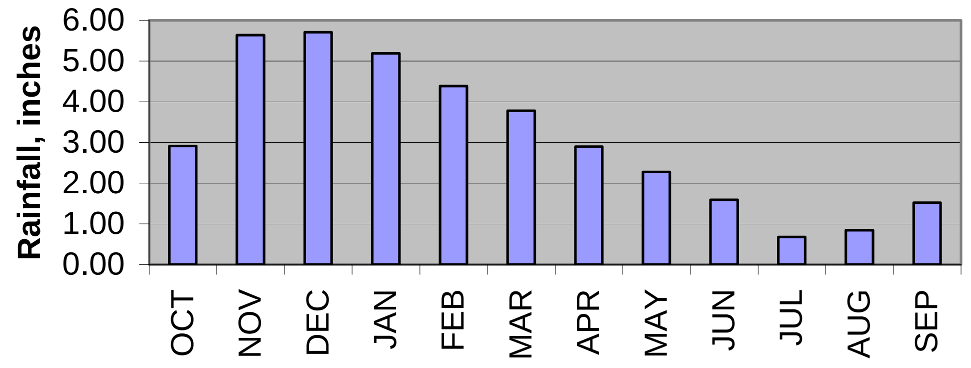
Annual Average Rainfall

(Rainfall depth, inches per season or year)

Gage Station	Winter (November through May)	Summer (June through October)	Annual
Vermont Hills	32.46	9.81	42.26
Collins	31.63	10.47	42.11
Sylvania	31.47	9.77	42.13
AVERAGE	**31.85**	**10.02**	**42.17**

Note: Period of record, 1995-2002.

Figure 4-1
Average Monthly Rainfall



Source: BES Modeling Group

The rainfall monitoring results show the pattern typical of the Mediterranean-type climate. The average annual precipitation is 42.17 inches, with 76 percent (31.85 inches) of the precipitation occurring during the winter season and only 24 percent (10.02 inches) occurring during the summer season. The summer season typically has extended periods without any precipitation, with both July and August averaging less then one inch of rain.

The monitoring results also show fairly uniform rainfall amounts over the region. However, localized variability in precipitation patterns could be expected, based on orographic effects (i.e. increased precipitation at higher elevation in the watershed).

The annual rainfall pattern strongly influences stream flow regimes in the watershed, particularly the low flows that are characteristic during the late summer.

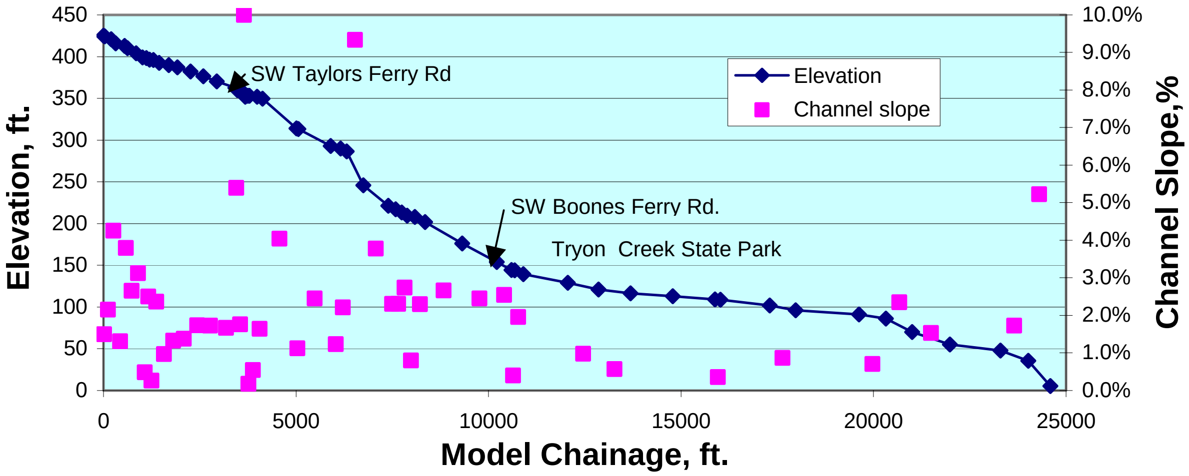
Topography

Topography (elevation) in the Tryon Creek Watershed varies from near mean sea level (msl) to 970 feet above msl. The lowest point in the watershed, about 10 feet above msl, is the confluence of Tryon Creek with the Willamette River; the highest point is at the top of Mt. Sylvania (BES 1997). Approximately 60 to 75 percent of the slopes within the watershed exceed a 30 percent grade (BES 1997). Some slopes exceed 50 percent grade, especially in the upper watershed (Map 9-Tryon Creek Contour Map, Map Atlas). The *Southwest Hills Resource Protection Plan* (Bureau of Planning 1992) classifies slopes in excess of 30 percent grade as generally having "severe landslide potential." Prominent topographic features in the Tryon Creek Watershed are the Palatine Hills, Portland's West Hills, and Mt. Sylvania.

Stream Profiles

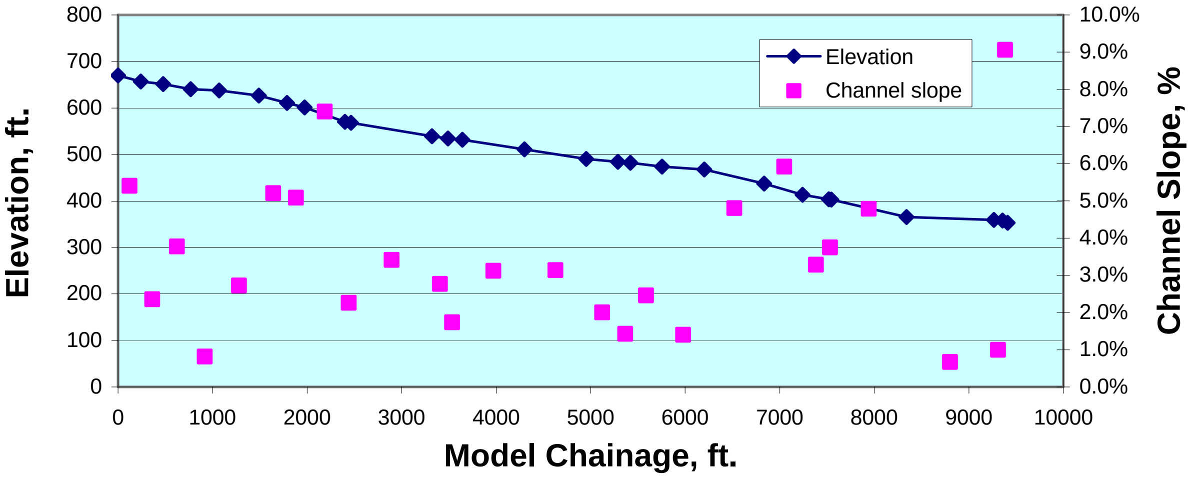
Figures 4-2, 4-3, and 4-4 show the modeled stream profile and channel slopes for Tryon, Falling, and Arnold Creeks, respectively.

Figure 4-2
Modeled Stream Profile and Channel Slopes for Tryon Creek



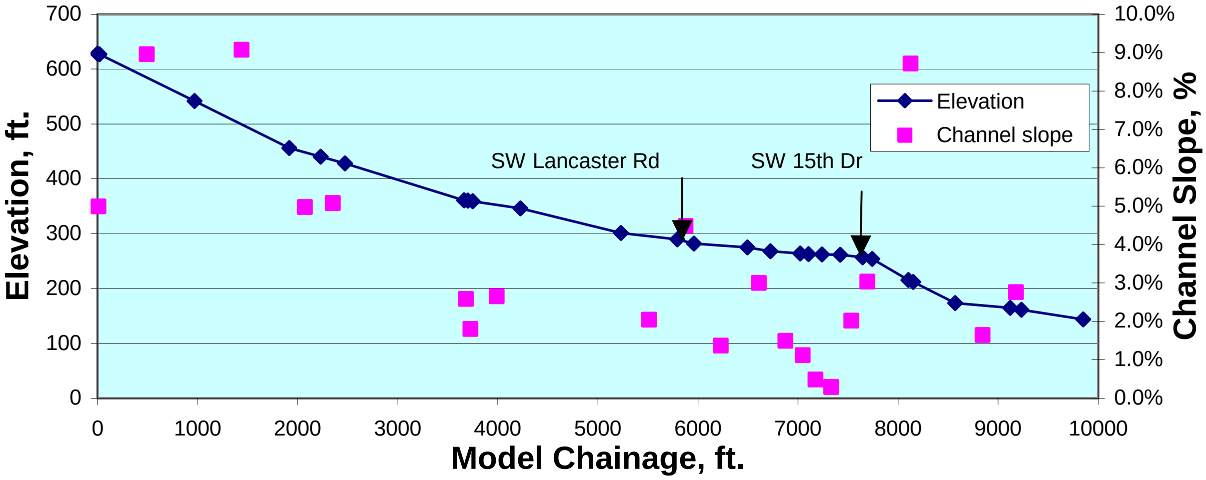
As shown in Figure 4-2, Tryon Creek upstream from SW Boones Ferry Road has a low to moderate gradient (average 2.3 percent slope). Downstream from SW Boones Ferry Road, within Tryon Creek State Natural Area, the stream slope flattens to a low gradient (average 0.7 percent slope); this approximately 1.8-mile reach of Tryon Creek is a potential depositional area for silt and sediments transported from the upper watershed. Downstream of the Tryon Creek State Natural Area, the stream slope increases back to a low to moderate gradient (average 2.3 percent slope). Further downstream, below State Street, there is another grade break, and Tryon Creek has moderate to steep gradients before it discharges into the Willamette River.

Figure 4-3
Modeled Stream Profile and Channel Slopes for Falling Creek



As shown in Figure 4-3, Falling Creek has a fairly uniform moderate gradient (average 3.4 percent slope).

Figure 4-4
Modeled Stream Profile and Channel Slopes for Arnold Creek



As shown in Figure 4-4, Arnold Creek has a moderate gradient stream (average 3.4 percent slope), with some moderate to steep reaches both in the upper headwaters and near the confluence with Tryon Creek.

Soils

The U.S. Geological Survey (USGS) Soil Survey Manual for Multnomah County shows the predominant soil classification in the Tryon Creek Watershed to be the Cascade series. The Cascade series is a moderately deep, poorly draining soil consisting primarily of dark brown silty loam. The percentage of Cascade soils in the three subwatersheds ranges from 80 to 96 percent. The remaining soils are made up of the Cornelius, Delena, Sifton, and Dabney series.

A fragipan layer exists throughout the Cascade series soils at a depth of 20 to 30 inches below the ground surface. This layer consists of a subsurface horizon of low porosity that is low in clays but high in silt or very fine sands, forming what appears to be a cemented layer that restricts root formation and infiltration. The fragipan layer ranges in thickness from two to four feet. When dry, the fragipan layer is very hard and dense. When wet, it tends to rupture suddenly under pressure. (U.S. Dept of Agriculture, 1983)

During the summer months, the Cascade soils can be dry to a depth of 4 to 12 inches, for up to 60 consecutive days. As a result of this dryness, the ground is hard and can act as an impervious surface, particularly for low-intensity, short-duration summer storms. In areas of relatively undisturbed soils, the permeability is slow, and available water capacity is between five and eight inches. In the months from December to April, the Cascade soils tend to have a water table at a depth of approximately 30 inches. The water table is typically perched on the fragipan layer. Depending on its location relative to the surface, the perched water table reduces the storage capacity of the soils, increasing the volume of runoff to the stormwater system during the winter season.

The Cascade series is further separated in two categories: Cascade silt loam and Cascade urban land complex. The Cascade soils in the developed portion of the upper watershed are classified primarily as the urban land complex. The Cascade silt loam is primarily native material, while the Cascade urban land complex consists of areas that are disrupted by urban development. These categories within the series are further subdivided based on land slope, with higher slopes having higher rates of runoff and erosion potential. The Cascade urban land complex is the predominant soil classification in the Tryon Creek Watershed.

The Delena soils are predominantly along the stream corridors and flat slope areas of the basin. These soils are also poorly drained and predominantly silty soils. The Delena soils make up the boundary surfaces of the streams and influence the streams' stability.

The remaining soils (Cornelius, Sifton, Dabney, and others) have minimal effect because of their limited distribution and area within the watershed.

Figures 4-5, 4-6, and 4-7 show the percentages of soil classifications in the Tryon Creek, Falling Creek, and Arnold Creek subwatersheds, respectively. (See Map 6-Tryon Creek Soil Maps by subwatershed, in the Map Atlas)

Figure 4-5
Tryon Creek Soils

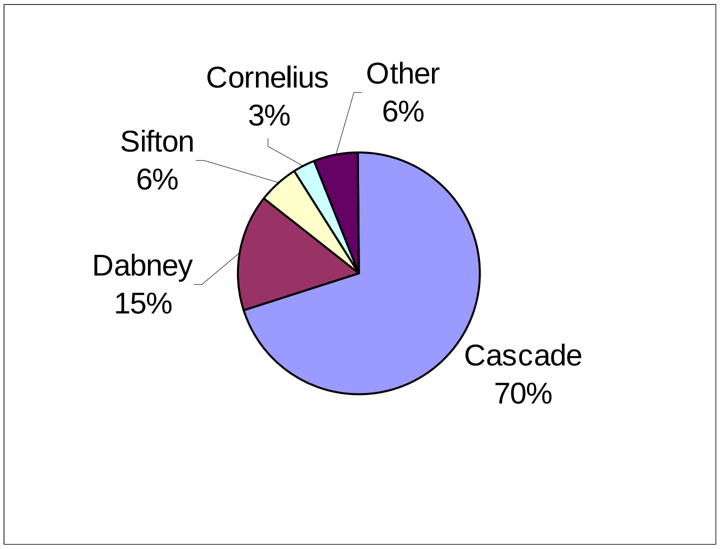


Figure 4-6
Falling Creek Soils

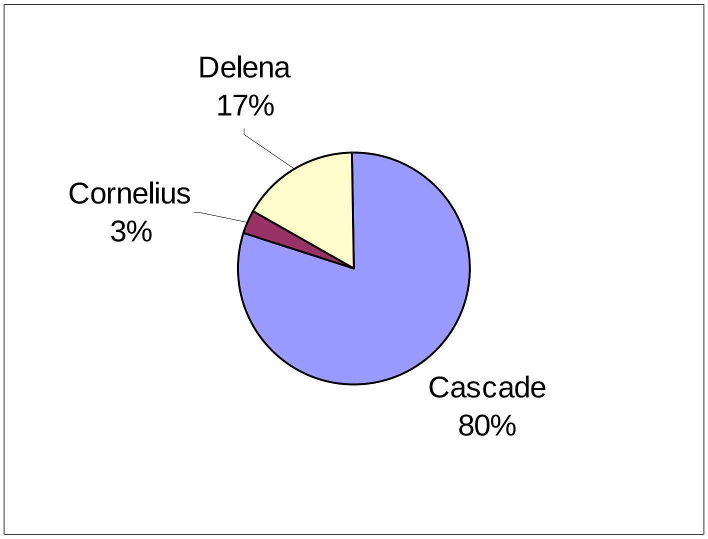
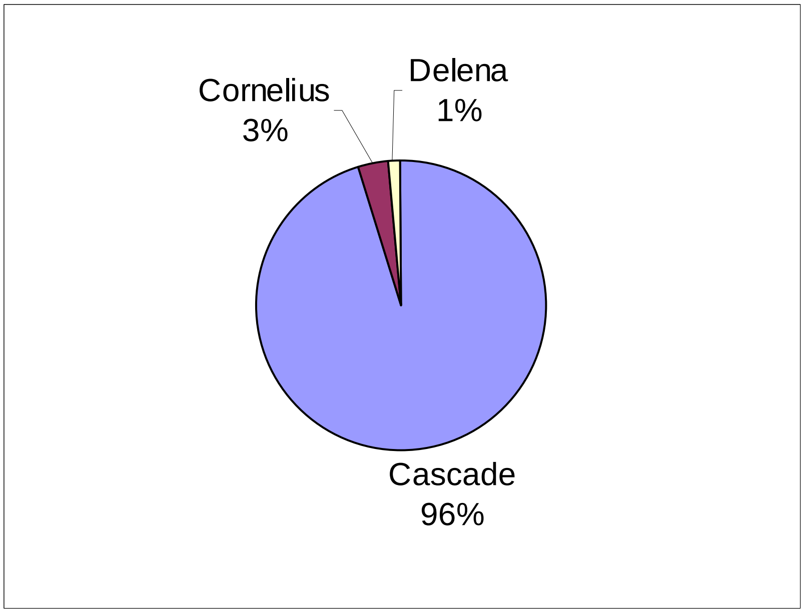


Figure 4-7
Arnold Creek Soils



HUMAN INFLUENCES

Land Use

Land use is a general indicator of the types of human and urban activities present in the watershed. Impacts from land use changes can include increased impervious area, alteration of natural flow patterns through development of urban infrastructure, and increased pollutant loads.

The predominant existing land use within the Tryon Creek watershed is single-family residential development (76 percent). Parks and open space are the second-largest land use, largely because of Tryon Creek State Natural Area (630 acres). The remaining commercial and multi-family residential land uses are concentrated along major transportation corridors, including Interstate 5 and SW Barbur Boulevard.

Figure 4-8 and Table 4-3 show land uses and associated coverage areas, based on current zoning adopted in the *Southwest Community Plan* (Bureau of Planning 2001).

Figure 4-8
Tryon Creek Watershed
Existing Zoning

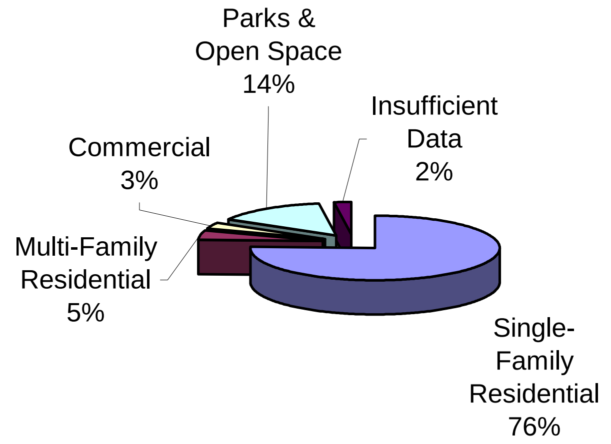


Table 4-3
Tryon Watershed Land Use Zoning

Land Use Category	Falling Creek Subwatershed		Arnold Creek Subwatershed		Tryon Creek Subwatershed		Outside City		Tryon Creek Watershed	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
Commercial	7	2%	0	0%	120	5%	7	1%	134	3%
Multi-family Residential	43	15%	0	0%	142	6%	5	1%	191	5%
Parks/Open Space	37	13%	54	8%	502	23%	0	0%	593	14%
Single-family Residential	197	69%	629	92%	1,463	66%	845	89%	3,134	76%
Insufficient Data	0	0%	0	0%	0	0%	92	10%	92	2%
Totals	**284**		**683**		**2,227**		**949**		**4,142**	**100%**

Figures 4-9, 4-10, and 4-11 show the percentage of tax lots built on between 1910 and 2003 in the Falling Creek, Arnold Creek, and Tryon Creek subwatersheds, respectively. Development within the Tryon Creek subwatershed began in the early 1900s, with increased activity in the 1950s. Development in the Falling Creek and Arnold Creek subwatersheds is more recent, with most development occurring after 1970. This is reflected in the average age of development in the three subwatersheds: Tryon Creek (43 years old), Falling Creek (34 years old), and Arnold Creek (26 years old).

It is estimated that the watershed is currently 80 percent "built out," based on tax lot data and the amount of vacant land in the watershed, as summarized in Table 4-4. Future growth will probably occur by in-filling of vacant land or minor parceling of large existing occupied lots, rather than by large land development projects. Based on the extent and age of development within the watershed, it would be expected that some impacts from construction and urbanization within the watershed have stabilized.

Figure 4-9
Tax Lots Built on in Falling Creek Subwatershed

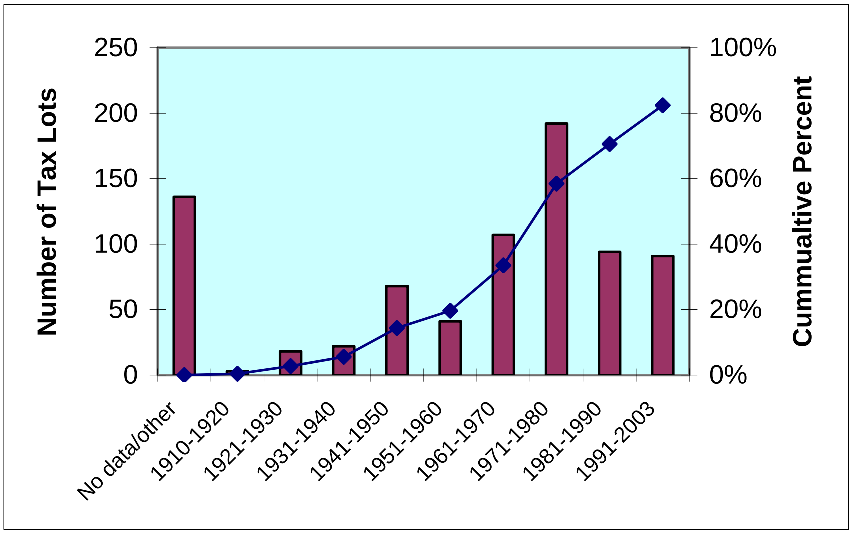


Figure 4-10
Tax Lots Built on in Arnold Creek Subwatershed

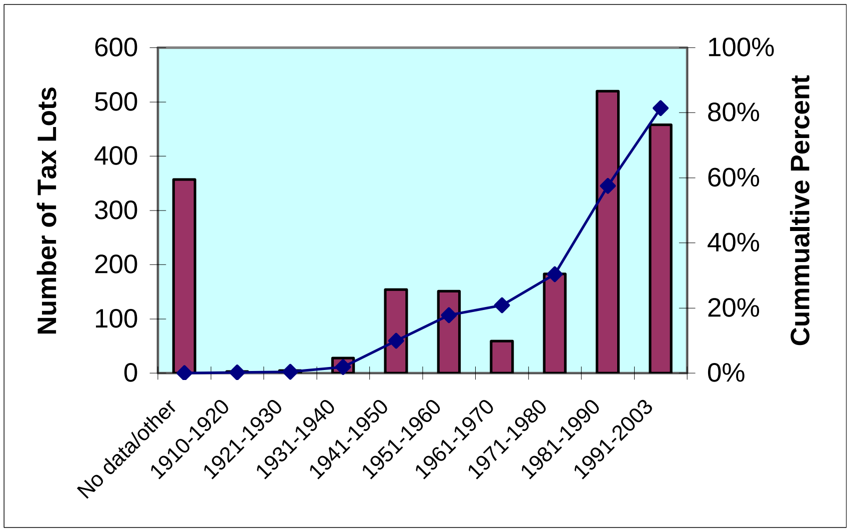


Figure 4-11
Tax Lots Built on in Tryon Creek Subwatershed

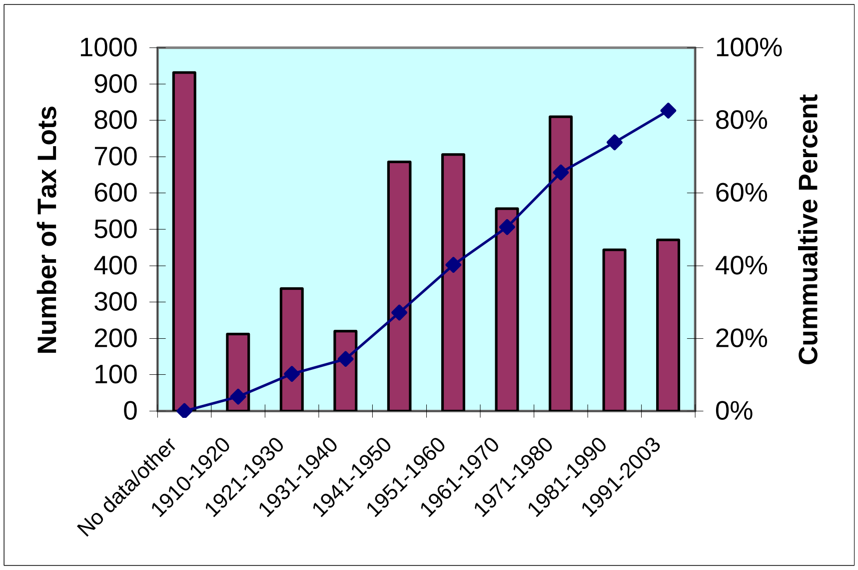


Table 4-4
Vacant Land in Tryon Creek Watershed

Subwatershed	**Area, acres**		**Percent Vacant**
	Vacant	***Total***	
Arnold Creek	152	775	19.6
Falling Creek	18	283	6.5
Tryon Creek	445	3,083	14.4
Total	**616**	**4,141**	**14.9**

In addition to land use designations, Portland has established environmental overlay zones to protect and conserve significant natural resources. The environmental overlay zones are based on extensive natural resource inventories that cover areas within the city. The environmental zoning program is also the City's primary tool for complying with State Land Use Planning Goal 5 to protect significant natural resources.

There are two types of environmental overlay zones, which currently affect approximately 1,017 acres in the Tryon Creek Watershed. **Protection (P) zones** have been established in areas that have very high-value resources and functional values. Development is approved in the protection zone only in very limited circumstances. Within **conservation (C) zones**, development is allowed if it meets certain standards and approval criteria to ensure that impacts on significant resources are avoided, limited, and mitigated.

Environmental overlay zones encompass many of the existing stream channels and riparian areas within the watershed and therefore serve to protect the natural hydrologic processes.
Table 4-5 summarizes environmental overlay zone coverage. (Also see Map 5-Tryon Creek Current Plan by subwatershed in the Map Atlas).

Table 4-5
Environmental Zone Coverage in Tryon Creek Watershed

Subwatershed	**C zone (acres)**	**P zone (acres)**	**Total E zones (acres)**	**Subwatershed Area (acres)**	**Percentage of Subwatershed**
Tryon Creek Mainstem	237.0	499.6	736.6	3,083.7	23.9
Arnold Creek	211.4	47.6	259.1	775.2	33.4
Falling Creek	17.6	4.2	21.7	283.6	7.7
Total (Watershed)	**466.0**	**551.4**	**1,017.4**	**4,142.3**	**24.6**

Impervious Area

One of the most pervasive and obvious changes to the natural system as the result of urbanization is an increase in impervious cover and a corresponding loss of natural vegetation (May et al. 1997). The increase of impervious area includes the construction of roads, parking lots, driveways, sidewalks, and rooftops, along with compaction of native soils. The effect of this increased impervious area is to alter the natural hydrologic cycle by changing flow paths, increasing runoff, and decreasing infiltration. These changes subsequently drive many of the physical and biological responses that affect urban streams.

The total impervious area in a watershed is often used as a measure of urbanization and corresponding effects on watershed health (Schueler 1994; Arnold and Gibbons 1996). Research on urban streams has shown that significant impairment of stream ecosystems (including hydrologic factors) begins when total impervious area in a watershed reaches a threshold of approximately 10 percent. A second threshold appears at about 25-30 percent total impervious area, when most indicators of stream health shift to a poor condition (Schueler 1994; SMRC 2004).

The Center for Watershed Protection has developed the impervious cover model, which classifies urban stream ecological health based on total impervious area (SMRC 2004). Stream classifications, with key associated hydrologic factors, are summarized below:

- Sensitive Streams (0-10 percent total impervious area): These streams are generally characterized by stable channels and do not exhibit frequent flooding and other hydrological changes resulting from urbanization.

- Impacted Streams (11-25 percent total impervious area): These streams have elevated storm flows that begin to alter stream geometry. Erosion and channel widening are evident, and streambanks become unstable.

- Non-Supporting Streams (more than 25 percent total impervious area): These streams exhibit highly unstable stream channels, with many reaches with severe widening, downcutting, and streambank erosion.

Table 4-6 summarizes total impervious area for the Tryon Creek Watershed and tributary subwatersheds. The average total impervious area for the Tryon Creek Watershed is 24.0 percent. Subwatershed total impervious areas range from 22.6 to 37.3 percent. Based on the impervious cover model described above, these streams would be classified as either impacted or non-supporting streams.

The actual effects from impervious areas would be expected to vary within the watershed, based on a combination of other related factors, including localized impervious area percentages, land slope, location relative to the stream, the stormwater conveyance system, and any implementation of onsite stormwater control measures. In the Tryon Creek Watershed, several of these factors have a significant influence. The areas with the highest percentage of impervious area tend to be concentrated in the upper watershed, therefore, they effect hydrology throughout the mainstem of Tryon Creek. Also, the effects of impervious area may be moderated because the "effective impervious area" (i.e., the impervious area directly connected to the stream or storm conveyance system) is estimated to be lower than the total impervious area. (See GIS Analysis). Still, most streams within the watershed have reaches that exhibit characteristics of impacted or non-supporting streams (increased storm flows, unstable streambanks, downcutting, and streambank erosion).

Table 4-6
Tryon Creek Watershed Impervious Area

Subwatershed	Impervious Area (Acres)	Subwatershed Area (Acres)	Percentage of Subwatershed
Tryon Creek Mainstem*	696.1	3,083.7	22.6
Arnold Creek	192.9	775.2	24.9
Falling Creek	105.9	283.6	37.3
Total (Watershed)	**994.9**	**4,142.3**	**24.0**

* If Tryon Creek State Natural Area (631 acres) is removed from the calculation, impervious area in Tryon Creek mainstem is 28.4 percent.

Infrastructure

Stormwater System

Along with the increase of impervious areas through urbanization, the construction of urban stormwater drainage systems is a major factor impacting the hydrology of urban streams. These drainage systems invariably increase the drainage density of the subcatchment and reduce the time necessary for overland flow to reach the stream. This results in faster runoff and higher stream velocities, along with higher and "flashier" flood flows (Hollis 1975).

The construction of the urban stormwater system also typically results in the loss of small headwater streams that are critically important to watershed health. Small intact streams provide natural flood control, recharge groundwater, trap sediments and pollution from fertilizers, recycle nutrients, create and maintain biological diversity, and sustain the biological productivity of downstream rivers, lakes, and estuaries (Moyers et al. 2003).

The construction of the stormwater system in the Tryon Creek Watershed has followed the development pattern within the watershed. Stormwater systems have been constructed as required to convey stormwater from constructed impervious surfaces, redirect natural flow paths to allow for construction of structures, and convey stormwater for roads and streets. The highest density of stormwater infrastructure is typically located in the upper portions of the subwatersheds. The stormwater systems are typically small systems that provide for localized drainage, with discharge to the local stream systems for further conveyance.

Culverts are another major element of the stormwater conveyance system in the Tryon Creek Watershed. Culverts are typically located at all roadway stream crossings in the watershed. Also private culverts are a common element of the local stormwater systems. In addition to protecting public health and property by conveying flood flows, the culverts often act as hydraulic controls and modify the natural hydraulic response of the stream systems, especially during storm events.

A major infrastructure impact on the hydrology within the Tryon Creek Watershed occurred with the construction of both Barbur Boulevard and the I-5 Freeway in the upper watershed. Both of these transportation corridors directly crossed Tryon Creek. During construction, portions of Tryon Creek were piped and rerouted with the natural creek channel eliminated. In addition, the natural drainage along the entire length of these transportation corridors was modified and replaced with a system of local culverts and storm drainage systems.

Sanitary Sewer System

The Tryon Creek sanitary sewer system conveys sewage from within the watershed to the Tryon Creek Wastewater Treatment Plant (TCWTP) located near the mouth of Tryon Creek for treatment and eventual discharge to the Willamette River. There are three primary sanitary sewer lines in the system: the Tryon Creek sanitary trunk, the Falling Creek collector, and the Arnold Creek collector.

The Tryon Creek sanitary trunk is the primary north-south conveyance line servicing the basin, ranging in size from 18-30 inches in diameter and also conveys some sanitary flows from the Fanno Creek watershed. The lower basin trunk, within the Tryon Creek Watershed begins at SW 31st Avenue and SW Multnomah and generally follows the natural drainage of Tryon Creek until it terminates at the TCWTP. The Tryon trunk collects flow from two major pipelines along its alignment: the Falling Creek and Arnold Creek collectors.

The Falling Creek collector ranges in size from 10 to 12 inches in diameter beginning south of I-5 and following the alignment of Falling Creek until joining the main trunk line at SW Taylors Ferry Road and SW Spring Garden Road.

The Arnold Creek collector ranges in size from 10 to 15 inches in diameter and runs along SW Arnold Street until it joins the main trunk at SW Arnold Street and SW Boones Ferry Road.

The sewerage system throughout the watershed is a gravity system constructed of concrete pipe. Because of the operating requirements of the gravity sewerage system and the watershed topography, the sanitary sewer pipes are often located within stream corridors, with numerous stream crossings. (See Map 10-Tryon Creek Existing Sanitary System Map in the Map Atlas).

The proximity of the sewers to the streams can also have impacts on the stream hydrology related to construction and maintenance. Studies have shown that installing sewers and other utilities in the riparian zone can alter groundwater flow patterns and the interaction of the stream with the saturated zone. Required maintenance or reconstruction of these sewers can also impact hydrology without proper mitigation measures. This will be an increasingly important issue within the Tryon Creek Watershed, as the aging sewer infrastructure requires more frequent maintenance. Breaks or blockages of the existing sewer lines can cause sewage to discharge directly to the streams.

GAGED STREAM FLOWS

Continuous stream flow data for the Tryon Creek Watershed are limited. Through a cooperative agreement with BES, the USGS has maintained a stream flow monitoring station on Tryon Creek near Nettle Creek since August 2001.

Figures 4-12 and 4-13 show the annual hydrographs for Tryon Creek near Nettle Creek for the 2002 and 2003 water years. The hydrographs show the typical pattern for the streams in the Tryon Creek Watershed, with an extended wet period with frequent higher flows from October through the end of May, followed by a dry summer period of lower flows. Winter season base flow is approximately 10 cubic feet per second (cfs) with summer base flow declining to approximately 1 cfs

These figures also show the response of the watershed to rainfall events, with rapid changes in flows evident. Average daily flows during winter storm events ranged from 60 to 120 cfs with average daily flows during summer storm events generally less than 20 cfs. This "flashy" response to rainfall is even more evident when looking at recorded instantaneous peak flow rates which can be much higher than the daily average flow for the watershed. Peak instantaneous flows of 340 and 447 cfs were recorded for Water Years 2002 and 2003, respectively. These flows represent an increase in flow of 30 to 40 times of base flow.

Figure 4-12
Tryon Creek Water Year 2002
(near Nettle Creek)

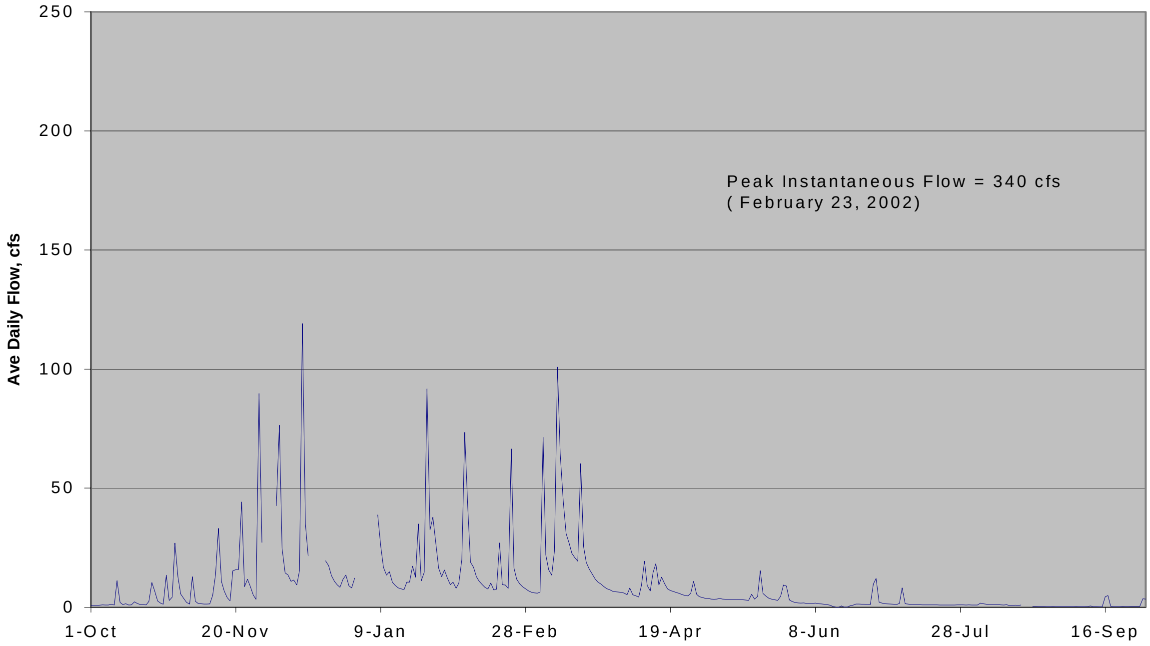


Figure 4-13
Tryon Creek Water Year 2003
(near Nettle Creek)

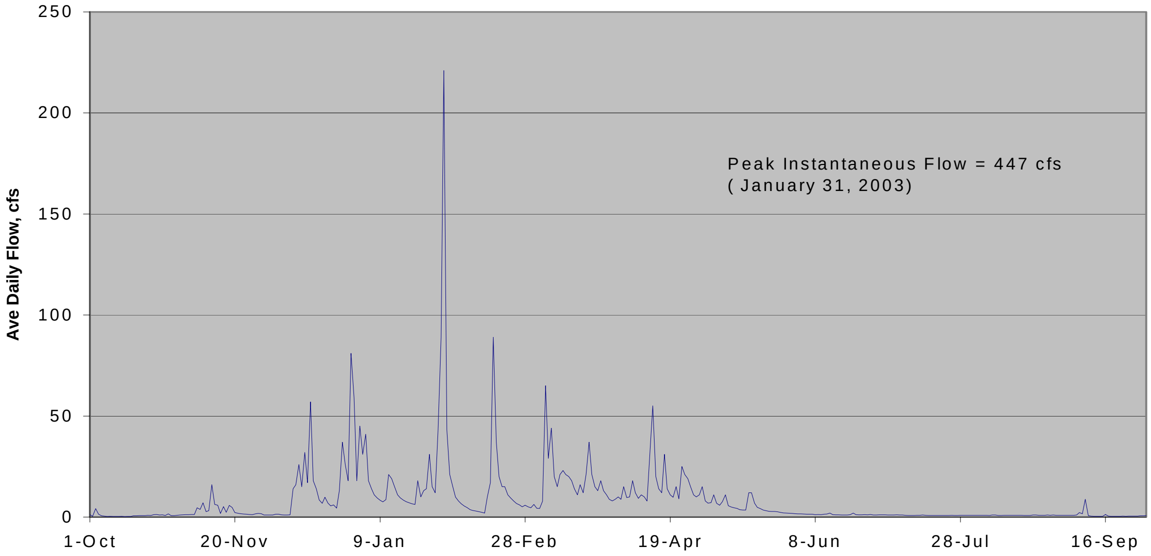


Figure 4-14 shows a flow duration curve for Tryon Creek (near Nettle Creek in the lower watershed) based on two years of flow gaging at this location. The flow duration curve shows the probability of exceeding any given flow. The curve is further divided into five flow regions: high flows, wet conditions, transition flows, dry conditions, and low flows. The curve indicates the two base flow conditions previously described of approximated 10 cfs (generally during the winter) and approximately 1 cfs (generally during the summer). It also shows the relatively infrequent but very high flows resulting from rainfall storm events as well as infrequent low flows which have been measured as less than 1 cfs during summer dry periods.

The flow duration curve and analysis when combined with associated water quality data can be very useful in understanding the relationship between stream flow and water quality and the development of management strategies.

Figure 4-14
Flow Duration Curve for Tryon Creek near Nettle Creek
USGS Gage 14211315 (10-01-01 to 9-30-03)

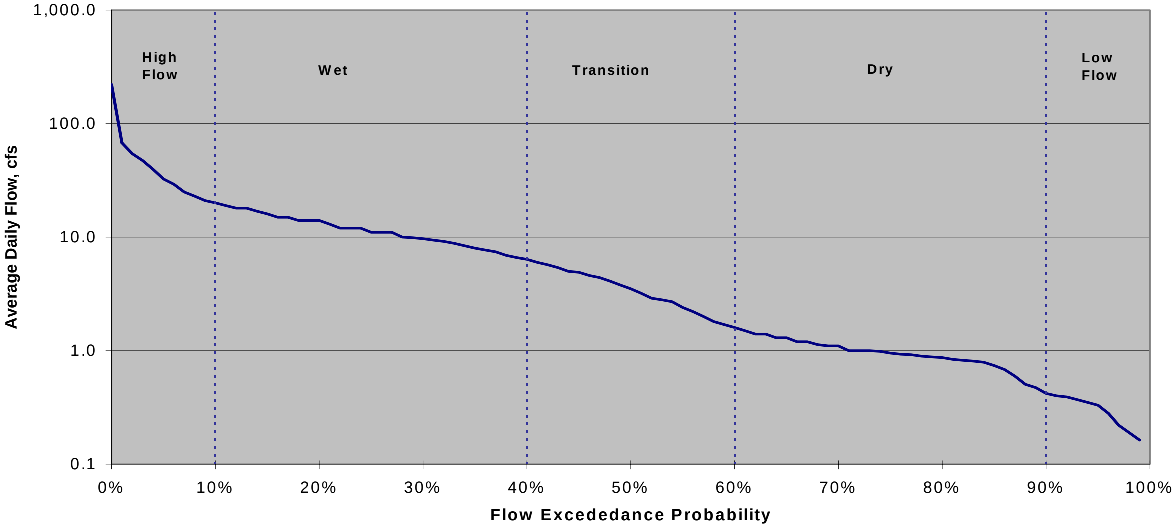
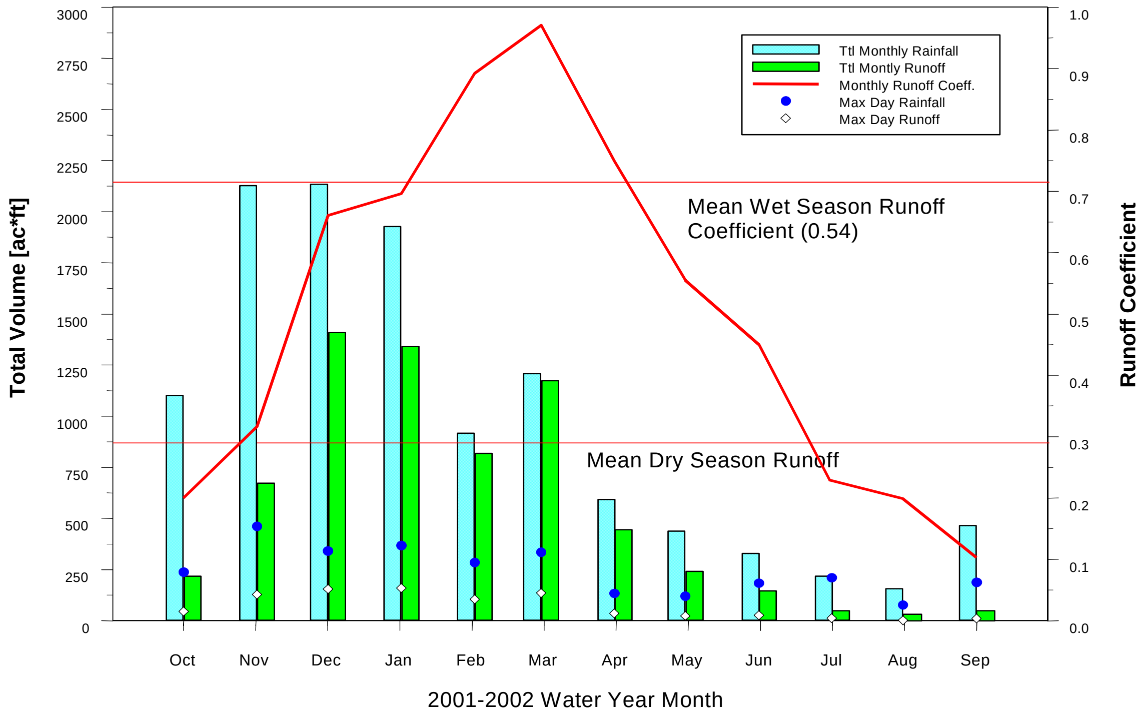


Figure 4-15 shows mean monthly rainfall and runoff volumes for the USGS Tryon Creek gage location. The figure also shows the monthly runoff coefficient (runoff volume/rainfall volume). The mean monthly volumes for both rainfall and runoff show the same general annual pattern as described above. Based on the monthly runoff coefficient, however, there appear to be significant differences in hydrologic response during different periods of the year. During the early part of the wet season, starting in September, the runoff coefficient is low, with only about 10-20 percent of the rainfall recorded as runoff. The percentage of runoff then steadily increases during the wet season until about March, when the runoff coefficient peaks at about 90 percent. This is followed by a decrease in the runoff coefficient throughout the summer dry season. It is hypothesized that this lag in system response at the beginning of the wet season is caused by a recharge of the shallow groundwater (soil profile) until it reaches saturation, along with possible higher rates of interception by deciduous vegetation and trees prior to leaf fall.

Figure 4-15
Tryon Creek Watershed Drainage for USGS Stream Gage below Nettle Creek
2001-2002 Water Year



Stream gaging data are not available for other subwatersheds within the Tryon Creek Watershed. Based on model results and observations, however, yearly stream hydrograph patterns and response to storm events would be expected to be similar. Flow magnitudes would be different, based on the drainage areas of the other subwatersheds.

CURRENT HYDROLOGIC ASSESSMENT

To support development of the Tryon Creek Watershed Plan, BES selected the Danish Hydraulics Institute’s (DHI) MIKE SHE and MIKE 11 models to perform additional hydrologic modeling of the watershed. The MIKE SHE and MIKE 11 models are integrated surface and groundwater models that simulate hydrologic, hydraulic, upland pollutant loading, and instream processes within a watershed. The MIKE models can simulate continuous rainfall events to generate seasonal and annual flows

The MIKE SHE model is a physically based, dynamic, fully distributed hydrologic model that simulates all major hydrological processes occurring in the land phase of the hydrologic cycle. Modeled hydrologic components include interception-evapotranspiration, infiltration, snow melt, overland flow, subsurface flow, groundwater flow, and stream-aquifer exchange.

Runoff flows generated by the MIKE SHE model are input into the MIKE 11model for routing through the modeled stormwater conveyance and stream system. The MIKE 11 model is a dynamic one-dimensional hydraulic model.

The MIKE SHE and MIKE 11 models are based on a grid system, where each model area is divided into a network of square grids. For the Tryon Creek Watershed, a constant 100-foot-square grid size was used, based on basin characteristics and computational constraints of the models.

Separate MIKE SHE and MIKE 11 models were developed for the major drainage subwatersheds in the Tryon Creek watershed: Tryon Creek mainstem, Falling Creek, and Arnold Creek. The models were calibrated and run for two basic model scenarios:

- An evaluation of subwatershed hydrology, using a continuous rainfall record developed for a “typical year,” based on an analysis of actual rainfall recorded in the watershed.
- An evaluation of the capacity of the existing drainage system to convey stormwater, using design storms with recurrence intervals of 2, 10, 25, and 100 years.

The technical memoranda at the end of this report provide a detailed description of how the MIKE models were developed and used for this project.

Modeling Results

Table 4-7 shows design storm flows for Tryon Creek at Boones Ferry Road.

Table 4-7
Design Storm Flow Results for Tryon Creek Basin Model

			Tryon Creek Gage at Boones Ferry Road Basin Area = 4,290 acres				
Storm Event	**Date**	**Rainfall (in.)**	**Modeled Peak Flow (cfs)**	**Rainfall Volume (M gal.)**	**Total Model Flow Volume (M gal.)**	**Modeled Flow Vol. per Acre (M gal./ac.)**	**Runoff Coefficient**
2-yr	12/1- 12/2/96	2.53	290.5	294.7	160.9	0.038	0.54
10-yr	12/1- 12/2/96	3.36	465.1	391.4	219.4	0.051	0.56
25-yr	12/1- 12/2/96	3.84	587.0	447.3	305.0	0.071	0.68
100-yr	12/1- 12/2/96	4.49	762.1	523.1	362.5	0.084	0.69

The Mike SHE and MIKE 11 models were also used to evaluate the capacity of the drainage system to convey stormwater under existing land use conditions. The evaluation was based on criteria in the City of Portland's Sewer Design Manual (BES 1991). A brief synopsis from the manual follows:

> All storm drainage facilities shall be designed to pass a 10-year storm without surcharge. Surcharging during a 25-year storm is permitted with a "stormwater only" system. Surcharged pipes and bankfull channels are acceptable for conveyance of the 100-year design storm provided that several health and safety conditions are met. The allowable headwater depth for culverts should be as great as practical, as long as it does not compromise safety, flood plain regulations, environmental considerations or property rights.

In general, the City designs a culvert or storm drainpipe to convey the 25-year flow without surcharge.

Table 4-8 summarizes the capacity deficiencies identified by the modeling evaluation.

Table 4-8
Summary of Capacity Deficiencies

Subwatershed	**Number of Culverts Modeled**	**Number and Percentage of Culverts Surcharged under 2-yr & 10-yr Storm**	**Number and Percentage of Culverts Expected To Have Roadway Flooding Problems**	**Number of Storm Pipes Modeled**	**Number and Percentage of Storm Pipes Surcharged under 2-yr & 10-yr Storm**
Arnold Creek	12	12 (100%)	4 (33%)	6	5 (83%)
Falling Creek	16	14 (88%)	10 (62%)	2	2(100%)
Nettle Creek	5	9 (1%)	0 (0%)	0	0 (0%)
Tryon Mainstem	31	21 (68%)	6 (19%)	13	12(92%)

The capacity analysis indicates that most of the modeled culverts in the watershed have some surcharging for storms with a 10-year or less return frequency. A much smaller percentage of the modeled culverts were expected to have roadway flooding problems (defined as water depth exceeding the roadway elevation for a 10-yr return frequency storm. Most of the modeled pipes in the watershed were surcharged for storms with a 10-year or less return frequency.

GIS Analysis

A GIS analysis, using the 100-foot by 100-foot grid system established for the MIKE SHE/MIKE 11 modeling, was performed to evaluate three indicators of human influence on hydrology: impervious area, zoning, and the stormwater system (ratio of piped storm infrastructure to open channels). To perform the analysis, the Tryon Creek watershed was first divided into 18 major drainage subcatchments based on topography and modeled stream segments (e.g. TRY329, TRY258, etc.), as shown in Figure 4-14. After an initial review of the GIS analysis results, these subcatchments were recombined into three major drainage areas within the watershed, which exhibited significant differences as follows:

- Drainage Area 1 – This area includes the upper two subcatchments,TRY329 (Falling Creek) and TRY258, which drain the areas upstream from SW Taylors Ferry Road.
- Drainage Area 2 – This area includes all the subcatchments between SW Taylors Ferry Road and SW Boones Ferry Road. This drainage area includes the Arnold Creek tributary.
- Drainage Area 3 – This area includes all the subcatchments downstream of SW Boones Ferry Road and includes the area within Tryon Creek State Natural Area as well as significant area outside the City of Portland.

The results of the GIS analysis for each subcatchment and the three major drainage areas described above are summarized in Table 4-9.

Figure 4-14
Tryon Creek Watershed Modeled Subcatchments

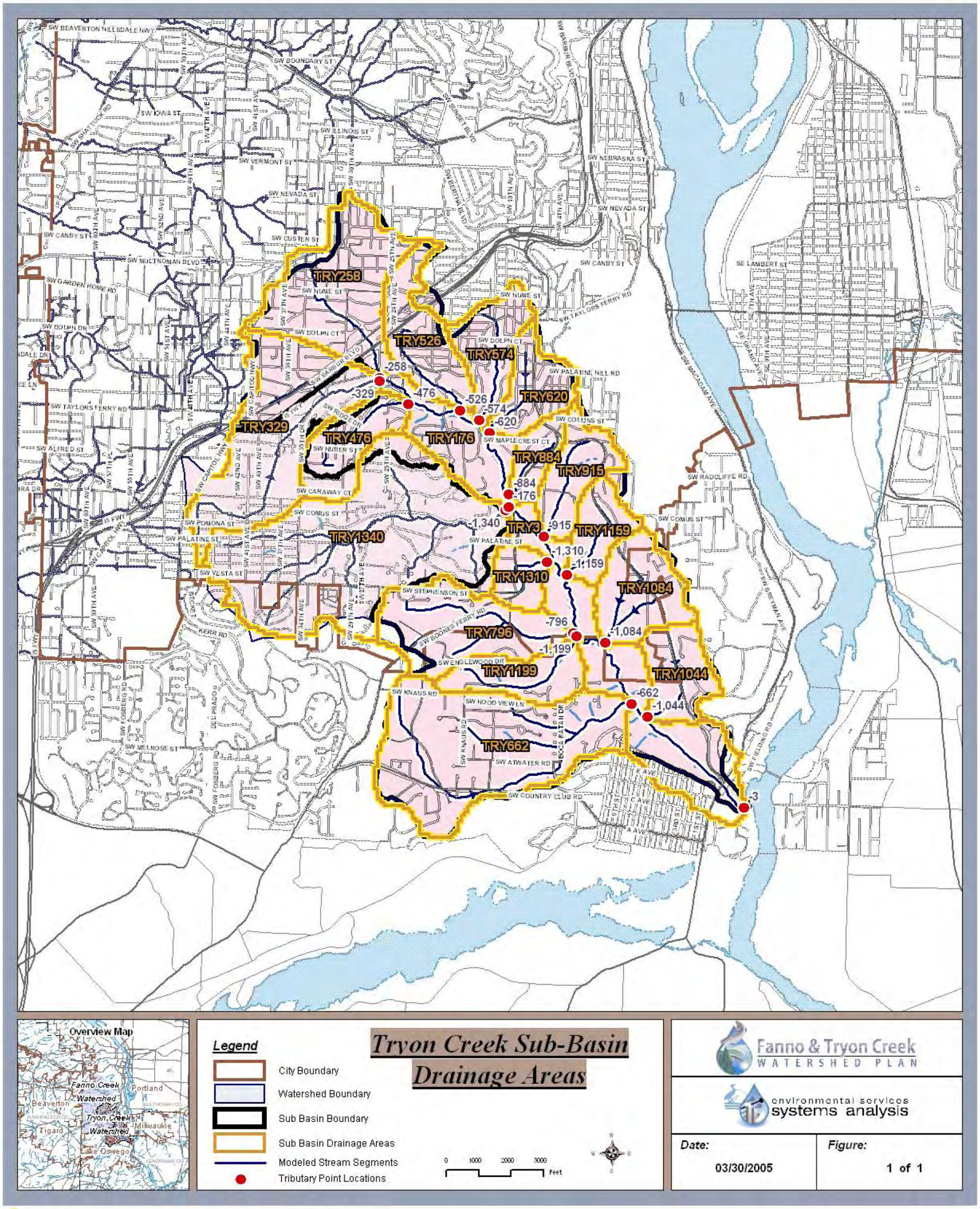


Table 4-9 GIS Anaylysis Results

Drainage Units	**AREA**				**ZONING**					**DRAINAGE SYSTEM**			**COMMENTS**
	Total	Non-City	IMPERVIOUS		COM	IND	SFR	MFR	POS	CHNL_FT	PIP_FT	Ratio	
	Acres	Acres	Acres	%	%	%	%	%	%	FT	FT		
(Upstream from SW Taylors Ferry Rd.)													
TRY329	412		180	44	12	0	67	11	10	16,500.03	44,876.17	2.7	Falling Cr
TRY258	330		138	42	16	0	65	17	2	13,435.86	35,323.72	2.6	Tryon Cr
Subtotal	742	0	318	43	14	0	66	14	6	29,935.89	80,199.89	2.7	
(SW Taylors Ferry Rd to SW Boones Ferry Rd.)													
TRY1340	780	75	167	24	0	0	92	2	6	61,123.74	49,705.77	0.8	Arnold Cr
TRY526	170		65	38	12	0	74	11	4	7,321.29	11,661.68	1.6	
TRY574	135		50	37	1	0	98	1	0	9,294.30	8,686.44	0.9	
TRY620	120		45	38	2	0	88	2	8	9,038.21	9,299.73	1.0	
TRY476	141		40	28	0	0	95	0	5	7,260.16	8,784.89	1.2	
TRY884	67		15	23	0	0	68	18	14	8,263.97	4,303.02	0.5	
TRY176	170		30	17	0	0	73	0	27	24,881.78	6,868.78	0.3	Direct Drainage
Subtotal	1,583	75	412	27	2	0	87	3	8	127,183.45	99,310.31	0.8	
(Downstream of SW Boones Ferry Rd.)													
TRY915	126		16	13	0	0	41	24	36	11,665.81	2,704.34	0.2	
TRY1310	68		8	12	0	0	65	0	35	5,164.07	1,418.45	0.3	
TRY1159	99		10	10	0	0	30	3	67	9,531.65	2,479.04	0.3	
TRY796	260	76	20	11	0	0	77	0	23	15,736.51	8,493.07	0.5	
TRY1199	128	126	0	0	0	0	99	0	1	2,965.59	69.99	0.0	
TRY1084	169	61	8	7	0	0	38	6	56	10,854.37	1,729.30	0.2	
TRY662	544	544	0	0	0	0	100	0	0				Nettle Creek
TRY1044	127	111	1	6	0	0	89	0	11	5,023.19	829.09	0.2	
TRY3	369	232	4	3	2	4	59	3	32	21,472.70	1,103.07	0.1	Direct Drainage
Subtotal	1,890	1,150	67	9	0	1	74	3	22	82,413.89	18,826.34	0.2	
Totals	4,216	1,225	797	27	3	<1	78	5	14	239,533	198,337	0.8	Watershed Totals

As shown in Table 4-9, the three major drainage areas exhibit different characteristics for the three indicators analyzed as follows:

- Drainage Area 1 - The land use within these subcatchments includes significant areas of commercial and multi-family zoning, in addition to the transportation system facilities. This includes both the I-5 and Barbur Boulevard transportation corridors and adjacent developments. This drainage area has the highest impervious area percentage (43 percent average) within the watershed. The high degree of development is also indicated by the degree of piped stormwater systems in these subcatchments (ratio of piped to open channel systems = 2.7). All these measures indicate that development has highly impacted the hydrology in the upper watershed. This impact on hydrologic response will be further discussed later in this chapter, based on modeled flow results.

- Drainage Area 2 – The land use within this area is predominately single family residential (87 percent). The percent impervious area is much lower (27 percent average) compared to Drainage Area 1 upstream in the watershed. The lower degree of development is also reflected in the degree of piped stormwater systems in these subcatchments (ratio of piped to open channel systems = 0.8) which is over three times lower than Drainage Area 1.

- Drainage Area 3 – Sixty percent of this drainage area is outside the City of Portland. Land use within the area is dominated by parks and open space (Tryon Creek State Natural Area) and single-family residential development outside the City of Portland. Areas within the City have a very low percentage of impervious area (9 percent average) and few piped stormwater systems (ratio of piped to open channel systems = 0.2)

Overall the results of the GIS analysis show that major human influences on hydrology in the Tryon Creek Watershed are concentrated in the upper watershed. Because of this fact, analysis of hydrologic conditions and any desired modification to hydrologic conditions throughout the watershed will have to consider and address hydrologic conditions in the upper watershed.

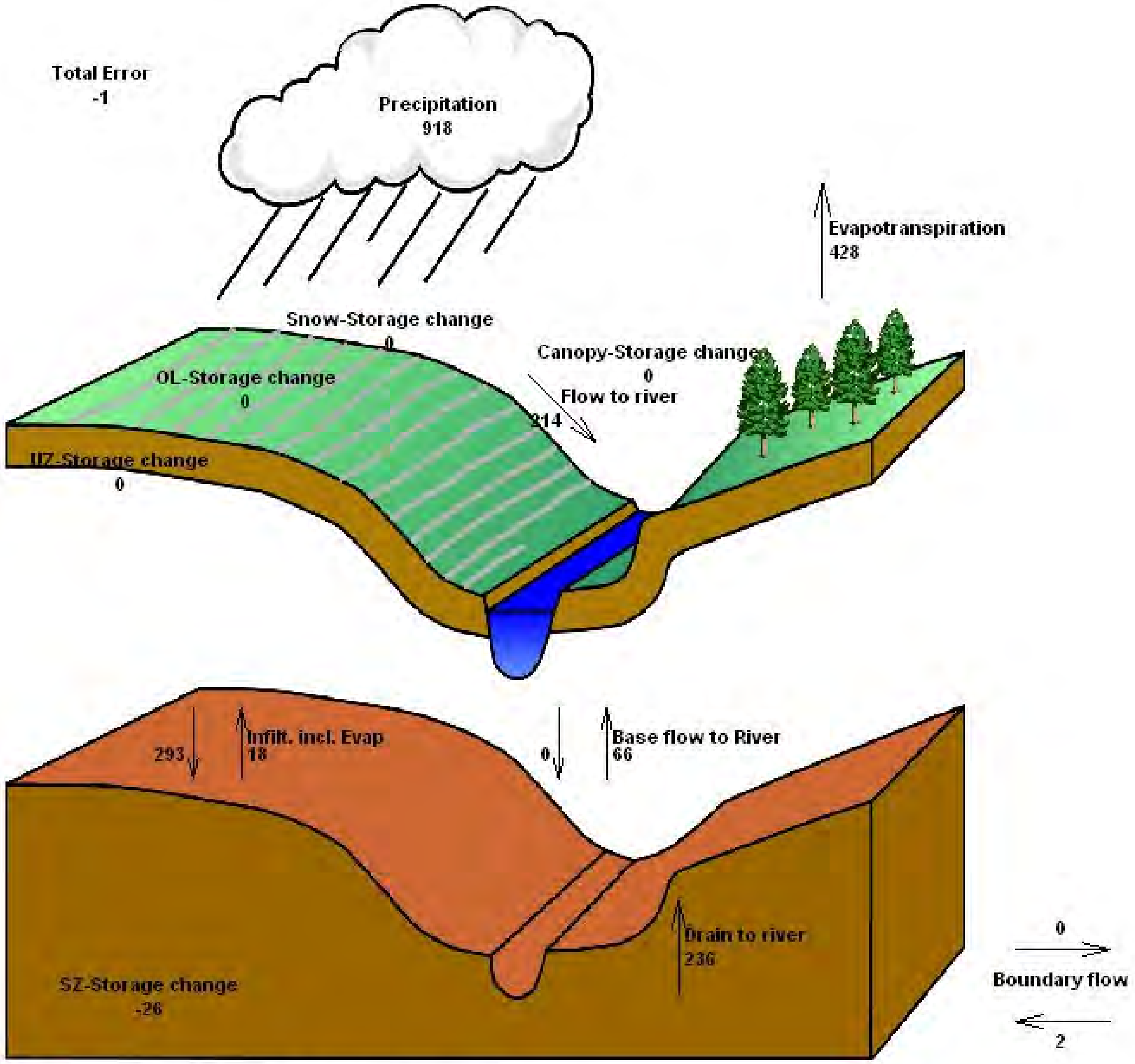
Typical Year Results

The Mike SHE/MIKE 11 model was run for the “typical year” rainfall record to evaluate hydrologic response in the watershed. Results of the modeling are discussed below.

Annual Water Balance

Figure 4-15 shows the annual water balance for the typical year rainfall. The results show that of the total annual precipitation, 23 percent is direct runoff to the stream, 26 percent drains to the stream as subsurface runoff, 47 percent is lost to evapotranspiration, and 7 percent drains to the stream as base flow during the year.

Figure 4-15
Annual Water Balance



Waterbalance accumulated from 10/1/2000 to 9/26/2001
Flow Result File : tryon_1yrSIM2.frf
Title : SIM2 Text : □Simulation of Average Year

Definition of the Terms in Water Balance Figure

Precipitation: Total precipitation falling in the watershed.
Canopy-storage change: Change in canopy interception storage, positive when increasing.
Evapotranspiration: Evaporation from canopy intercepted water (positive out) + evaporation from ponded water on ground + evaporation from oil (in unsaturated zone) + transpiration from root zone (in unsaturated zone) + evapotranspiration in saturated zone.
Snow-storage change: Not used in this study.
OL-storage change: Change in overland storage.
Overland boundary inflow: Potential flow into subcatchment or watershed.
Overland boundary outflow: Potential flow out of subcatchment + exchange from overland flooded areas to river outside the subcatchment.
Overland flow to river: Overland flow to river + overland flow directly to river (from paved areas) + exchange from overland flooded areas to river inside the subcatchment.
UZ-storage change: Unsaturated zone (UZ) and saturated zone (SZ) storage adjustment term (difference in unconfined storage capacity for UZ and SZ) + change in UZ deficit.
Infil. incl. Evap: Infiltration to SZ + UZ-SZ recharge – evapotranspiration from SZ (downwards arrow represents infiltration and other gains to SZ; upwards arrow represents loss from SZ).
Base flow to river: SZ aquifer inflow to river (upwards arrow) and river flow to SZ aquifer (downwards arrow).
Drain to river: SZ drainage flow (i.e., interflow) to river.
SZ-storage change: Change in SZ.

Annual Hydrographs

The annual hydrographs for the subwatersheds (Figures 4-16, 4-17, and 4-18) all show the same typical yearly runoff pattern, with frequent higher flows during the winter period and low summer flows. The hydrographs also show the fast system response to rainfall events.

Figure 4-16
Falling Creek Average Daily Flows

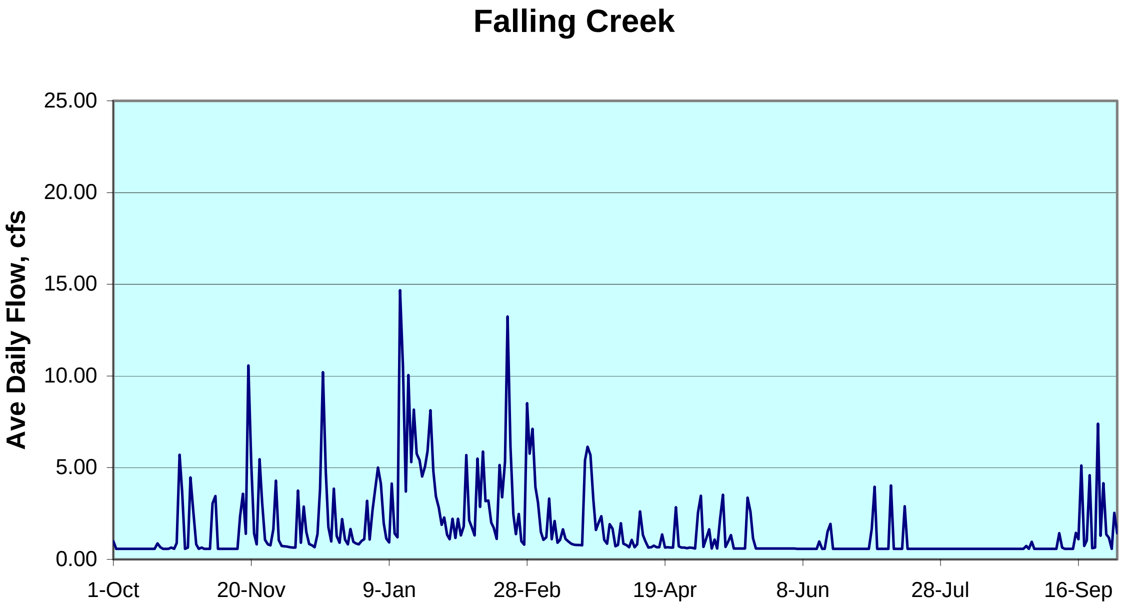


Figure 4-17
Arnold Creek Average Daily Flows

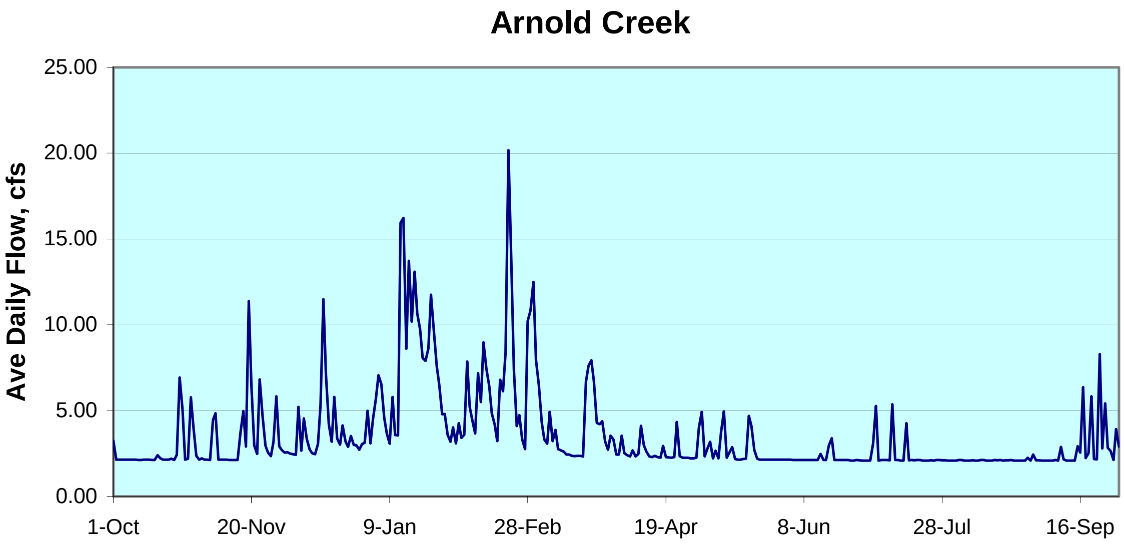
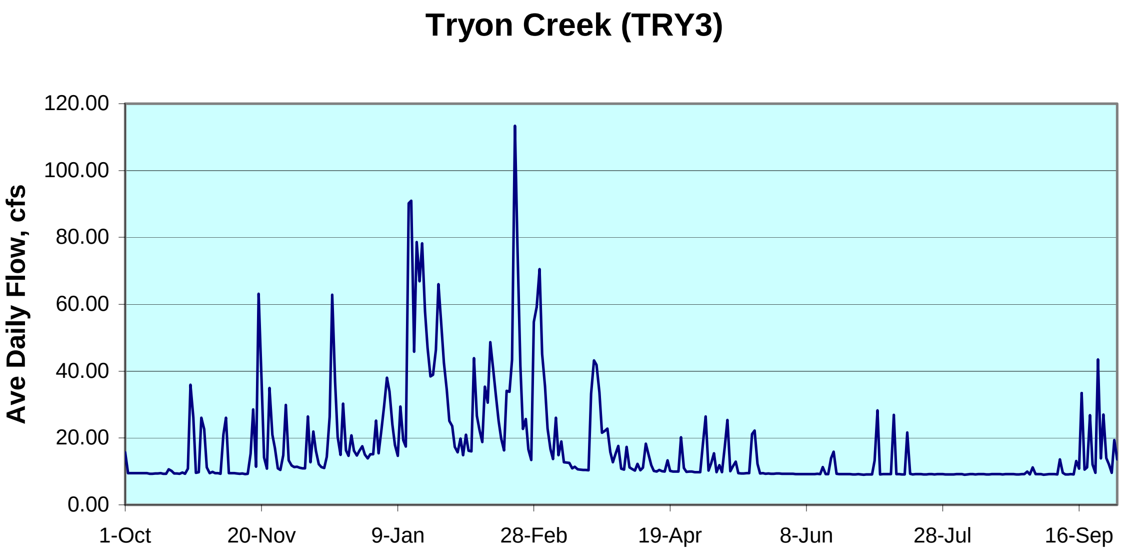


Figure 4-18
Tryon Creek Average Daily Flows



Average Monthly Flow

All the average monthly flow charts (Figures 4-19, 4-20, and 4-21) show the same typical annual flow pattern. They also show the increased runoff rates during the later part of the wet season (December-February), as discussed previously under "Gaged Stream Flows."

Figure 4-19
Falling Creek Average Monthly Flow

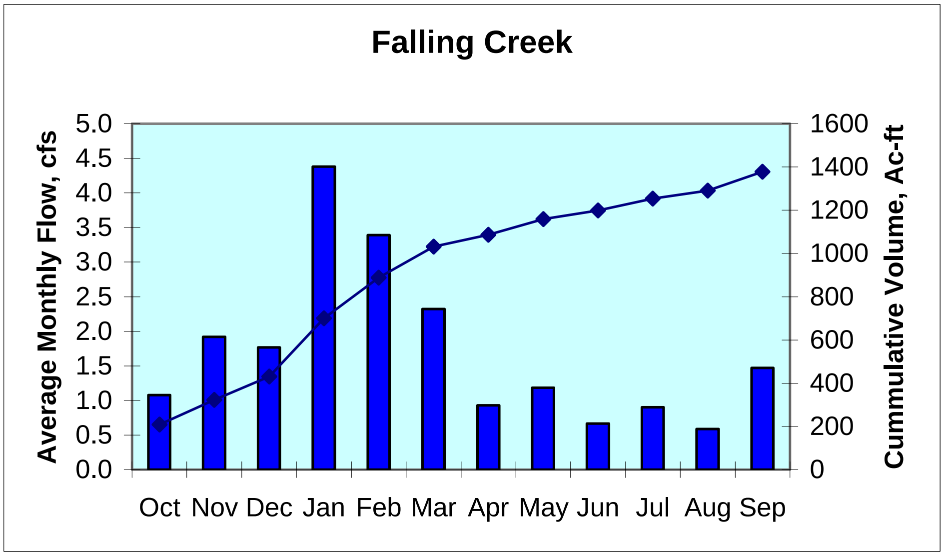


Figure 4-20
Arnold Creek Average Monthly Flow

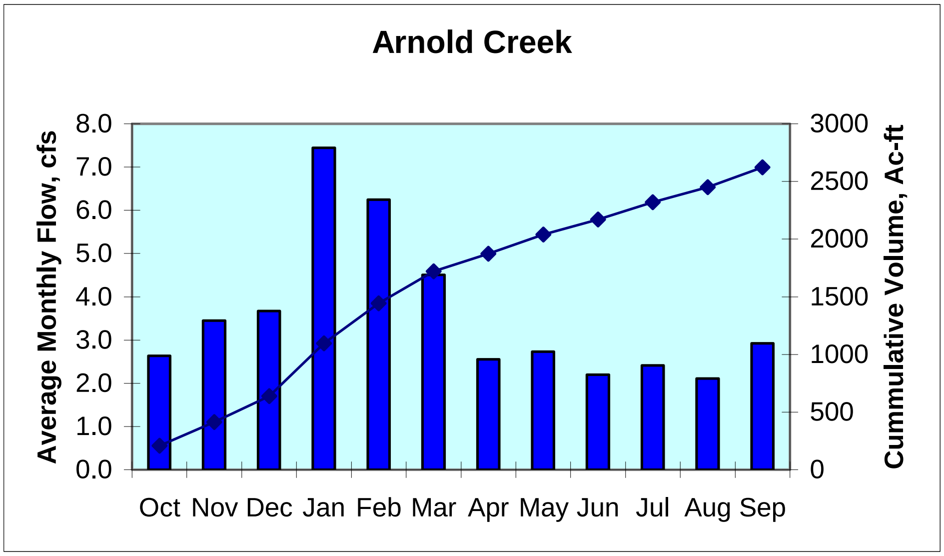
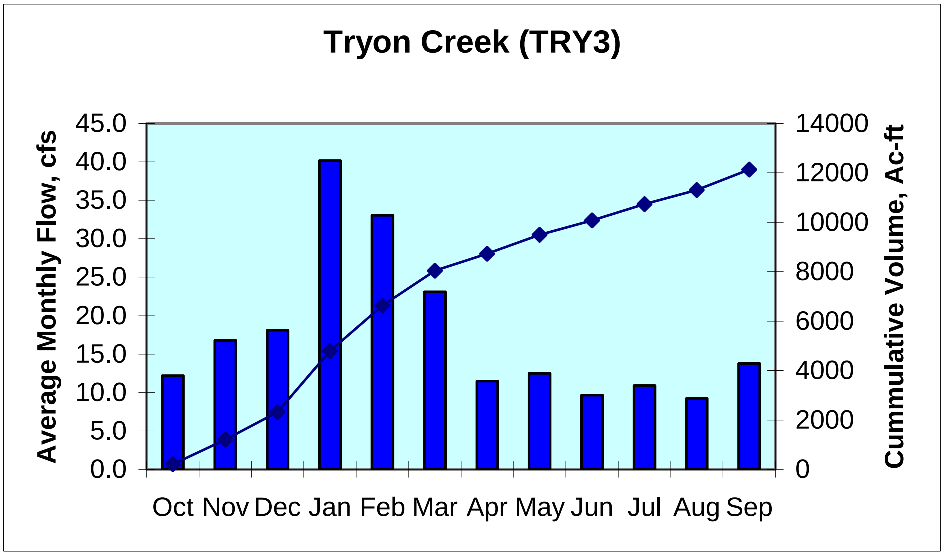


Figure 4-21
Tryon Creek Average Monthly Flow

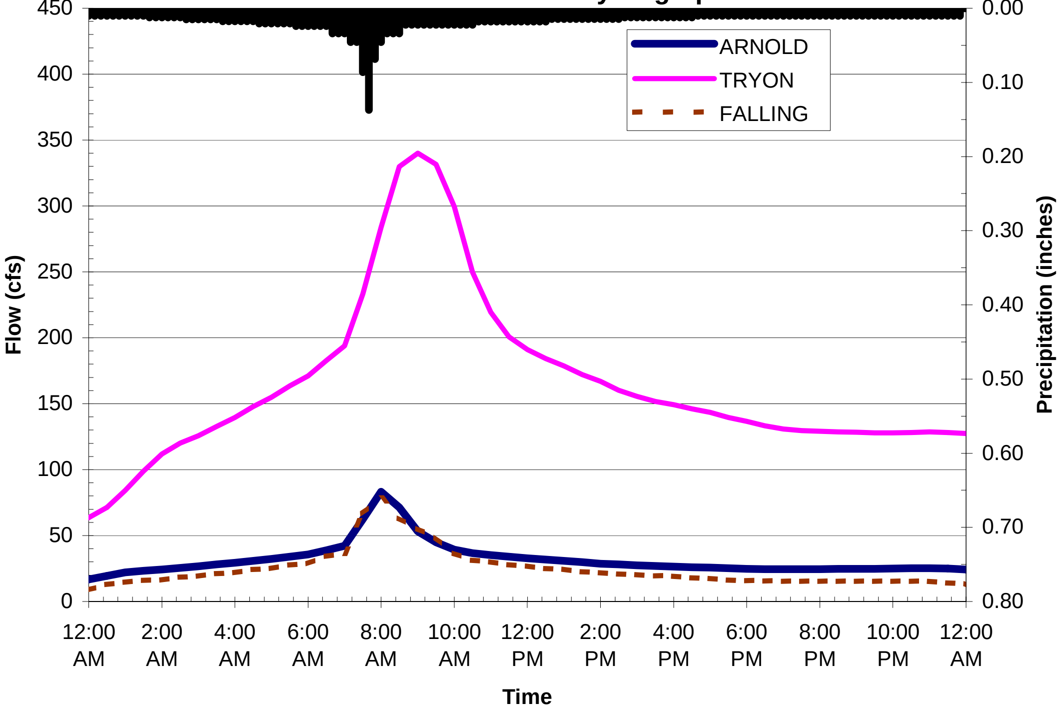


Design Storm Results

The MIKE model was run for design storms with return frequencies of 2, 10, 25, and 100 years. Model results for key locations in the subwatershed were previously summarized in Table 4-10. Figure 4-23 shows the hydrograph for the 2-year storm.

As shown in Table 4-11, the volume of runoff (as measured by the runoff coefficient) and peak flows for the Falling Creek (TRY329) subbasin are approximately double those of the other locations in the watershed. This is consistent with the GIS analysis, which showed this subbasin to be the most highly impacted by development. The effects of the higher flows from the upper watershed are somewhat attenuated going downstream; however, they still clearly impact the hydrologic response in the lower watershed.

Figure 4-23
Tryon Creek, Arnold and Falling Creek
Main Stem 2-Year Hydrograph



The hydrograph for the 2-year design storm shows the rapid response of the system to rainfall events and the high peak flows relative to base flow. Also, the peak flows for Falling Creek are approximately the same as those for Arnold Creek, even though the drainage area for Arnold Creek is twice as large.

SUMMARY OF FINDINGS

The hydrology of Tryon Creek and its tributaries is typical of low to moderate gradient Willamette Valley headwater streams with steep landscape slopes. The hydrologic response of the watershed was modified by the effects of development and urbanization with major factors including the following:

- Loss of native vegetation including mature forest cover.
- Increase of impervious surfaces.
- Construction of roads and streets including the I-5 and Barbur Boulevard corridors.
- Construction of stormwater conveyance systems including storm sewer systems and culverts.

The development in the Tryon Creek Watershed is concentrated in the upper watershed and therefore affects the hydrology of the entire mainstem of Tryon Creek.

The annual hydrograph for Tryon Creek reflects the climatic precipitation pattern, with higher flows and frequent storm flow events during the wet period from approximately October through May, followed by lower flows during the summer dry period from June through September. Winter base flows average approximately 10 cfs with summer base flows of 1 cfs or less. The watershed also shows very quick, “flashy” response to storm events with instantaneous peak stream flows in the lower watershed as high as 30 to 40 times base flow. This flashy response is partially the result of the altered hydrology resulting from development in the watershed. The high storm event flows also contribute to streambank erosion, sedimentation and downcutting of stream beds in the watershed. Although not quantified, the summer base flows are probably lower then historic flows due to a decrease in groundwater inputs as the result of decreased infiltration of rainfall due to construction of impervious surfaces and stormwater conveyance systems.

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CHAPTER 5

Water Quality: Fanno Creek Watershed

This chapter characterizes the water quality of the Fanno Creek Watershed. It includes:

- Background
- Water Quality Monitoring Program
- Water Quality Modeling
- Water Quality Assessment
- Summary of Findings

BACKGROUND

The Bureau of Environmental Services (BES) has been managing surface water quality in the Fanno Creek Watershed since the late 1980s, when the Oregon Department of Environmental Quality (DEQ) listed the Tualatin River and its tributaries as water quality limited under section 303(d) of the federal Clean Water Act. DEQ has identified BES as the designated management agency (DMA) responsible for regulatory compliance within the City of Portland's jurisdiction. As a result of the 303(d) listing, DEQ established a total maximum daily load (TMDL) for total phosphorus for Fanno Creek and its tributaries in 1988. In 2001, DEQ revised the TMDL for total phosphorus and established additional TMDLs for temperature, bacteria, and dissolved oxygen.

BES and the other DMAs in the Tualatin Basin have continued to work cooperatively to meet TMDL compliance requirements. Major BES milestones include development of the following documents:

- *Portland's Tualatin River Water Quality Management Plan (1990):* This plan was completed in March 1990 to comply with TMDL requirements and submitted to DEQ for review and approval.

- *Natural Resources Evaluation of Pollution Reduction Facilities and Stream Tributaries in Portland's Tualatin Basin (Scientific Resources Inc. 1991):* BES developed this document to provide further guidance for administration of the Tualatin Basin program.

- *Fanno Creek Resource Management Plan (RMP) – (1997):* The RMP generally reflected DEQ's thinking and guidelines for developing water quality management plans to meet the phosphorus TMDL. Developing the RMP was also in line with BES' efforts to set and meet goals and objectives for watershed health in Portland's Tualatin Basin. The RMP is an action-oriented document that identifies basin wide problems and proposes strategies for solutions. BES continues to implement some of the projects recommended in the RMP.

DEQ and the Tualatin Basin DMAs are responsible for and working to develop implementation plans for the new TMDLs established in 2001. The implementation plans address the TMDL load allocations (LAs) for nonpoint sources. BES submitted the *Fanno Creek Watershed TMDL Implementation Plan* to DEQ in August 2003. The TMDL waste load allocations (WLAs) for point source discharges will be addressed through the City's National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Discharge Permit.

In July 2000, BES initiated work on the comprehensive *Fanno and Tryon Creeks Watershed Plan* to achieve multiple watershed health goals and objectives in addition to the TMDL regulatory requirements. The *Watershed Plan* will provide the technical/scientific basis for achieving and meeting specific watershed, stream, infrastructure, habitat, and water quality improvement and restoration objectives in the watershed. (See the Introduction to this document for additional background information about the *Watershed Plan*.) This water quality characterization is an important component of the Watershed Plan.

WATER QUALITY MONITORING PROGRAM

BES's water quality monitoring program is a key component of the water quality characterization and is the major source of available water quality data for the characterization.

BES's Water Pollution Control Laboratory provides sample collection, laboratory analyses, and flow monitoring services. The water quality monitoring program has five basic objectives:

- Determine recent and current water quality conditions to determine and compare compliance with water quality standards, criteria, TMDL limits, and support of beneficial uses.

- Determine general temporal trends in environmental conditions: increasing/decreasing, improving/degrading.

- Determine the effectiveness of specific environmental management activities and initiatives (e.g., best management practices).

- Understand pollutant sources and the relationship between land uses and water quality.

- Comply with regulatory requirements for monitoring and reporting.

Key elements of BES's monitoring program for the Fanno Creek Watershed are described below.

Fixed-Station Water Quality Monitoring

BES has been monitoring the water quality of Fanno Creek and its tributaries since 1989. Cedar Mill Creek, a tributary of Rock Creek, is also monitored. Table 5-1 and Figure 5-1 show the ten sampling sites. All sites are monitored monthly, and three of the sites are monitored weekly during the TMDL compliance period of May through October. Water quality analyses include 14 field and laboratory parameters.

Table 5-1
Current BES Water Quality Monitoring Sites

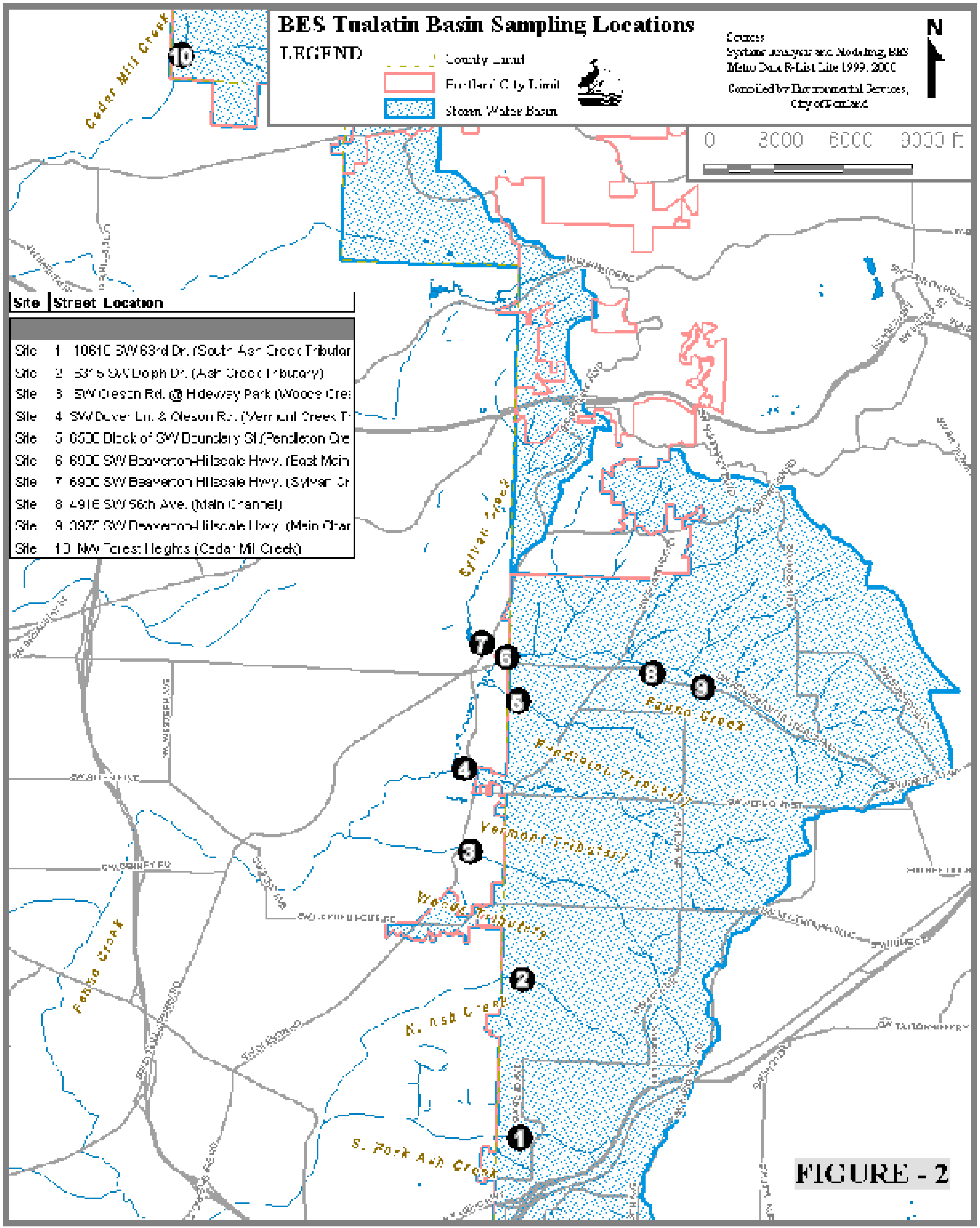
Site	Description	Start	Frequency
1	South Ash Creek (10610 SW 63rd Street)	5/30/90	Monthly
2	North Fork Ash Creek (6315 SW Dolph Drive)	5/30/90	Monthly
3	Woods Creek (SW Oleson Road)	5/30/90	Monthly
4	Vermont Creek (SW Dover Lane & Oleson Road)	5/30/90	Weekly[1]
5	Pendleton Creek (6500 SW Boundary Street)	5/30/90	Monthly[3]
6	Fanno Creek – East Main Channel (6900 SW Beaverton-Hillsdale Hwy)	7/20/93	Weekly[1]
7	Sylvan Creek (6900 SW Beaverton-Hillsdale Hwy)	9/17/93	Monthly[3]
8	Fanno Creek – 56th (4916 SW 56th Street)	5/30/90	Weekly [2]
9	Fanno Creek – 39th (975 SW Beaverton-Hillsdale Hwy)	5/30/90	Monthly
10	Cedar Mill Creek (NE Forest Heights)	5/30/90	Monthly

[1] Weekly (May – October) otherwise monthly

[2] Monitored biweekly year-round starting in 2003

[3] Discontinued December 2005

Figure 5-1
BES Tualatin Basin Sampling Locations



Site	Street Location
Site 1	10610 SW 63rd Dr. (South Ash Creek Tributar
Site 2	5315 SW Dolph Dr. (Ash Creek Tributary)
Site 3	SW Oleson Rd. @ Hideaway Park (Woods Cre
Site 4	SW Dover Ln. & Oleson Rd. (Vermont Creek Tr
Site 5	6500 Block of SW Boundary St.(Pendleton Cre
Site 6	6900 SW Beaverton-Hillsdale Hwy. (East Main
Site 7	6900 SW Beaverton Hillsdale Hwy. (Sylvan Cr
Site 8	4916 SW 56th Ave. (Main Channel)
Site 9	10975 SW Beaverton-Hillsdale Hwy. (Main Char
Site 10	NW Forest Heights (Cedar Mill Creek)

Temperature Monitoring

BES has installed and maintained continuous temperature recorders during the summer season (May through October) since 1998 at two locations: Fanno Creek at SW 56th Avenue and Woods Creek at Hideaway Park. The temperature recorders provide hourly temperatures at these sites.

Flow Monitoring

Through a cooperative agreement with BES, the U.S. Geological Survey (USGS) has maintained a streamflow monitoring station on Fanno Creek at SW 56th Avenue since 1991. (Further discussion of flow monitoring results can be found in Chapter 3, Hydrology: Fanno Creek Watershed).

NPDES Stormwater Monitoring

BES has maintained an instream stormwater sampling site in Fanno Creek at SW 56th Avenue since 1991. A total of 27 storm events have been monitored at this site and include both flow-weighted composite and grab samples. This is also one of ten monitoring sites that BES originally established as part of the NPDES stormwater program to evaluate pollutant loads from different land uses.

Fanno–Tryon Storm Monitoring Project

To further characterize pollutant loads from different land uses, BES established four stormwater sampling sites in the Fanno Creek and Tryon Creek Watersheds that represent the predominant land use types in these watersheds: residential, multi-family residential, commercial, and transportation (highways). A total of four storms were sampled at these sites between September 2000 and January 2001.

Data and Reporting

All of the collected water quality data are stored electronically in BES's Janus water quality data base and are available for retrieval, analysis, and reporting. The fixed station water quality monitoring data are submitted to DEQ annually.

The results of these monitoring efforts are discussed in detail in the Water Quality Assessment section, below.

WATER QUALITY MODELING

Hydrologic/hydraulic and water quality models have been developed for the Fanno Creek Watershed to help characterize water quality and examine the correlation between streamflows and pollutant loadings. The current characterization uses the following models:

- **MIKE SHE/MIKE 11 (DHI):** MIKE SHE and MIKE 11 are integrated surface and groundwater programs that can be used to simulate hydrology, hydraulics, upland pollutant loadings, and instream water quality. MIKE SHE is a hydrologic model that converts precipitation falling on the watershed into runoff. MIKE 11 is a hydraulic model that routes runoff generated by MIKE SHE through modeled stream or conveyance system segments.

GIS/GRID Model: BES developed this GIS-based model to estimate potential pollutant loadings within the watershed, based on factors that include land use, topography, impervious area, vegetation, soil type, slope, and precipitation. The model uses the same 100-foot by 100-foot grid areas used by the MIKE SHE/MIKE11 model as the basis for analysis.

WATER QUALITY ASSESSMENT

Fanno Creek and its tributaries within the City of Portland are small headwater streams located within an urban environment. They exhibit many of the characteristics typical of urban streams, which result from changes in hydrology and increased pollutant loadings from urban development. These characteristics include altered flow patterns and degraded water quality.

This water quality characterization evaluates the water quality in the Fanno Creek Watershed from three perspectives:

- *Framework for Integrated Management of Watershed and River Health* guidelines
- Oregon water quality index
- Water quality standards/TMDLs

Framework Guidelines

The City's Endangered Species Act (ESA) Program developed the *Framework for Integrated Management of Watershed and River Health* (Framework) in 2004. The *Framework* outlines scientific principles, four watershed health goals, and a process for developing and implementing watershed management plans. It identifies the following water quality indicators for evaluating watershed health:

- Temperature
- Dissolved oxygen
- Nutrients and chlorophyll *a*
- Total suspended solids
- Toxic contamination of water sediment, sediment, and biota
- Groundwater quality
- 303(d) listed parameters
- Other parameters (as determined by the weight of evidence)

Specific watershed targets and metrics for evaluating these water quality indicators are currently being developed.

Of the listed indicators, temperature, dissolved oxygen, and nutrients (chlorophyll *a*/total phosphorus) currently do not meet water quality standards in the Fanno Creek Watershed. TMDLs have been established for total phosphorus, bacteria, temperature, and dissolved oxygen, as discussed below in the section on Water Quality Standards/TMDLs.

Monitoring has shown that total suspended solids (TSS) are also elevated in the Fanno Creek Watershed, particularly during storm events. There is no current water quality standard for TSS. Monitoring results for TSS and the relationship between TSS and both the total phosphorus and dissolved oxygen TMDLs are discussed later in this chapter under Water Quality Standards/TMDLs.

Very little data are currently available on toxics for the Fanno Creek Watershed. Arsenic, manganese, and iron were listed on the 1998 303(d) list for exceeding water quality standards in Fanno Creek, based on data collected in 1993 by the USGS. DEQ subsequently delisted these parameters, based on a finding that the levels reflected natural background concentrations in the watershed. No other toxic substances have been identified as exceeding water quality standards at this time. It should be noted that no current data exist on potential toxic organic pollutants, such as pesticides or herbicides.

Based on the above findings, it is reasonable to assume that the existing water quality conditions in the Fanno Creek Watershed are causing some impairment of watershed health. This impairment can be further quantified when the appropriate targets and metrics are developed for the water quality indicators.

Oregon Water Quality Index

DEQ initially developed the Oregon Water Quality Index (OWQI) in the 1970s. The OWQI methodology was updated to its current form in 1995 to reflect advances in the knowledge of water quality and in the design of water quality indices. The purpose of the OWQI is to improve the understanding of water quality issues by integrating complex data into a single index score, which can be used to describe water quality status and evaluate water quality trends (Cude 2000).

DEQ developed the OWQI to assess data collected through DEQ's Ambient River Water Quality Monitoring Network, with an emphasis on general recreational uses (fishing and swimming). As such, the OWQI is a general index of water quality and cannot be used to determine the quality of water for specific uses. It also should not be used to provide definitive information on water quality without considering all appropriate chemical, biological, and physical data (Cude 2000). The strengths of the OWQI, as well as other water quality indexes, are their use for comparing water quality among different locations and for assessing long-term trends.

DEQ and others have widely used the OWQI to report water quality status and trends in Oregon. The OWQI is currently included as a benchmark for Willamette River water quality in the City of Portland's annual Service Efforts and Accomplishments (SEA) Report. BES incorporated the OWQI into its water quality monitoring program for the Fanno Creek Watershed in 2001.

The OWQI is calculated by integrating the measurement of eight water quality variables:

- Temperature (Temp)
- Dissolved oxygen (DO)
- Biochemical oxygen demand (BOD)
- pH
- Total solids (TS)
- Ammonia + nitrate nitrogen (NH3/NO3)
- Total phosphorus (TP)
- Fecal coliform (FC).

The OWQI is determined by first using a series of algorithms and equations to calculate a unit-less subindex value for each water quality variable. The individual subindex values are then aggregated into the overall index value (OWQI) based on an “unweighted harmonic square mean” of the subindex values. An index score of 100 corresponds to the highest water quality, and a score of 10 represents the poorest water quality. In addition, DEQ has established a descriptive narrative scoring system, ranging from very poor (0-59) to excellent (90-100).

In February 2001, BES initiated monthly monitoring for all the parameters required to calculate the OWQI at four representative locations in the Fanno Creek Watershed: Fanno Creek at SW 56th Avenue, Vermont Creek, Woods Creek, and Cedar Mill Creek. Table 5-2 summarizes the OWQI values for these sites, based on data collected between February 2001 and May 2003. The overall water quality at these four sites ranged from very poor (Vermont Creek, OWQI=51; Cedar Mill Creek, OWQI=55) to poor (Fanno Creek, OWQI=66; Woods Creek, OWQI=60). Figures 5-2 through 5-5 show the OWQI values and the subindex values for the four sites.

Table 5-2
Oregon Water Quality Index Summary for Fanno Creek

Summary: Oregon Water Quality Index										
	Mean Subindex Values								**Overall**	Water Quality
Location	NO3/NH3	TP	BOD5	TS	FC	DO	pH	Temp	**OWQI**	Rating
Fanno Creek - 56th	71	69	78	63	57	91	96	99	**66**	Poor
Vermont Creek	68	42	74	58	60	80	89	98	**51**	Very Poor
Woods Creekl	68	64	78	58	57	90	90	99	**60**	Poor
Cedar Mill Creek	76	61	68	54	54	93	99	95	**55**	Very Poor

Notes:
Results of BES monthly ambient water quality sampling between 2/6/01 and 5/3/03
Index Ranking: 0-59 Very Poor, 60-79 Poor, 80-84 Fair, 85-89 Good, 90-100 Excellent

Figure 5-2
Fanno Creek - SW 56th
Oregon Water Quality Index

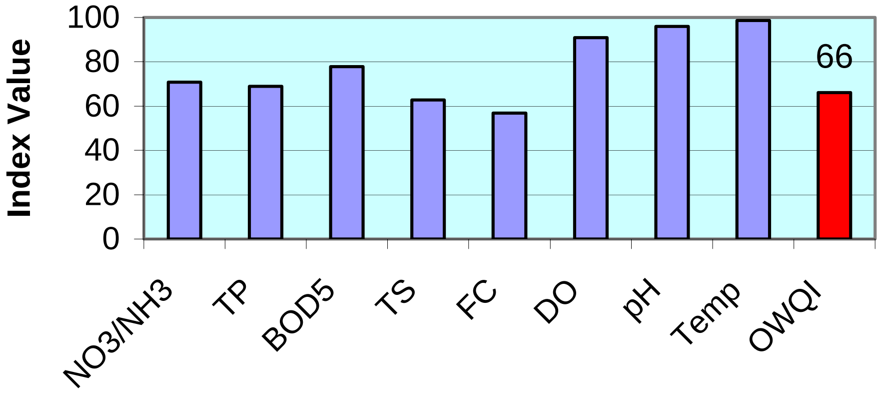


Figure 5-3
Vermont Creek
Oregon Water Quality Index

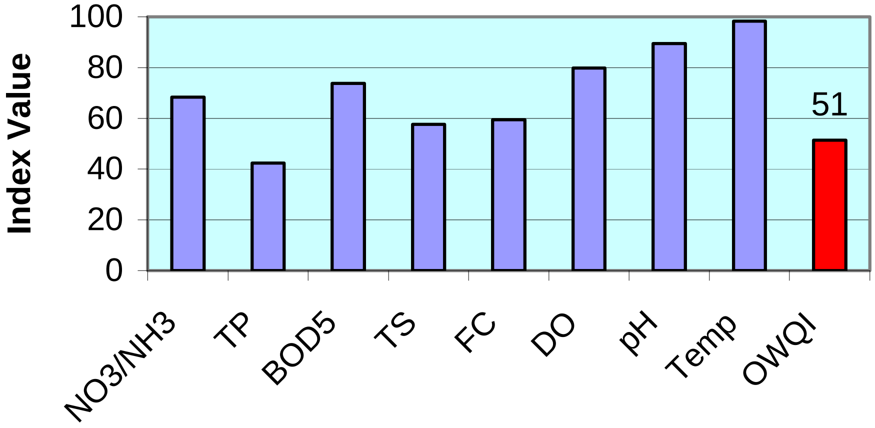


Figure 5-4
Cedar Mill Creek
Oregon Water Quality Index

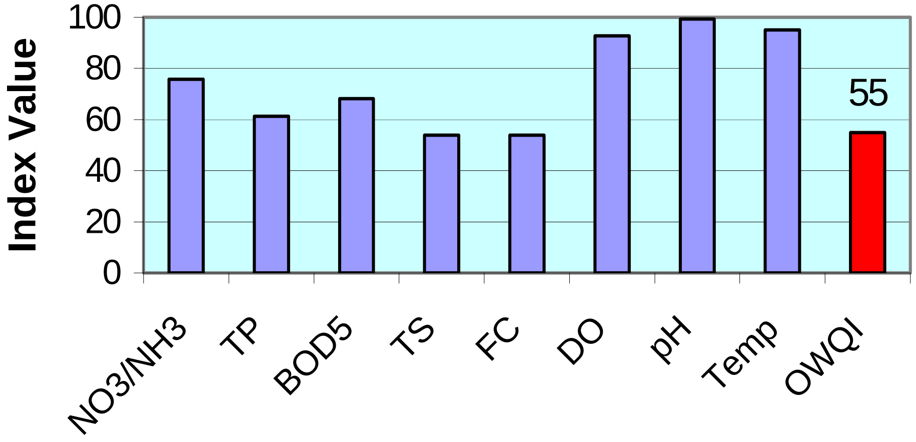
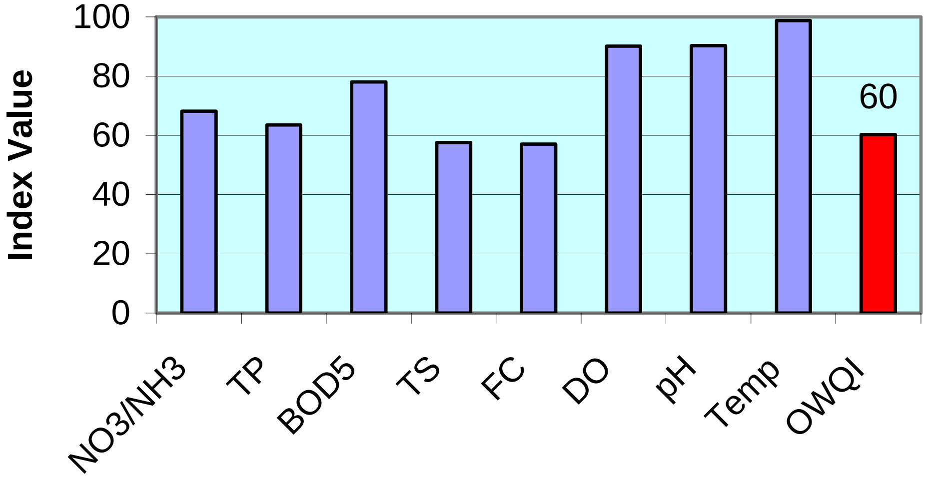


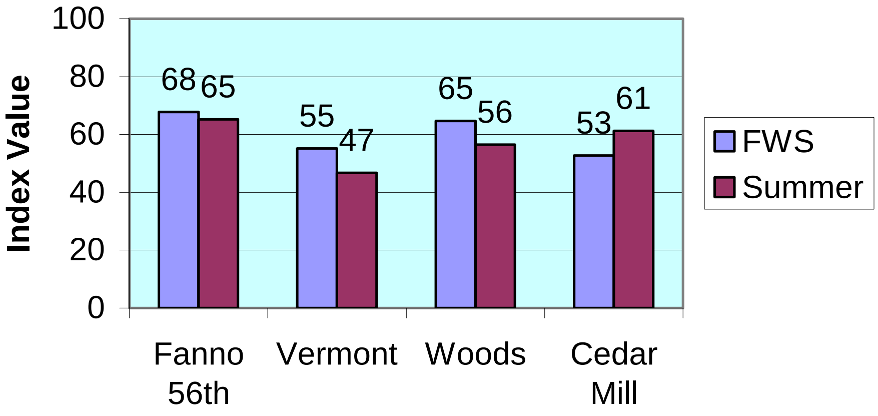
Figure 5-5
Woods Creek
Oregon Water Quality Index



An examination of these results shows that high levels of bacteria (fecal coliform), total phosphorus, and total solids are the major reason for the low overall index scores. Ammonia + nitrate nitrogen and biochemical oxygen demand also have some influence on the low index values. These results are consistent with previous results (Aroner 2000), which used a modified version of the OWQI because of an incomplete available data set. They also are consistent with the TMDLs for Fanno Creek, which include total phosphorus and bacteria (E. *coli*).

Because seasonal variability affects many water quality parameters, it is often appropriate to analyze monitoring results on a seasonal basis. Figure 5-6 shows seasonal OWQI values for summer (June through September) and fall/winter/spring (November through May). In general, the results show slightly lower OWQI values during the summer season.

Figure 5-6
Oregon Water Quality Index
By Season



Water Quality Standards/TMDLs

Designated Beneficial Uses

Pursuant to Oregon administrative rules (OAR), the Oregon Water Resources Commission establishes the beneficial uses of waters of the state. To protect these uses, DEQ establishes a set of numeric and narrative water quality standards. DEQ has identified Fanno Creek and tributaries in the Tualatin Basin as waters of the state, with all the designated beneficial uses and their associated water quality standards. Table 5-3 lists designated beneficial uses for Fanno Creek and its tributaries. Table 5-4 identifies water quality standards and criteria for the Tualatin Basin, including Fanno Creek and its tributaries.

Table 5-3
Fanno Creek Listed Beneficial Uses

Designated Beneficial Uses	**Fanno Creek**
Public Domestic Water Supply	X
Private Domestic Water Supply	X
Industrial Water Supply	X
Irrigation	X
Livestock Watering	X
Anadromous Fish Passage	**X**[1]
Salmonid Fish Rearing	**X**[1]
Salmonid Fish Spawning	**X**[1]
Resident Fish and Aquatic Life	**X**[1]
Wildlife & Hunting	**X**[1]
Fishing	X
Boating	X
Water Contact Recreation	**X**[1]
Aesthetic Quality	**X**[1]

[1] Primary Current Uses

Table 5-4
Water Quality Standards and Criteria in Tualatin Basin

Parameter	Water Quality Standard	Criteria/Comments
Dissolved Oxygen (DO)	8.0 mg/l (30 day mean minimum)	Cold water aquatic life
	At least 90% of saturation	If climatic conditions preclude goal of 8.0
	6.5 mg/l (7-day minimum mean)	
	6.0 mg/l (absolute minimum)	
Temperature	18° C (64.4° F) maximum	If area is designated for salmonids
	13° C (55.4° F) maximum	If area supports native salmonid spawning, egg incubation, and fry emergence
Turbidity	Maximum of a 10% cumulative increase (NTU)	Relative to a control point immediately upstream of activity
pH	6.5 – 8.5	All other basin waters
Bacteria (E. *coli*)	126 organisms per 100 ml.	Geometric mean based on a minimum of 5 samples
	406 organisms per 100 ml.	Maximum for any single sample.
Dissolved Gases (CO_2, H_2S, etc.)	No sufficient quantities allowed to cause objectionable odors	Objectionable odors are deleterious to aquatic life, navigation, or recreation
Development of Fungi	No sufficient quantities allowed	No deleterious effects on stream bottoms or aquatic life, or effects that are injurious to health, recreation, or industry
Total Dissolved Solids	100.0 mg/l	Willamette River and tributaries.
	No exceedence of natural background levels	In waters of the state if amounts, concentrations, or combinations are harmful
Toxic Substances	No exceedence of criteria listed in Table 20 from EPA.	As published in *Quality Criteria for Water* (EPA 1986)

Compliance with Water Quality Standards

Water quality in the Tualatin Basin, including the Fanno Creek Watershed, has not been in compliance with certain water quality standards. As a result, DEQ listed the basin and its tributaries on the 303(d) list as water quality limited for temperature, bacteria, dissolved oxygen, phosphorus, and toxics (arsenic, iron, manganese). Under the federal Clean Water Act, DEQ established TMDLs for total phosphorus in 1988. In 2001, DEQ revised the TMDL for total phosphorus and established TMDLs for temperature, bacteria, and dissolved oxygen. DEQ delisted the Tualatin River and tributaries for toxics because it concluded that the toxics were high as a result of naturally occurring conditions.

Existing TMDLs

Table 5-5 summarizes the existing TMDLs for Fanno Creek and its tributaries, along with load allocations (LAs) for nonpoint sources of pollution and waste load allocations (WLAs) for point source discharges. The following sections then provide additional information about the existing TMDLs for total phosphorus, temperature, bacteria, and dissolved oxygen.

Table 5-5
Fanno Creek Watershed TMDL Load Allocations

Parameter	Load Allocation (LA)	Comments	Waste Load Allocation (WLA)	Comments
Total Phosphorus	No	Background allocation (groundwater sources) set at 0.13 mg/l at mouth of Fanno. City of Portland does not have LA for runoff sources and does not have to meet instream concentrations for compliance with TMDL.	Yes	Summer (May 1 – October 31) WLA = 0.13 mg/l (summer median) for discharges from MS4
Bacteria (E. *coli*)	No	City of Portland not assigned a LA. Instream E. *coli* concentrations exceed water quality standard. DEQ may require a "bacteria management plan" through OARs even though TMDL does not assign a LA.	Yes	Summer (May 1-October 31) WLA = 12,000 E *coli* counts/100ml (event mean concentrations during runoff events) = 406 (grab sample – all other times) Winter (November 1 – April 31) WLA = 5000 E. *coli* counts/100ml (event mean concentrations during runoff events) = 406 (grab sample – all other times)
Temperature	Yes	LA = system potential measured as effective shade.	No	No increase in stream temperatures allowed for point source discharges.
Dissolved Oxygen (Settleable Volatile Solids, SVS)	Yes	LA = 50% reduction in SVS in runoff sources. Required reductions assumed by DEQ during TMDL development to be met by temperature TMDL requirements (e.g., improvement of riparian areas, stream bank stabilization, etc.).	Yes	WLA = 50% reduction in SVS in MS4 discharges.

Total Phosphorus TMDL

In 1988, a TMDL was set for total phosphorus in the Tualatin Basin, including portions of the Fanno Creek and Rock Creek subbasins within the City of Portland. The compliance period for the total phosphorus TMDL is May 1 to October 31.

The goal of the 1988 total phosphorus TMDL was to control the growth of algae in the lower reaches of the Tualatin River by limiting one of algae's nutrients, phosphorus. The TMDL uses chlorophyll *a* as the measure of algal concentration. Algal blooms in the Tualatin River resulted in exceedences of the state chlorophyll *a* action level of 15 µg/liter, measured as a three-month average concentration. The excessive algae blooms also resulted in exceedences of state water quality standards for aesthetics, pH, and dissolved oxygen (DO) in the Tualatin River during the summer period. Non-attainment of these water quality standards can result in impairment of designated beneficial uses for the water body, including water contact recreation, aesthetic quality, resident fish and aquatic life, salmonid fish rearing, and salmonid fish spawning.

In the Tualatin subbasin tributaries, water quality standard violations associated with algal growth are limited to DO. No exceedences of the upper pH criterion have been observed in the tributaries. The DO water quality standard is expected to be met for the tributaries through reductions in volatile solids and temperature. Therefore, a reduction in phosphorus loads to the tributaries is not necessary to meet water quality standards on the tributaries. However, since the phosphorus loads from the tributaries impact the mainstem Tualatin River, control of tributary loads are necessary to achieve standards on the mainstem.

The 1988 total phosphorus TMDL established a target concentration of 0.07 mg/l total phosphorus for the summer period (May 1 to October 31) for the Fanno Creek and Rock Creek subbasins. This target concentration applied to both background levels and runoff sources. After the 1988 total phosphorus TMDL was developed, studies conducted by the Oregon Graduate Institute and the USGS indicated that the natural phosphorus loads from groundwater may constitute a significant portion of low-flow (non-runoff period) tributary loads. These background concentrations were found to be greater than the established target concentration of 0.07 mg/l. The studies further concluded that natural sources are the most probable cause of the elevated loads in the groundwater.

As a result of these findings, DEQ revised the phosphorus TMDL for the tributaries in 2001. The revised total phosphorus TMDL establishes LAs for background (groundwater) and nonpoint sources, and WLAs for runoff sources.

LOAD ALLOCATIONS (LA)

The LAs for total phosphorus are defined as background groundwater sources. In developing the LAs, however, DEQ recognized the probability that existing groundwater total phosphorus concentrations are elevated as a result of anthropogenic (human) sources. These sources may be indirect, such as releases from sediments deposited during runoff events, or direct, such as irrigation runoff or car washing. The TMDL accounts for these sources by including a margin of safety in the final LAs.

Table 5-6 shows the LAs for background (groundwater) sources for Fanno Creek and Rock Creek. The Tualatin subbasin TMDL also established an LA of 0.13 mg/l total phosphorus for nonpoint sources of runoff in the Fanno Creek subbasin, but did not assign a LA to the City of Portland.

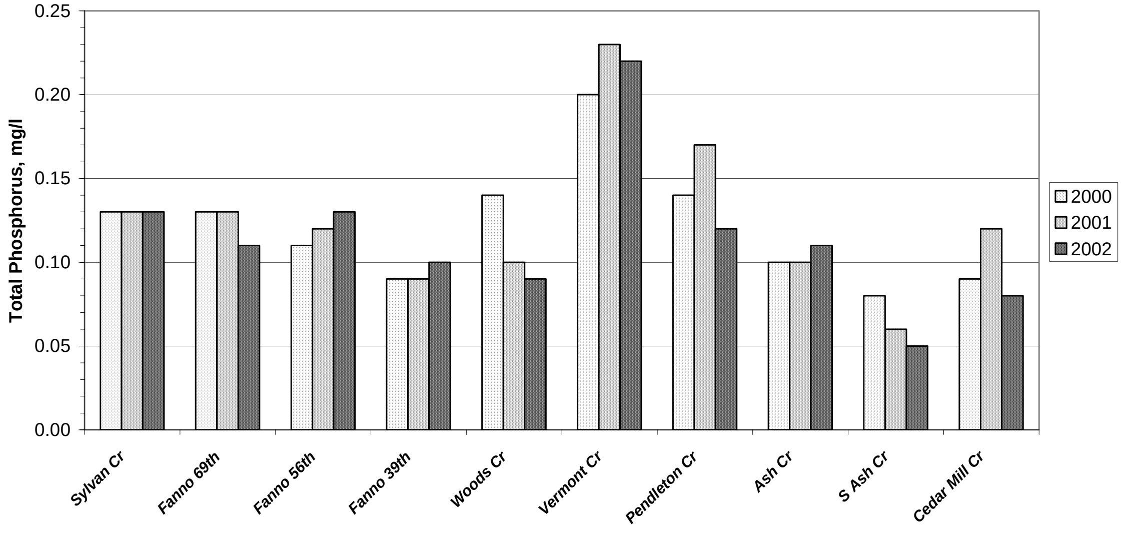
Table 5-6
Tualatin River Subbasin Total Phosphorus Load Allocations for Background (Groundwater) Sources

Stream Segment	Total Phosphorus Concentrations (Summer Median – mg/l)
Fanno Creek @ mouth	0.13
Rock Creek @ mouth	0.19

Source: DEQ, January 2001, Tualatin Subbasin Total Maximum Daily Load (TMDL), Table 46.

As shown on Figure 5-7, the results of BES ambient water quality monitoring from 2000-2002 indicate that background concentrations of total phosphorus in Fanno Creek and its tributaries were generally below the Fanno Creek subbasin target concentration of 0.13 mg/l at all monitored sites except Vermont Creek. The summer median total phosphorus concentration for Vermont Creek was 0.22 mg/l.

Figure 5-7
Summer Median Total Phosphorus 2000-02



WASTE LOAD ALLOCATIONS (WLA)

Table 5-7 shows the WLAs assigned to the City of Portland for stormwater runoff discharges from the City of Portland's Municipal Separate Storm Sewer System (MS4).

Table 5-7 Tualatin River Subbasin Total Waste Load Allocations for Point Sources

Designated Management Agency/Source	Source Discharging to (Subbasin)	Total Phosphorus Concentrations (Summer Median – mg/l)
City of Portland[1]	Fanno Creek at Mouth	0.13
	Rock Creek at Mouth	0.13

[1] WLA= 134.7 lbs Total Phosphorus expressed as a seasonal total load (May to October)

Source: DEQ, January 2001, Tualatin Subbasin Total Maximum Daily Load (TMDL), Table 47

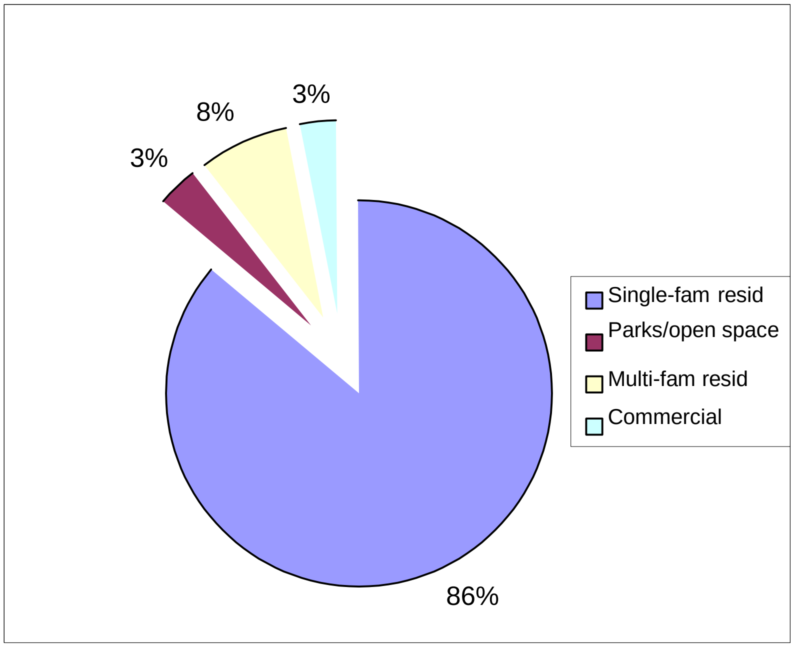
PHOSPHORUS MONITORING RESULTS

Monitoring of storm event water quality in the Fanno Creek Watershed within the City of Portland can be divided into two major categories: instream water quality monitoring and land use-based water quality monitoring.

INSTREAM WATER QUALITY MONITORING

As a part of the monitoring program associated with the City's NPDES stormwater permit, BES has maintained a stormwater sampling station (designated as site R1) on the mainstem of Fanno Creek at SW 56th Avenue since 1997. The uppermost 1,594 acres of the Fanno Creek Watershed drain to this site. This represents the major portion of the mainstem Fanno Creek subwatershed within the City of Portland. The area is predominantly residential (86 percent), with smaller areas of multi-family residential, commercial, and open space. The more heavily developed multi-family and commercial areas are generally along the SW Beaverton Hillsdale Highway corridor. Figure 5-8 shows the land uses within the subwatershed.

Figure 5-8
Zoning Area for Fanno Creek Mainstem Tributary to SW 56th Street Gage



Streamflow data are available at this site from a flow gage installed and maintained by the USGS through a cooperative agreement with the City of Portland. The streamflow data for this subbasin reveal the characteristics of a flashy, urban headwaters stream with significant impervious areas. Monthly high flows are routinely five to 25 times greater than corresponding monthly low flows. During larger rainfall events, flows can change from a typical low-flow condition in the range of one cubic foot per second (cfs) to peak flows of over 200 cfs.

Since 1991, 16 storm events have been monitored at this site. Of these, eight events were monitored during the summer regulatory period (May 1 to October 31) established for the phosphorus TMDL. Storm sampling has included collection of both grab samples and flow-weighted composite samples that enable event mean concentrations (EMCs) to be determined for the sampled constituents.

The results of the stormwater quality sampling at this site exhibit the variability typical of stormwater quality that is influenced by a wide range of variables, including variations in rainfall amounts, rainfall intensities, and antecedent conditions. They also exhibit characteristics consistent with the rapid changes in streamflow during storm events described previously.

During storm events, the concentration of TSS in Fanno Creek is highly elevated compared to the low-flow concentrations. Figure 5-9 compares median TSS concentrations during non-storm and storm events. The increase in TSS is also reflected in elevated concentrations of total phosphorus. Figure 5-10 compares median phosphorus concentrations during non-storm and storm events.

Figure 5-9
Median TSS Concentrations
Fanno Creek at SW 56th

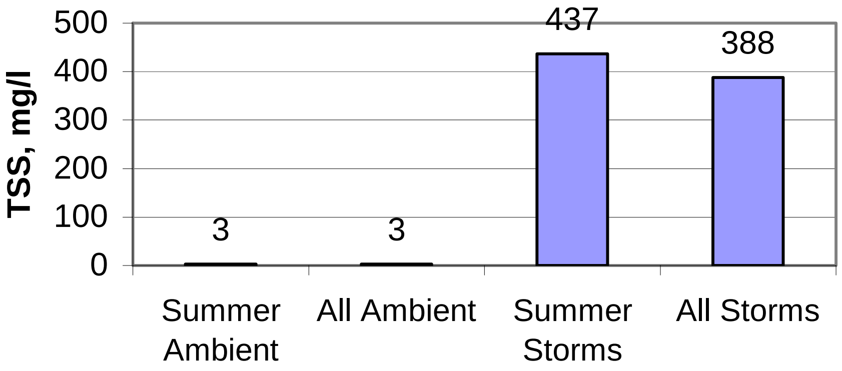
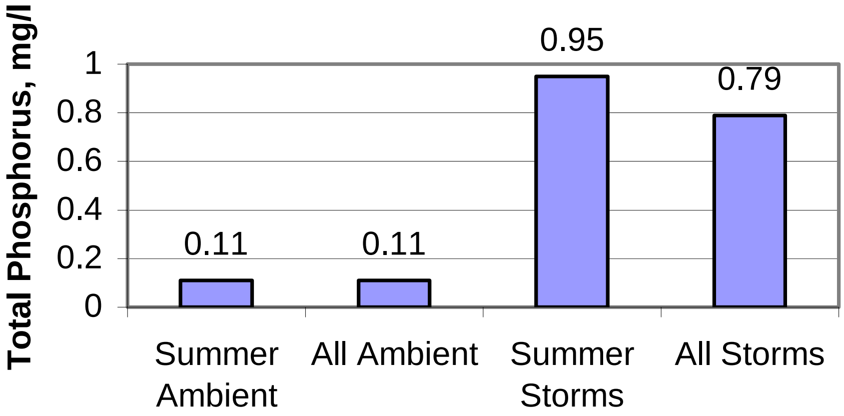


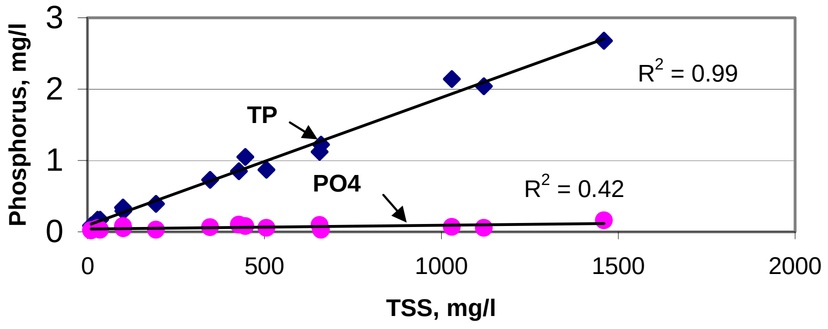
Figure 5-10
Median Total Phosphorus Concentrations
Fanno Creek at SW 56th



The median phosphorus concentrations as measured instream at this location are 0.95 mg/l for monitored summer storm events and 0.79 mg/l for all monitored storms. These storm event concentrations are six to seven times higher then the basin instream TMDL target concentration of 0.13 mg/l total phosphorus for all runoff sources.

Figure 5-11 shows the strong correlation between increased TSS and total phosphorus concentrations during storm events. Total phosphorus (TP) concentrations vary directly with increasing TSS concentrations. Conversely, dissolved orthophosphate (PO4) concentrations do not show a direct relation to TSS and remain relatively constant during storm events

Figure 5-11
Total and Dissolved Phosphorus Event Mean Concentrations vs TSS



Instream stormwater monitoring has not been conducted at other locations within the Fanno mainstem subwatershed or other tributaries. However, results of routine ambient water quality monitoring at these other sites during wet weather periods indicate a similar response to total phosphorus and TSS concentrations during storm events.

The results of the instream storm event monitoring are useful as a measure of overall water quality and for evaluating attainment of water quality standards and subbasin TMDL goals. However, they cannot be used to directly evaluate the City's WLA for total phosphorus, which applies to direct discharges of runoff from the City's municipal separate storm sewer system. The instream sampling results also reflect other influences on water quality, including erosion, instream processes such as downcutting of stream channels and resuspension of sediments, and other non-point sources that discharge directly to the stream. All of these other factors have been observed to occur within this subwatershed.

Land Use-Based Water Quality Monitoring

Land use-based water quality monitoring consists of monitoring runoff discharges from known land uses to quantify the pollutant loading from those land uses. The resulting pollutant loading rates can be used to assess the direct loads to the City's storm sewer system and therefore can be used more directly than instream water quality data to evaluate the City's WLAs. Land use-based water quality data are available from several sources. One source is the extensive stormwater monitoring programs conducted by BES and other public agencies as part of their NPDES stormwater permit programs. The purpose of that monitoring was to characterize pollutant loads from different land uses. In 1996, the Association of Clean Water Agencies (ACWA) published a report that analyzed the data collected by agencies throughout Oregon. Figures 5-12 and 5-13 show the median event mean concentrations (EMCs) for TSS and total phosphorus (TP) from the ACWA database. The EMC values are shown for open space, single-family residential, multi-family residential, commercial, and highway land uses, which are the predominant land uses within the Fanno Creek Watershed.

Figure 5-12
TSS EMCs by Landuse

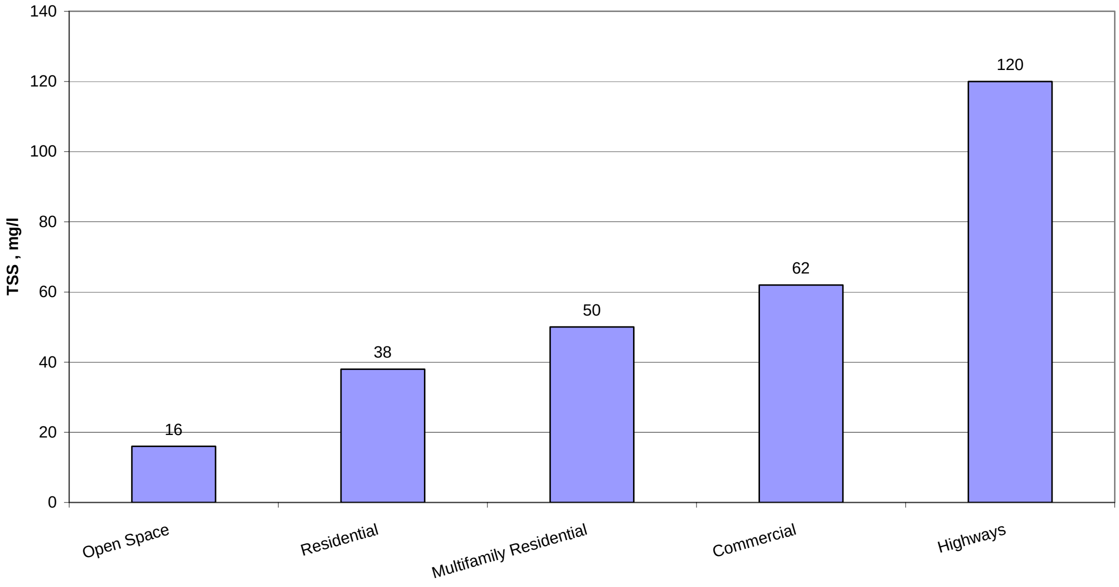
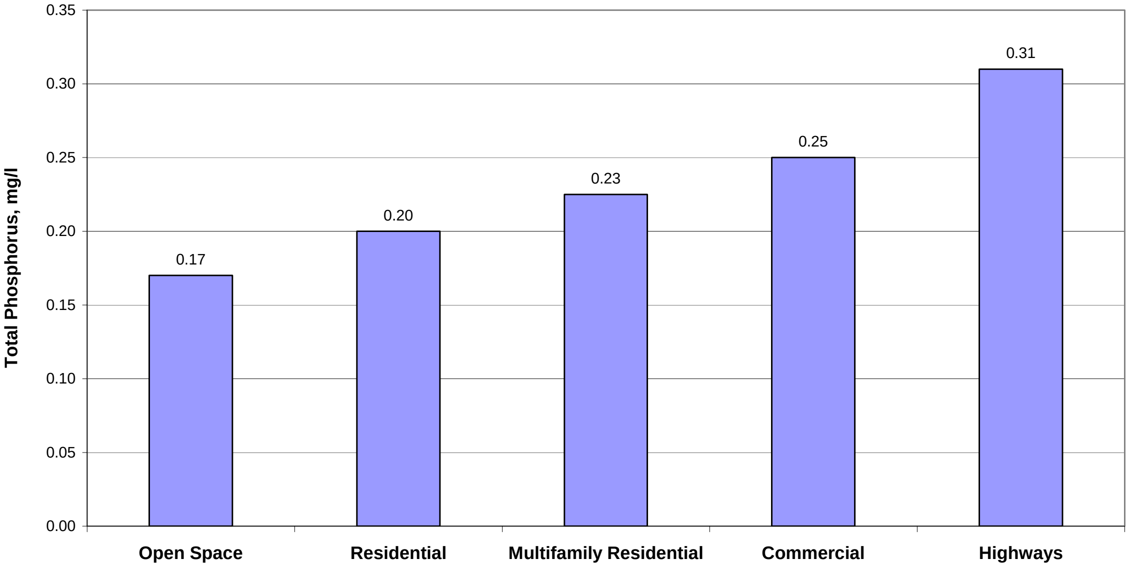
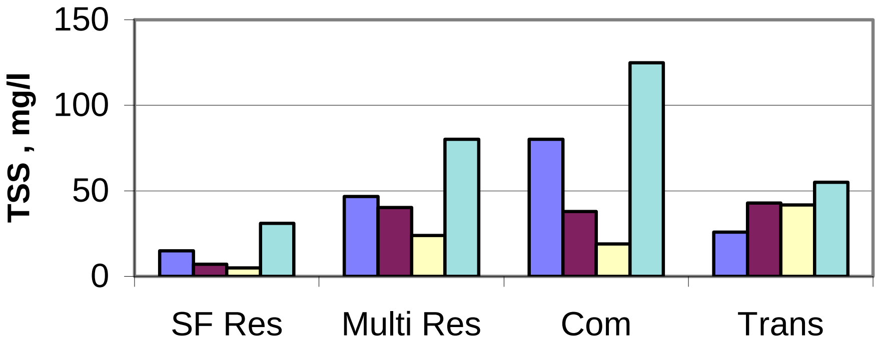


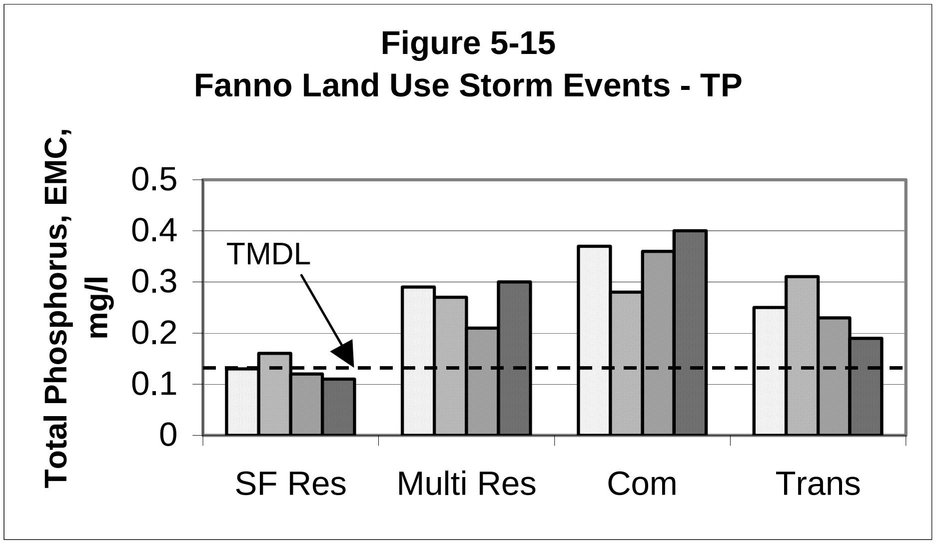
Figure 5-13
Total Phosphorus EMCs by Landuse



Another source of land use-based water quality data is the storm monitoring project in the Fanno Creek and Tryon Creek Watersheds (described above in the Water Quality Monitoring Program section). The objective of this project was to more accurately characterize pollutant loading from predominant land uses within these watersheds, including residential, multi-family residential, commercial, and transportation land uses. Four sampling locations were established, corresponding to these four land uses. Four storm events were monitored at these locations between September 2000 and January 2001. The samples were collected from locations in the MS4 collection system. Figures 5-14 and 5-15 show event mean concentrations from this monitoring for total suspended solids and total phosphorus, respectively.

Figure 5-14
Fanno Land Use Storm Events - TSS





As shown in Figure 5-15, the total phosphorus EMC for the single-family residential land use was equal to the WLA of 0.13 mg/l. The EMCs for the other land uses were above the WLA of 0.13 mg/l; however, the relative magnitudes among land uses are similar to the NPDES storm event sampling results collected by ACWA (see Figure 5-13). It should be noted that most of the sampled storms were not in the summer regulatory period for the TMDL. Figure 5-16 compares the ACWA data and the Fanno/Tryon storm sampling for total phosphorus.

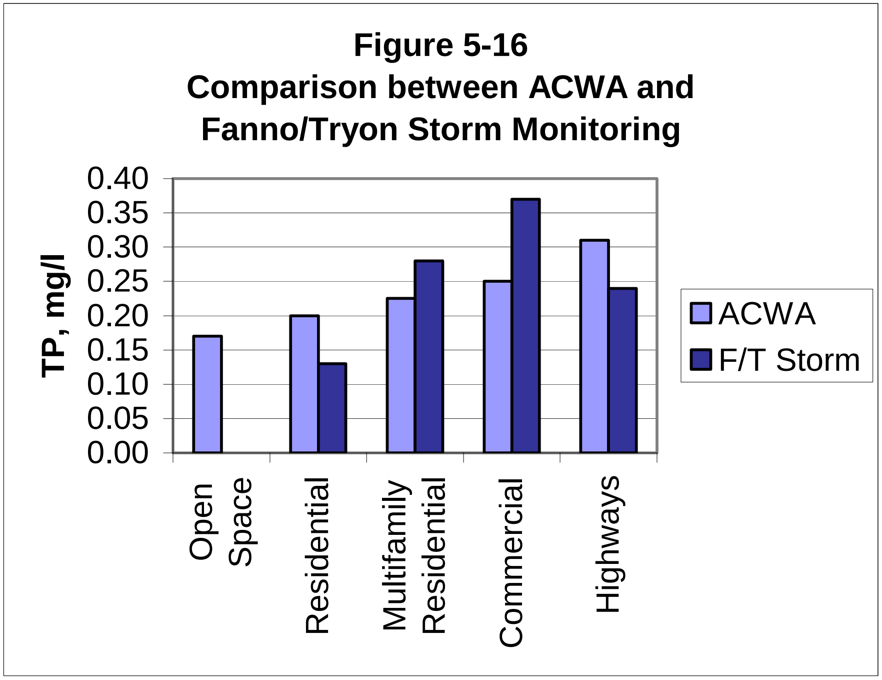


Table 5-8 summarizes the total phosphorus land use loadings from the two data sets (Fanno-Tryon storm monitoring and ACWA) and compares them to the total phosphorus TMDL waste load allocation.

Table 5–8
Total Phosphorus Loadings by Land Use
Median EMCs, mg/l

Land Use	ACWA	Fanno Storm	% of TMDL*
Open Space	0.17	--	131
Residential	0.20	0.13	100-154
Multi-family	0.22	0.28	169-215
Commercial	0.25	0.37	192-285
Highways	0.31	0.24	185-238

* WLA = 0.13 mg/l total phosphorus

As shown, there is general agreement between the ACWA and Fanno/Tryon storm monitoring results. All of the land uses fall within the range of 100-285 percent of the TMDL target of 0.13 mg/l. This is in contrast to the instream monitoring results for Fanno Creek at SW 56th Avenue (described above), which show a 731 percent exceedance of the target. The instream results are consistent with the previous analysis conducted as part of the ACWA data review, which found the monitoring results from the SW 56th Avenue location to be statistically different from other residential land use sites. It was hypothesized at the time that the difference might be explained by the site's physical characteristics and the fact that it was the only instream station. The instream phosphorus and total suspended sediment concentrations observed at the SW 56th Avenue site also may not reflect only land use loading. Other factors, such as instream processes, resuspension of sediment, erosion, other non-point source loadings, and the collection system, may be significant sources of the observed loads.

GIS GRID MODEL RESULTS

As discussed under the Water Quality Monitoring section above, BES has developed a GIS-based model for estimating pollutant loading potential. The model uses a grid system for delineating areas to be evaluated, which is compatible with the DHI MIKE 11 and MIKE SHE hydraulic and water quality models. For the Fanno basin, the grid model breaks the area into 100-foot by 100-foot grids. The model then uses a combination of land use, physical data (e.g., impervious area, vegetation, soils, slope), and rainfall data to predict the potential pollutant loading from each grid. For the Fanno basin analysis, the median pollutant load values from the ACWA stormwater database (described above) were used to estimate land use pollutant loads. See Map 12-Fanno Creek Total Suspended Solids Maps by Subwatershed and also Map 13-Fanno Creek Total Phosphorus Maps by Subwatershed in the Map Atlas.

Findings from analysis of the grid modeling include the following:

- As expected, areas with concentrations of commercial and multi-family land uses show up as areas with higher potential pollutant loads.

- The major transportation corridors (Interstate 5 and SW Beaverton Hillsdale Highway) show up as areas with higher potential pollutant loads.

- The street systems tend to show higher potential pollutant loads.

- Because of the homogenous land use within the watershed (80 to 90 percent residential), many areas have similar potential pollutant loads.

- Further analysis is required to correlate the pollutant loading potential with proximity to streams and the conveyance system.

- The Grid model does not account for changes to pollutant loadings from effects of flow routing or pollutant decay.

EXISTING SOURCES

The major contributing sources of phosphorus during runoff periods include industrial, commercial, and residential impervious areas and transportation areas (roads). On a different scale, rural areas, parks, and vacant lands also contribute to the overall phosphorus loading. The volume of runoff from non-urbanized watersheds is generally less than from urbanized watersheds for an equal amount of rain and land area, and the pollutant concentrations are different. The amount of precipitation necessary to cause runoff is greater in non-urbanized watersheds than in urbanized watersheds, and the relationship is more dependent on the antecedent rainfall. It has been estimated that rural residential sources of phosphorus typically have the same concentrations as single-family residential sources, although the amount of runoff from rural runoff sites is less.

Total phosphorus concentrations were less than 0.2 mg/l at nearly 80 percent of the sites measured in the Fanno Creek subwatershed during the 1996 sampling, suggesting that groundwater base flow could account for most of the phosphorus present during non-runoff periods. Concentrations of total phosphorus throughout the subwatershed also correlated positively with barium, iron, and aluminum), suggesting a common geological source of these constituents, such as would be present in groundwater (USGS 2000).

Temperature TMDL

LOAD ALLOCATIONS (LA)

The temperature standard for the Tualatin subbasin mandates that no measurable surface water temperature increase resulting from anthropogenic (human) activities is allowed:

a) In a basin for which salmonid rearing is designated as a beneficial use, and in which surface waters exceed the 64° F (17.8° C) criterion needed for fish survival.

b) In waters and periods of the year determined by DEQ to support native salmonid spawning, egg incubation, and fry emergence from the gravels in a basin, which exceeds 55° F (12° C).

c) In waters determined by the State to be ecologically significant cold water refugia.

d) In stream segments containing federally listed threatened and endangered species.

e) In Oregon waters when the dissolved oxygen (DO) levels are within 0.5 mg/l or 10 percent saturation of the water column or intergravel DO criterion.

f) In natural lakes.

Nineteen stream segments in the Tualatin River subbasin were listed on the 1998 303(d) list for water temperature violations. The listed stream segments included Fanno Creek and its tributaries and Cedar Mill Creek. Both streams were listed for their entire length from mouth to headwaters, based on the 17.8° C (64° F) salmonid rearing criterion. A TMDL for temperature was established in 2001.

The water quality standard mandates a loading capacity based on the condition that meets the no measurable surface water temperature increase resulting from anthropogenic activities. This condition is termed *system potential* and is achieved when (1) nonpoint source solar radiation loading is representative of a riparian vegetation condition without human disturbance, and (2) point source discharges cause no measurable temperature increases in surface waters. Table 5-9 summarizes the temperature TMDL LAs.

Table 5-9
Temperature Allocation Summary

Nonpoint Sources	
Source	***Load Allocation***
Background	System Potential
Anthropogenic Sources (Urban, Rural, Transportation)	0 (No measurable increase)

In Fanno Creek and its tributaries, DEQ calculated solar radiation by using system potential riparian vegetation, at current channel and stream aspect conditions. The solar radiation loading at system potential is much less than levels currently observed on Fanno Creek (DEQ 2001).

The Tualatin River subbasin temperature TMDL uses “effective shade” as a surrogate measure of solar heat loadings to assess system potential. The TMDL defines effective shade as the percent reduction of potential solar radiation load delivered to the water surface. The TMDL therefore uses effective shade as a linear translator for solar loading capacity.

The DEQ analysis focused on the lower reaches of Fanno Creek and its tributaries downstream from the City of Portland. However, the analysis indicated that the upper reaches of Fanno Creek might be close to the system potential as measured by effective shade. Based on an assumed near-stream disturbance zone of less than 50 feet, the potential effective shade for

Fanno Creek and its tributaries within the City of Portland would be greater than 90 percent (DEQ 2001, p. 55).

EXISTING CONDITIONS ASSESSMENT

TEMPERATURE MONITORING RESULTS

BES installed and has maintained continuous temperature recorders at two locations in the Fanno Creek Watershed since 1988: the Fanno Creek mainstream at SW 56th Avenue and the Woods Creek tributary at Hideaway Park. Hourly temperature data are collected at these two sites during the summer period (May through October).

Figures 5-17 and 5-18 show the results of the temperature monitoring at these two locations compared to the 17.8° C temperature standard (measured as the seven-day average of the maximum daily temperature) for salmonid rearing. The monitoring results are also summarized in Tables 5-10 and 5-11.

Figure 5-17

7-Day Ave Max Temperature

Fanno Creek at SW 56th Avemue

1998 - 2002

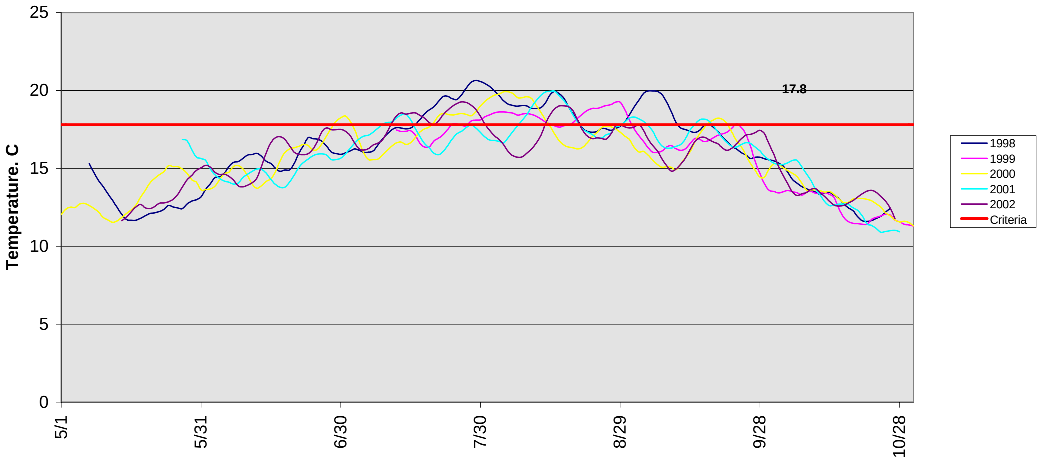


Figure 5-18

7-Day Ave Max Temperature

Woods Creek at Hideway Park

1998 - 2002

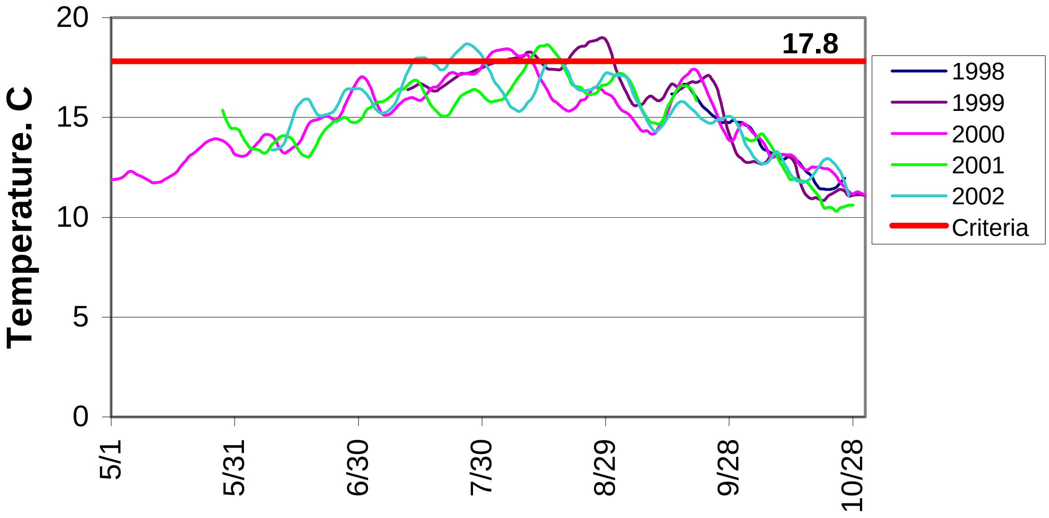


Table 5-10

Summer Temperature Monitoring: Fanno Creek at SW 56th Avenue

Summary 1998-2002

	1998	1999	2000	2001	2002
Max Temperature	22.0	19.7	21.0	20.8	20.5
Day of Maximum	July 28	August 28	July 31	August 12	August 13
Days > Standard	48	34	34	29	31
First date > Std.	July 17	August 3	July 31	August 11	July 14
Last Date > Std.	Sep 10	August 31	August 11	August 18	August 18

Table 5-11

Summer Temperature Monitoring: Woods Creek at Hideaway Park

Summary 1998-2002

	1998	1999	2000	2001	2002
Max Temperature	Incomplete Data Set	19.4	19.2	19.2	19.2
Day of Maximum		August 24	July 31	August 12	July 22
Days > Standard		21	12	8	16
First date > Std.		August 3	July 31	August 11	July 14
Last Date > Std.		August 31	August 11	August 18	August 18

The monitoring results from both sites show exceedences of the 17.8° C criterion during the summer period. The Fanno Creek site averaged more days of exceedence than the Woods Creek site: 35 days versus 14 days. The highest temperatures at both sites were generally during the period from mid-July until the end of August. This period corresponds to the highest yearly ambient temperatures and solar heat loading to the streams.

ASSESSMENT OF EXISTING SHADE

The Oregon Department of Fish and Wildlife (ODFW) collected shade data as part of the stream habitat surveys conducted for BES in 2001. These surveys were conducted for the mainstem of Fanno Creek, Vermont Creek, Woods Creek, North Ash Creek, and South Ash Creek.

The shade data were collected using a clinometer from the midpoint of the stream channel and measuring the shade angles for both sides of the channel. Results are recorded as a percentage of a 180-degree arc that is shaded (percent shade). The “percentage shade” is not the same as “effective shade”; the latter determines the percentage of actual solar radiation shaded from the stream by taking into account additional factors such as solar radiation, stream aspect, and channel width. However, the percentage shade still provides a good measure of the existing vegetative shade and a qualitative estimate of the effects on stream temperature.

See Map 14– ODFW Suvery Results by Subwatershed in the Map Atlas.

Table 5-12 summarizes the ODFW survey shade results.

Table 5-12
Existing Shade
Oregon Department of Fish & Wildlife 2001 Shade Survey

Stream	Reach	Length (m)	Shade (%)	Range (%)
Fanno Creek	1	1,641	94	61-100
Fanno Creek	2	768	88	39-100
Fanno Creek	3	919	86	31-100
Fanno Creek	4	614	85	22-100
Fanno Creek	5	1,091	94	67-100
Fanno Creek	6	630	99	89-100
		Average	***90***	
Vermont Creek	1	2,555	79	22-100
Vermont Creek	2	1,098	91	47-100
		Average	***91***	
Woods Creek	1	2,877	79	11-100
Woods Creek	2	1,916	91	58-100
		Average	***85***	
North Ash Creek	1	2,906	87	28-100
North Ash Creek	2	720	89	53-100
		Average	***89***	
Ash Creek	1	2,693	47	11-100
Ash Creek	2	1,007	91	61-100
Ash Creek	3	1,766	90	35-100
		Average	***90***	

Notes: Shaded reaches are partially or totally outside the City.
Averages are for reaches within the City.

As shown on the ODFW survey shade maps and summarized in Table 5-12, all these streams have good existing shade, with the average percent shade values ranging from 85 to 91 percent. As also seen on the figures, areas with lower percent shade values tend to be short, localized stream segments.

Shade data are not currently available for other locations within the Fanno Creek Watershed, but the above results are expected to be generally representative of the overall watershed.

TMDL EXCEEDENCES

Measurements of effective shade are not currently available for Fanno Creek or its tributaries; therefore, a direct evaluation of the TMDL effective shade requirement is not possible. Available percent shade data indicate generally good existing shade conditions in the watershed.

*Temperature monitoring data, however, show that the temperature water quality standard, based on the 17.8^o C criterion for salmonid rearing, is exceeded during the summer at locations within the Fanno Creek Watershed.

LOAD REDUCTION REQUIREMENTS

The temperature TMDL requires the establishment of system potential effective shade for Fanno Creek and its tributaries. The system potential is estimated to be approximately 90 percent effective shade.

SOURCE IDENTIFICATION

Solar radiation is the major source of heat that causes the water quality standard for temperature in Fanno Creek and its tributaries to be exceeded. The existing solar heat loading to the streams is elevated as a result of altered natural riparian vegetation conditions.

Other anthropogenic sources of heat to these streams have not been identified or quantified.

There are no identified point source discharges of heat to Fanno Creek or its tributaries within the City of Portland.

Bacteria TMDL

The water quality standard for bacteria states that organisms of the coliform group commonly associated with fecal sources shall not exceed:

a) A 30-day log mean of 126 E. *coli* organisms per 100 ml, based on a minimum of five samples.

b) No single sample shall exceed 406 E. *coli* organisms per 100 ml.

Water contact recreation is the most sensitive beneficial use related to bacteria in the Tualatin River subbasin, including Fanno Creek and its tributaries.

The 1998 303(d) list identified Fanno Creek as exceeding the bacteria standard throughout the entire year.

DEQ's analysis for the bacteria TMDL in Fanno Creek and its tributaries was broken down into two broad categories: bacteria from runoff sources, and bacteria from other sources. The allocations for runoff sources are based on a computer model that estimates the bacteria coming off specific land uses during rain events. The reductions necessary to achieve the state's bacteria standard are derived from this modeling and are then used as the basis for allocations. Allocations for non-runoff periods are based on an analysis of instream bacteria levels and the percent reductions necessary to achieve standards.

DEQ based its model calibrations on allocations set for two storm events: a winter storm in which the cropland and forests would be saturated and contribute runoff, and a summer event in which the soil was dry and only impervious (commercial, industrial, and residential) areas contribute to instream concentrations (DEQ 2001).

Based on the DEQ modeling, the bacteria TMDL was developed on a seasonal basis, with TMDLs set for the summer period (May 1 – October 31) and the winter period (November 1 – April 31).

LOAD ALLOCATION (LA)

The TMDL does not establish a bacteria (E. *coli*) load allocation (nonpoint sources) for the City of Portland.

EXISTING CONDITIONS ASSESSMENT

BES monitors E. *coli* concentrations in the Fanno Creek Watershed as part of its ambient water quality monitoring program (described previously). Tables 5-13 and 5-14 summarize the results of this monitoring for sites on the Fanno Creek mainstem and tributaries within the City of Portland for the summer and winter regulatory periods, respectively.

The monitoring results show frequent exceedences of water quality standards for E. *coli* bacteria. The median summer E. *coli* concentration at all sites, except the SW 39th Avenue site on Fanno Creek mainstem and the South Ash Creek tributary, exceed the water quality standard of 406 counts/100 ml during non-runoff periods. These sites therefore do not meet the water quality criteria for approximately 50 percent of the samples collected during the summer period. The SW 39th Avenue site and the South Ash Creek site exceed the water quality criteria approximately 25 and 10 percent of the time, respectively.

The monitoring results show that the E. *coli* concentrations are lower during the winter season; the water quality criteria are exceeded between 10 and 25 percent of the time at all sites except the South Ash Creek location.

Figure 5-24 compares the summer and winter median E. *coli* concentrations for all sampling locations.

Table 5-13
Summer (May – October) E. *Coli* Concentrations (counts/100 ml)

Percentile	Fanno Creek			Tributaries					
	SW 69th	SW 56th	SW 39th	Pendleton	Vermont	Woods	N. Ash	S. Ash	Cedar Mill
10%	**218**	**218**	64	98	138	218	156	20	115
25%	**325**	**350**	120	193	230	325	235	37	258
50%	**600**	**820**	**280**	**430**	**550**	**570**	**540**	81	**450**
75%	**1,425**	**1,200**	**760**	**950**	**1,150**	**1,500**	**920**	223	**1,085**
90%	**6,000**	**3,190**	**4,600**	**3,820**	**5,100**	**4,110**	**3,550**	**719**	**3,970**

Note: Shaded values indicate concentrations greater than the 406 count/100ml water quality criterion for single grab samples. Bold values indicate concentrations greater than the 126 counts/100ml water quality criterion for a 30-day geometric mean.

Table 5-14
Winter (November – April) E. *Coli* Concentrations
(counts/100 ml)

Percentile	Fanno Creek			Tributaries					
	SW 69th	**SW 56th**	**SW 39th**	**Pendleton**	**Vermont**	**Woods**	**N. Ash**	**S. Ash**	**Cedar Mill**
10%	63	73	31	20	39	40	71	10	98
25%	**130**	120	**150**	33	**200**	100	**130**	20	**130**
50%	**280**	**330**	**330**	**130**	**370**	**270**	**280**	20	**400**
75%	**740**	**620**	**780**	**180**	**1,200**	**350**	**680**	**130**	**1,100**
90%	**1,620**	**1,880**	**2,100**	**796**	**3,400**	**1,312**	**1,180**	**352**	**2,680**

Note: Shaded values indicate concentrations greater than the 406 count/100ml water quality criterion for single grab samples. Bold values indicate concentrations greater than the 126 counts/100ml water quality criterion for a 30-day geometric mean.

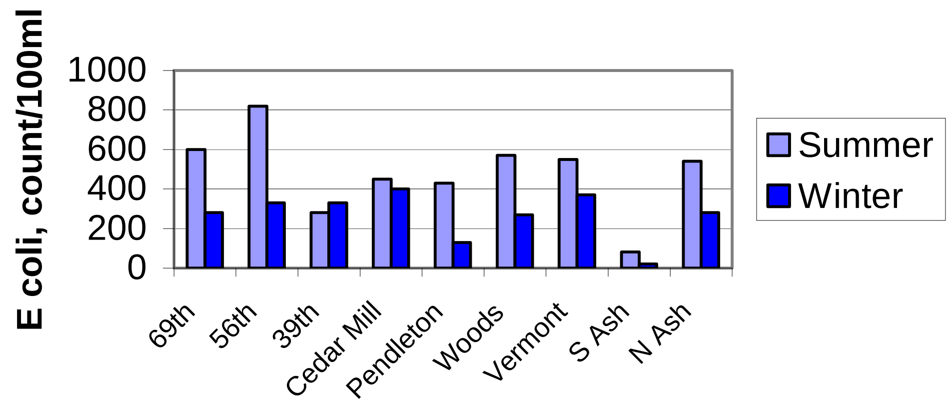


Figure 5-24
Median E. *Coli* Concentrations

WASTE LOAD ALLOCATION (WLA)

Tables 5-15 and 5-16 show the WLAs for E. *coli* bacteria assigned to the City of Portland for discharges from the City's municipal separate storm sewer system (MS4) for summer and winter regulatory periods, respectively.

Table 5-15
Summer (May 1 – October 31) Waste Load Allocations for Discharges from Municipal Separate Storm Sewer Systems

Designated Management Agency	**5th –Field Subbasin**	**Waste Load Allocation – E. *coli* counts/100 ml**	
City of Portland	All Land Uses/ Covered by MS4 Permits	During Runoff Events (measured as event mean concentration)	All Other Times (measured as a grab sample)
	Lower Tualatin	12,000	406

Source: DEQ, January 2001, Tualatin Subbasin Total Maximum Daily Load (TMDL), Table 17

Table 5-16
Winter (November 1 – April 31) Waste Load Allocations for Discharges from Municipal Separate Storm Sewer Systems

Designated Management Agency	**5th –Field Subbasin**	**Waste Load Allocation – E. *coli* counts/100 ml**	
City of Portland	All Land Uses/ Covered by MS4 Permits	During Runoff Events (measured as effective mean concentration)	All other times (measured as a grab sample)
	Lower Tualatin	5,000	406

Source: DEQ, January 2001, Tualatin Subbasin Total Maximum Daily Load (TMDL), Table 18

EXISTING CONDITIONS ASSESSMENT

The City of Portland's waste load allocations apply only to discharges from the City's municipal separate storm sewer system. The best available measure of existing conditions is the land use-based stormwater monitoring (described previously). Figure 5-25 shows the results of land use storm event monitoring in the Fanno and Tryon Creek Watersheds, and Table 5-17 summarizes the results.

Figure 5-25
Fanno/Tryon Storm Monitoring: E. *Coli*

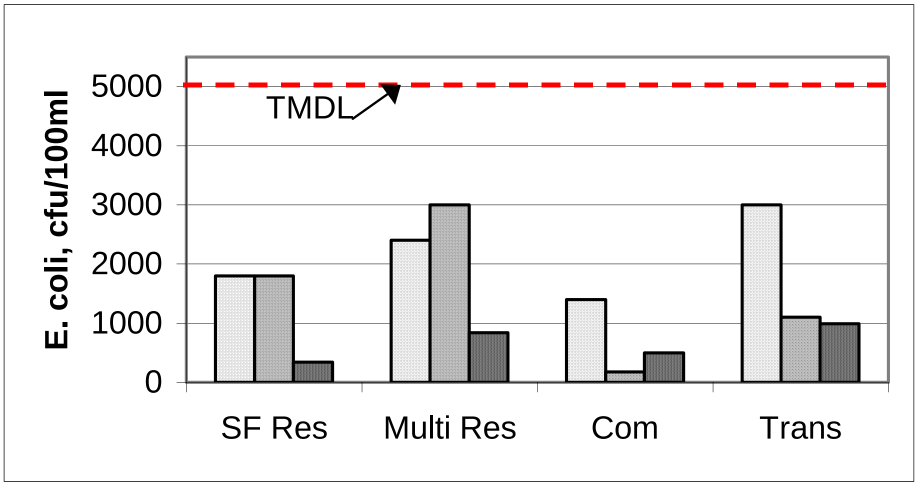


Table 5-17
Fanno/Tryon Storm Monitoring: E. *Coli*
(cfus/100 ml)

	Land Use			
Storm Date	***Single-Family Residential***	***Multi-Family Residential***	***Commercial***	***Transportation***
9/25/01	1,800	2,400	1,400	3,000
11/13/01	1,800	3,000	180	1,100
1/18/02	340	840	500	990
Mean	1,300	2,080	690	1,700
WLA	5,000	5,000	5,000	5,000
% WLA	26%	42%	14%	34%

Notes: WLAs based on effective mean concentrations.
All storm samples were grab samples.

As shown, all the monitored E. *coli* concentrations for all land uses during these three storm events were well below the winter season WLA. The monitored land uses represent the major land uses within the Fanno Creek Watershed. A comparison of the mean E. *coli* concentrations by land use to the WLA (based on an effective mean concentration) shows the values to be from 14 to 34 percent of the WLA concentration. These results are consistent with the results discussed previously for instream storm event E. *coli* concentrations. Based on these results, it is expected that the WLAs would be met for typical storm events at these sites.

TMDL EXCEEDENCES

LOAD ALLOCATION (LA)

No LA for City of Portland

LOAD REDUCTION REQUIREMENTS

Although the bacteria TMDL does not identify a LA for the City of Portland, the results of ambient water quality monitoring in the Fanno Creek Watershed show that a reduction in bacteria loads will be required during non-runoff periods to meet the state water quality standard for bacteria (E. *coli*).

SOURCE IDENTIFICATION

Potential pathways of human sewage to surface waters may include sanitary sewer overflows, illegal sanitary connections to storm drains, transient dumping of wastewater into storm drains, and failing septic systems (Center for Watershed Protection 1999).

Documented non-human sources of fecal coliform bacteria in urban watersheds are dogs, cats, raccoons, rats, beaver, gulls, geese, and pigeons. According to van der Wel (1995), a single gram of dog feces contains 23 million fecal coliform bacteria. Dogs have also been identified as significant hosts for giardia and salmonella. (Center for Watershed Protection 1999).

Greater outdoor physical activity by humans and pets during warm summer months and more continuous diluting rainfall/runoff during winter months are the most likely causes of the seasonal variations in the bacteria indicator species. The warm-weather increases in bacteria concentrations are not likely to be caused by bacterial mortality in cold weather. Research into survival of enteric bacteria in aquatic environments suggests that cold water favors the survival of bacteria by reducing their metabolic requirements under circumstances where fewer nutrients are available, compared to the mammalian guts where they have evolved (Center for Watershed Protection, 1999).

No specific sources of bacteria for the Fanno Creek Watershed have been identified.

Dissolved Oxygen TMDL

The standards for the Tualatin subbasin mandate that the following dissolved oxygen (DO) criteria be met:

a) For water bodies identified by DEQ as providing cold-water aquatic life, the dissolved oxygen shall not be less than 8.0 mg/l as an absolute minimum.

b) For water bodies identified by DEQ as providing cool-water aquatic life, the dissolved oxygen shall not be less than 6.5 mg/l as an absolute minimum.

A total of 22 stream segments in the Tualatin subbasin were listed on the 1998 303(d) list for not meeting the DO criteria, including Fanno Creek and Ash Creek. The 303(d) listings that were the basis for the DO TMDL were based on the cool-water criteria. Subsequently, some tributaries within the Tualatin basin were designated as providing cold-water aquatic life, including Fanno Creek and Ash Creek. The TMDL DO allocations were based on meeting the cold water criteria.

LOAD ALLOCATIONS (LA)

During development of the TMDL, DEQ determined that load reductions were required for ammonia, sediment oxygen demand (SOD), and temperature to meet the DO criteria in the mainstem Tualatin River and the subbasin tributaries, including those within the City of Portland. The continued control of algal blooms is also necessary (total phosphorus TMDL). Table 5-18 shows the LAs for SOD, as measured by settleable volatile solids. (Previous sections of this chapter address total phosphorus and temperature.) DEQ assumed that the implementation of temperature TMDL management measures would also result in meeting the settleable volatile solids LA.

Table 5-18
Tualatin River Subbasin Load Allocations for Settleable Volatile Solids
(Applicable May 1 – October 31)

Designated Management Agency (DMA)	Stream	Load Allocation
City of Portland	Fanno Creek Ash Creek	50% reduction of settleable volatile solids in runoff.
City of Portland	All other streams	20% reduction of settleable volatile solids in runoff.

Source: DEQ, January 2001, Tualatin Subbasin Total Maximum Daily Load (TMDL), Table 37

EXISTING CONDITION ASSESSMENT

BES does not currently have data on existing concentrations of settleable volatile solids for current nonpoint sources or for discharges from the MS4 system. Data were also not available for other Tualatin Basin streams during TMDL development. Because of the lack of settleable volatile solids data, DEQ and the DMAs anticipated that the allocations would initially be based on a similar parameter for which data were available. The DEQ proposal that total suspended solids (TSS) be used for this purpose is still under discussion.

Summary of Results

Fanno Creek and its tributaries within the City of Portland exhibit many of the characteristics of many urban streams as a result of changes in hydrology, increased pollutant loadings, and other anthropogenic effects. These characteristics include altered flow patterns and degraded water quality.

The degradation in water quality and resulting impacts on watershed function and health are evident when evaluating the existing conditions using metrics such as the *Framework for Integrated Management of Watershed and River Health* guidelines or Oregon water quality index.

Specific water quality impairment within the Fanno Creek Watershed includes established Total Maximum Daily Loads (TMDLs) for total phosphorus, temperature, dissolved oxygen, and bacteria, as summarized below.

Total Phosphorus

- Summer instream concentrations generally meet TMDL requirements, with the exception of higher concentrations in the Vermont and Pendleton tributaries.

- Total phosphorus concentrations are elevated and exceed TMDL requirements during storm events. This results from a combination of land use effects and instream processes.

- Higher-density development (commercial, multi-family residential, and transportation land uses) tend to have higher total phosphorus loadings.

Temperature

- Summer instream temperatures exceed the water quality standard of 64 degrees F for the protection of salmonid fish rearing.

- Shading of the stream is the major factor controlling instream temperature.

- Stream temperatures are elevated despite generally good shade conditions within the watershed.

Dissolved Oxygen

- Dissolved oxygen concentrations are a concern during the summer.

- Low dissolved oxygen concentrations are caused by a combination of increased water temperature and the decay of organic matter in the stream.

- TMDL requirements are for a 50 percent reduction in volatile settleable solids.

Bacteria (E. *coli*)

- E *coli* concentrations exceed the water quality standard (406 counts/100ml) in over half the samples.

- Instream bacteria concentrations are higher in the summer than the winter.

- Bacteria concentrations are higher during runoff (rainfall) events.

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CHAPTER 6

Water Quality:
Tryon Creek Watershed

This chapter characterizes the water quality of the Tryon Creek Watershed. It includes:

- Background
- Water Quality Monitoring Program
- Water Quality Modeling
- Water Quality Assessment
- Modeling Results
- Summary

BACKGROUND

The Bureau of Environmental Services (BES) manages the public sanitary sewer collection and treatment facilities, monitors for water quality, and is responsible for the stormwater facilities located within Portland's portion of the Tryon Creek Watershed. BES is actively involved in the Tryon Creek Watershed Council and is working cooperatively with citizens, businesses, and other agencies to develop a Tryon Creek Watershed stewardship program.

Major BES milestones include development of the following documents:

- *Upper Tryon Creek Corridor Assessment (1997)* - This study consisted of a comprehensive assessment of the natural resources, channel conditions, and hydrology of the stream corridor upstream of Tryon Creek State Park including Tryon, Falling and Arnold Creeks.

- *Public Facilities Plan (1999)* – The 1999 Public Facilities Plan evaluated City facilities associated with storm and sanitary sewage service including treatment facilities. The plan identified system deficiencies and recommended projects.

In July 2000, BES initiated work on the comprehensive *Fanno and Tryon Creeks Watershed Plan.* The *Watershed Plan* will build on previous BES management efforts in the watershed, including addressing regulatory requirements of the Clean Water Act and the Endangered Species Act. (Tryon Creek is listed as water quality limited for temperature under Section 303(d) of the Clean Water Act.) The *Watershed Plan* will provide the technical/scientific basis for achieving and meeting specific watershed, stream, infrastructure, habitat, and water quality improvement and restoration objectives in the watershed. This water quality characterization is an important component of the *Watershed Plan.* (See the Introduction to this document for additional background information about the *Watershed Plan*.)

WATER QUALITY MONITORING PROGRAM

BES’s water quality monitoring program is a key component of the water quality characterization and is the major source of available water quality data for the characterization.

BES’s Water Pollution Control Laboratory provides sample collection, laboratory analyses, and flow monitoring services. The water quality monitoring program has five basic objectives:

- Determine recent and current water quality conditions to determine and compare compliance with water quality standards, criteria, TMDL limits, and support of beneficial uses.
- Determine general temporal trends in environmental conditions: increasing/decreasing, improving/degrading.
- Determine the effectiveness of specific environmental management activities and initiatives (e.g., best management practices).
- Understand pollutant sources and the relationship between land uses and water quality.
- Comply with regulatory requirements for monitoring and reporting.

Key elements of BES’s monitoring program for the Tryon Creek Watershed are described below:

Fixed-Station Water Quality Monitoring

BES has been monitoring instream water quality in Tryon Creek monthly since 1997. Initially, sampling was limited to one site located on the mainstem of Tryon Creek at SW Boones Ferry Road. This sampling site is located in the mid-part of the watershed, downstream from the major commercial and residential development. In December of 2004, two additional sampling locations were added in the upper Tryon Creek watershed where preliminary characterization analysis had identified priority areas for additional water quality data collection. These two sites are located on the mainstem of Tryon Creek upstream and downstream of the two major transportation corridors (Barbur Boulevard and I-5 Freeway) in the watershed. Figure 6-1 and Table 6-1 show the three current sampling sites. Water quality analyses include 14 field and laboratory parameters as shown in Table 6-2.

Figure 6-1
Tryon Watershed Sampling Locations

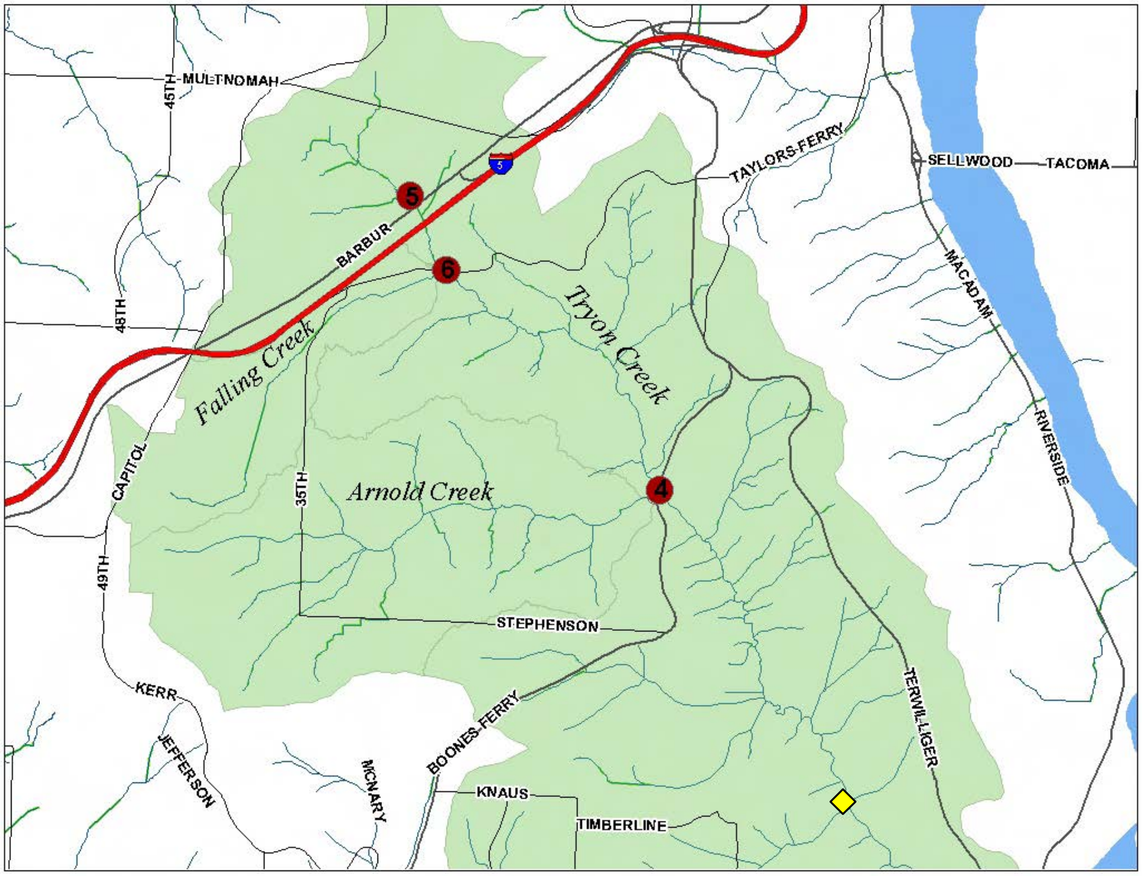


Table 6-1
Current BES Water Quality Monitoring Sites

Site	Description	Start	Frequency
4	Tryon Creek (10750 SW Boones Ferry Road)	8/19/97	Monthly
5	Upper Tryon Creek (SW 26th Way and Barbur Blvd.)	12/06/04	Monthly
6	Tryon Creek below Falling Creek (9323 SW Lancaster Road)	12/06/04	Monthly

Table 6-2
Water Quality Monitoring Summary for Tryon Creek

Parameter	Reporting Limit Units	Monitoring Frequency
Ammonia Nitrogen	1 mg/l	Monthly
Nitrate-Nitrogen	0.1 mg/l	Monthly
Nitrite–Nitrogen	0.01 mg/l	Monthly
Ortho Phosphorous	0.02 mg/l	Monthly
Total Phosphorous	0.03 mg/l	Monthly
Total Solids	1 mg/l	Monthly
Total Suspended Solids	1 mg/l	Monthly
E. *coli*	1 MPN/100ml	Monthly
Temperature[1]	Degrees Celsius	Hourly (May-Oct)
Dissolved Oxygen[1]	0.1 mg/l	Monthly
pH[1]	0.1	Monthly
Conductivity[1]	1 micro ohms/cm	Monthly
BOD5	2 mg/l	Monthly
Total Oil and Grease	5 mg/l	Monthly

[1] Field Measurement

Temperature Monitoring

BES installed and has maintained a continuous temperature recorder during the summer season (May through October) since 1998 at the Boones Ferry Road sampling location. The temperature recorder provides hourly temperatures at this site. Additional temperature recorder installations are scheduled for the other two sampling locations beginning in summer 2005.

Flow Monitoring

Through a cooperative agreement with BES, the U.S. Geological Survey (USGS) has maintained a streamflow monitoring station on Tryon Creek near Nettle Creek in the lower Tryon Creek Watershed since 2001 (USGS Gage 14211315). (Further discussion of flow monitoring results can be found in Chapter 4, Hydrology: Tryon Creek Watershed).

Fanno–Tryon Storm Monitoring Project

To further characterize pollutant loads from different land uses, BES established four stormwater sampling sites in the Fanno Creek and Tryon Creek Watersheds that represent the predominant land use types in these watersheds: residential, multi-family residential, commercial, and transportation (highways). A total of four storms were sampled at these sites between September 2000 and January 2001.

Additional storm event monitoring is scheduled for the three fixed station sampling sites during 2005 and 2006.

Data and Reporting

All of the collected water quality data are stored electronically in BES' Janus water quality data base and are available for retrieval, analysis, and reporting.

The water quality and flow data collected through this monitoring are used to determine the existing status of water quality in relation to state water quality standards and criteria. The monitoring is also essential for watershed planning and to assess the impact of various management activities in the watershed.

WATER QUALITY MODELING

Hydrologic/hydraulic and water quality models have been developed for the Tryon Creek Watershed to characterize water quality by better understanding streamflows and pollutant loadings. The current characterization uses the following models:

- **MIKE SHE/MIKE 11 (DHI):** MIKE SHE and MIKE 11 are integrated surface and groundwater programs that can be used to simulate hydrology, hydraulics, upland pollutant loadings, and instream water quality. MIKE SHE is a hydrologic model that converts precipitation falling on the watershed into runoff. MIKE 11 is a hydraulic model that routes runoff generated by MIKE SHE through modeled stream or conveyance system segments.

- **GIS/GRID Model:** BES developed this GIS-based model to estimate potential pollutant loadings within the watershed, based on factors that include land use, topography, impervious area, vegetation, soil type, slope, and precipitation. The model uses the same 100-foot by 100-foot grid areas used by the MIKE SHE/MIKE11 model as the basis for analysis.

WATER QUALITY ASSESSMENT

Tryon Creek and its tributaries within the City of Portland are small headwater streams located within an urban environment. They exhibit many of the characteristics typical of urban streams, which result from changes in hydrology and increased pollutant loadings from urban development. These characteristics include altered flow patterns and degraded water quality.

Point sources of pollution to Tryon Creek include two stormwater outfalls classified as major outfalls under the City's National Pollutant Discharge Elimination System (NPDES) stormwater permit: WCMS #3826 – 243D and WCMS # 3826-367D. Combined, these two outfalls drain an area of 368 acres (BES 1993) discharging directly into Tryon Creek at Interstate 5 and Barbur Boulevard and constitute the entire flow from the upper part of the watershed. The City is required to calculate seasonal pollutant load, investigate illicit connections, and evaluate the need for pollution reduction facilities for stormwater mitigation. Based on land use, these two outfalls contribute about 48 percent of the total suspended solids (TSS) entering Tryon Creek for both wet and dry seasons (as calculated by the NPDES stormwater program).

Nonpoint sources of pollution are managed through implementation of the City's NPDES stormwater permit. This includes tracking stormwater quality in the watershed through analyses of land use and best management practices (BMPs). BES has developed a priority pollutant matrix for the Tryon Creek Watershed, based on a stormwater quality load model. The matrix lists priority pollutants from various land uses. Elevated temperature, nutrients, and TSS are listed as high-priority pollutants in the watershed. This matrix helps select appropriate BMPs and management strategies to address stormwater quality issues.

Previous studies have shown that the Tryon Creek Watershed is seriously compromised because the large woody material has been depleted. The continued removal of wood from stream channels to facilitate recreation and facility maintenance destabilizes the channel and causes degradation. Under these conditions, each high-water event flows unchecked downstream, surging from side to side, eroding the streambank, and preventing the reestablishment of vegetation needed to help restabilize the channel. The loss of wood from these streams also affects the transport and storage of sediments. Large wood functions to temporarily store sediments within the channel. It also functions to slow and back up water, forcing flows out onto the floodplain area where sediments settle out. These deposits provide sites for vegetation to establish (National Riparian Service Team 2001).

This water quality characterization evaluates the water quality in the Tryon Creek Watershed from three perspectives:

- *Framework for Integrated Management of Watershed and River Health* guidelines
- Oregon water quality index
- Water quality standards/303(d) listed parameters

Framework Guidelines

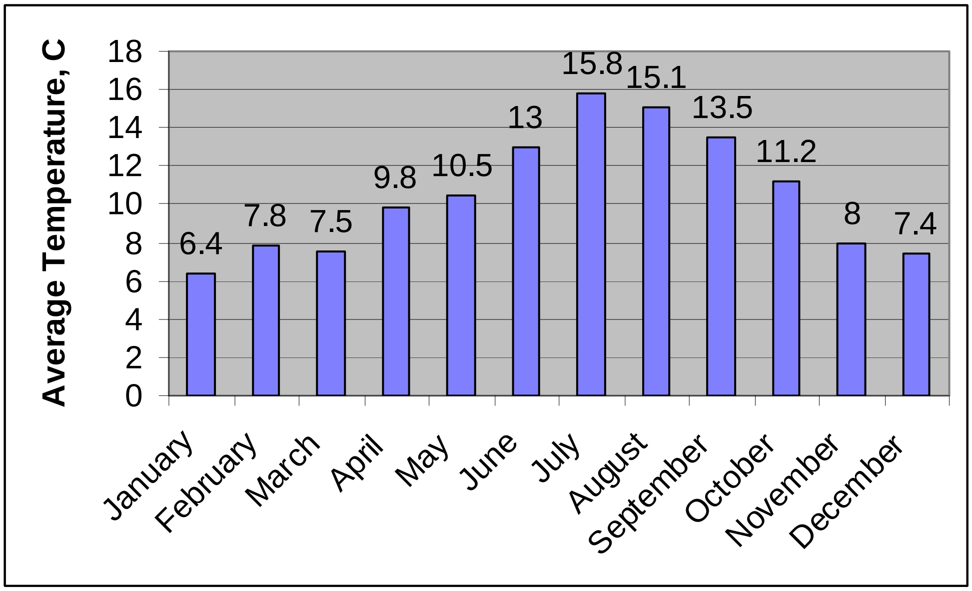
The City's Endangered Species Act (ESA) Program developed the *Framework for Integrated Management of Watershed and River Health* (Framework) in 2004. The *Framework* outlines scientific principles, four watershed health goals, and a process for developing and implementing watershed management plans. It identifies the following water quality indicators for evaluating watershed health:

- Temperature
- Dissolved oxygen
- Nutrients and chlorophyll a
- Total suspended solids
- Toxic contamination of water, sediment, and biota
- Groundwater quality
- 303(d) listed parameters
- Other parameters (as determined by the weight of evidence)

Specific watershed targets and metrics for evaluating these water quality indicators are currently being developed.

TEMPERATURE – Temperature is the only water quality indicator that does not currently meet water quality standards in the Tryon Creek Watershed. Figure 6.2 shows the average monthly temperatures based on the fixed station monitoring the Boones Ferry Road sampling location between 1997 and 2004.

Figure 6-2
Average Monthly Temperature[1]
Tryon Creek at Boones Ferry Road



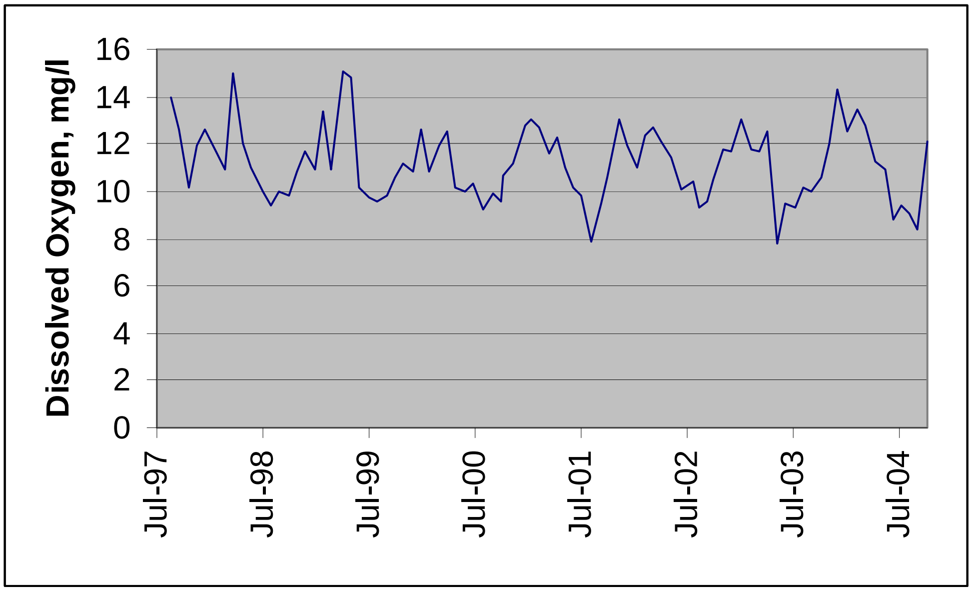
[1] Temperature data may not reflect maximum temperatures

Figure 6-2 shows the yearly cycle of instream temperatures. Solar radiation is the main source of heat resulting in maximum temperatures during July and August. (Note: the displayed temperature data is summarized from the monthly ambient water quality monitoring at this site which was conducted at different times of day and therefore, does not represent the maximum instream temperatures).

A total maximum daily load (TMDL) for temperature is being developed. Temperature is discussed in more detail in the Water Quality Standards/TMDLs section, below.

DISSOLVED OXYGEN – Figure 6-3 shows results of monitoring of dissolved oxygen in Tryon Creek at the SW Boones Ferry Road sampling location. The dissolved oxygen concentrations reported meet the water quality criteria of 8.0 mg/l for cold-water aquatic life. The lowest dissolved oxygen concentrations occur during the late summer and are primarily the result of increased instream water temperatures.

Figure 6-3
Dissolved Oxygen Concentrations
Tryon Creek at SW Boones Ferry Road



NUTRIENTS and CHLOROPHYLL *A* - Nutrients have not been identified as a water quality concern in Tryon Creek. Figure 6-4 shows the results of total phosphorus monitoring at the Boones Ferry Road site. The highest total phosphorus concentrations are typically correlated with increased suspended solids concentrations as a result of storm events. The median total phosphorus concentration for all samples was 0.085 mg/l. For comparison, the target TMDL total phosphorus concentration in the Fanno Creek Watershed for both background and stormwater discharges is 0.13 mg/l.

Figure 6-5 shows the results of monitoring for nitrate-nitrogen (NO_3-Nitrogen) at the Boones Ferry Road site. The figure shows an annual cycle of nitrate concentrations with peak concentrations during the wet season (November – January) consistent with earlier studies in the Willamette Basin (USGS 2003). It has been hypothesized that this is the result of flushing of nitrate from the shallow groundwater system as it becomes saturated in the winter.

Currently, there is no chlorophyll a data available for Tryon Creek.

Figure 6-4
Total Phosphorus Concentrations
Tryon Creek at Boones Ferry Road

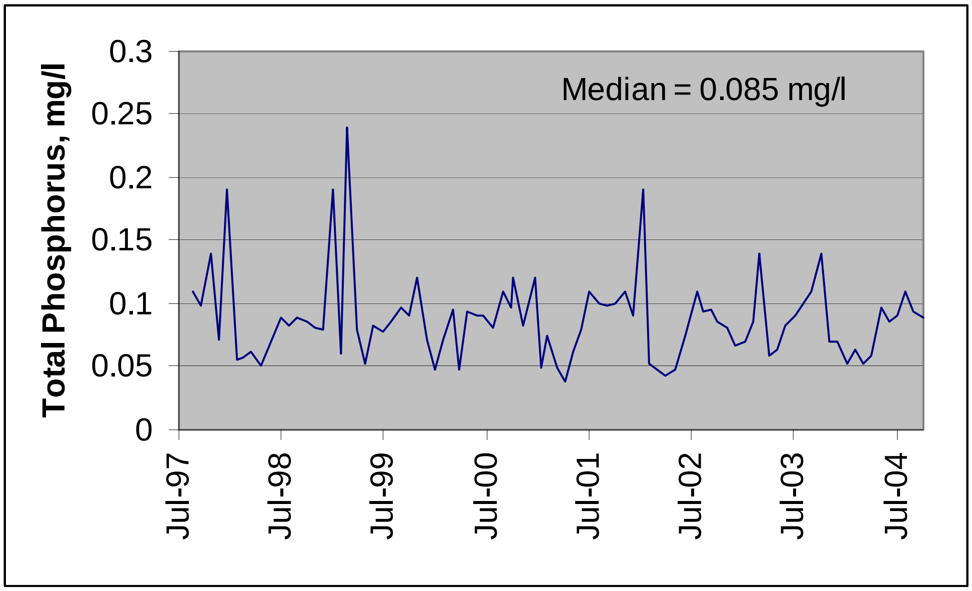
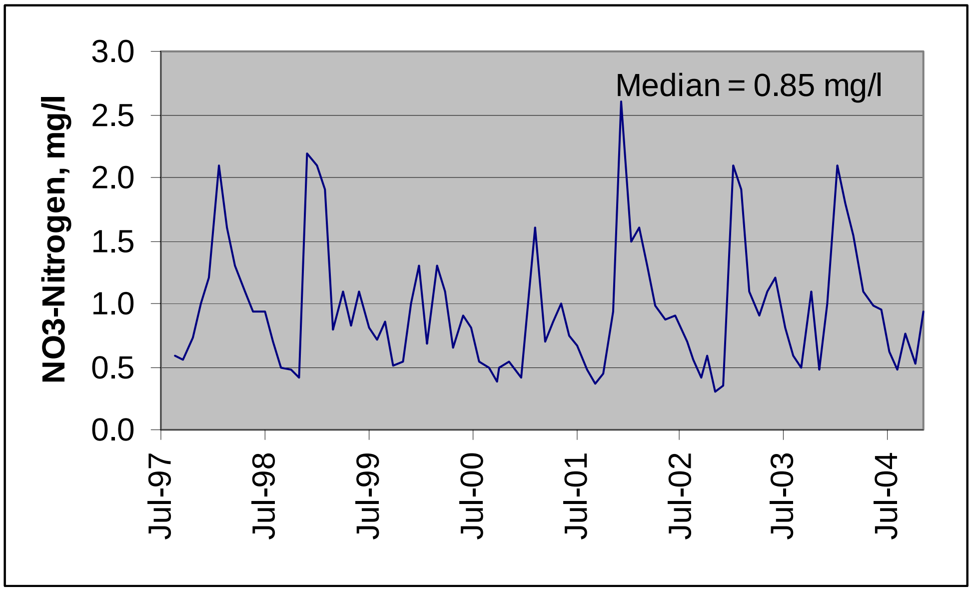
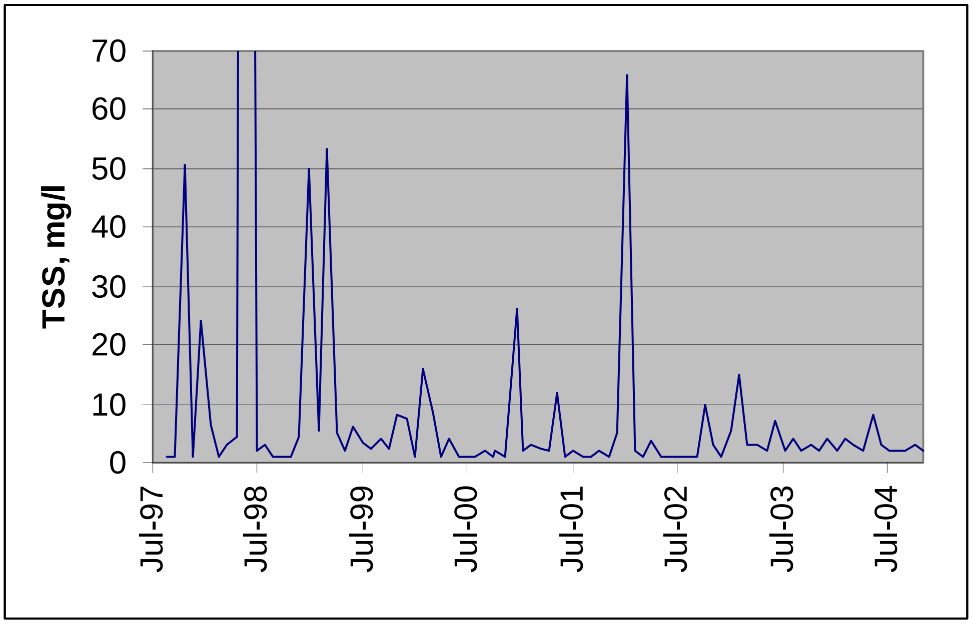


Figure 6-5
Nitrate-Nitrogen Concentrations
Tryon Creek at Boones Ferry Road



TOTAL SUSPENDED SOLIDS – Figure 6- 6 shows the results of monitoring for total suspended solids (TSS). The results show that the TSS concentrations are generally less than 5 mg/l except during storm events or extended wet periods when the total suspended solids (TSS) are elevated. There is no current water quality standard for TSS, but elevated TSS concentrations are a potential concern because many pollutants from urban areas are commonly associated with total suspended solids.

Figure 6-6
Total Suspended Solids
Tryon Creek at SW Boones Ferry Road



TOXICS - Toxics

Very limited water quality data are available for toxics in Tryon Creek or its tributaries. No data are currently available for organic contaminants (pesticides, herbicides, etc.). Available toxics data are limited to six metals that were sampled for three times in 1999 and early 2000 at the SW Boones Ferry Road site. Table 6-3 summarizes those monitoring results. It also shows the chronic and acute water quality criteria for the protection of aquatic life for the metals.

Table 6-3
Summary of Metals Concentrations
Tryon Creek at SW Boones Ferry Road

Parameter	**Criteria**		**Sample Date**		
	Acute	***Chronic***	***5/29/99***	***9/28/99***	***1/25/00***
Cadmium	1.8	0.66	<0.1	<0.1	<0.1
Chromium	980	120	0.93	0.42	1.59
Copper	9.2	6.5	1.49	8.73	2.55
Lead	34	1.3	0.85	0.77	1.13
Nickel	1,100	56	0.94	1.46	1.41
Zinc	180	180	6.64	11.6	11

Note: All concentrations in µg/l.

As shown, all samples met both the acute and chronic water quality criteria except a single sample that exceeded the chronic criterion for copper.

Very little data on toxics are currently available for the Tryon Creek Watershed. No toxic substances have been identified as exceeding water quality standards at this time. It should be noted that there are no current data on potential toxic organic pollutants such as pesticides or herbicides.

Based on the above findings, it is reasonable to assume that the existing water quality conditions in the Tryon Creek Watershed are causing some impairment of watershed health. This impairment can be further quantified when the appropriate targets and metrics are developed for the water quality indicators.

Oregon Water Quality Index

The Oregon Department of Environmental Quality (DEQ) initially developed the Oregon Water Quality Index (OWQI) in the 1970s. The OWQI methodology was further updated to its current form in 1995 to reflect advances in the knowledge of water quality and in the design of water quality indices. The purpose of the OWQI is to improve the understanding of water quality issues by integrating complex data into a single index score, which can be used to describe water quality status and to evaluate water quality trends (Cude 2000).

DEQ developed the OWQI to assess data collected through DEQ's Ambient River Water Quality Monitoring Network, with an emphasis on general recreational uses (fishing and swimming). As such, the OWQI is a general index of water quality and cannot be used to determine the quality of water for specific uses. It also should not be used to provide definitive information on water quality without considering all appropriate chemical, biological, and physical data (Cude 2000). The strengths of the OWQI, as well as other water quality indexes, are their use for comparing water quality among different locations and for assessing long-term trends.

DEQ and others have widely used the OWQI to report water quality status and trends in Oregon. The OWQI is currently included as a benchmark for Willamette River water quality in the City of Portland's annual Service Efforts and Accomplishments (SEA) Report. BES incorporated the OWQI into its water quality monitoring program for the Tryon Creek Watershed in 1997.

The OWQI is calculated by integrating the measurement of eight water quality variables:

- Temperature (Temp)
- Dissolved oxygen (DO)
- Biochemical oxygen demand (BOD)
- pH
- Total solids (TS)
- Ammonia + nitrate nitrogen (NH3/NO3)
- Total phosphorus (TP)
- Fecal coliform (FC)

The OWQI is determined by first using a series of algorithms and equations to calculate a unit-less subindex value for each water quality variable. The individual subindex values are then aggregated into the overall index value (OWQI) based on an "unweighted harmonic square mean" of the subindex values. An index score of 100 corresponds to the highest water quality, and a score of 10 represents the poorest water quality. In addition, DEQ has established a descriptive narrative scoring system, ranging from very poor (0-59) to excellent (90-100).

Table 6-4 and Figure 6-7 show the OWQI and associated subindex values for the individual parameters. As shown, the overall OWQI for Tryon Creek at SW Boones Ferry Road is 74. Based on DEQ's descriptive scoring system, this would correspond to a "poor" water quality rating. As shown on Figure 6-8, however, this score is higher than the scores of other local urban streams, such as Fanno Creek and its tributaries.

Table 6-4
Oregon Water Quality Index Summary for Tryon Creek

	Mean Subindex Values								**Overall**	WQ
Location	NO3/NH3	TP	BOD5	TS	FC	DO	pH	Temp	**OWQI**	Rating
Tryon Cr	66	74	82	66	76	99	96	99	74	Poor

Notes:
Results of BES monthly ambient water quality sampling since 1997
Index Ranking: 0-59 Very Poor, 60-79 Poor, 80-84 Fair, 85-89 Good, 90-100 Excellent

The subindex results show that major factors lowering the overall OWQI include elevated nutrients (total phosphorus, nitrate, and ammonia nitrogen), total solids, and bacteria (fecal coliform).

Figure 6-7
Oregon Water Quality Index
Tryon Creek at SW Boones Ferry Road

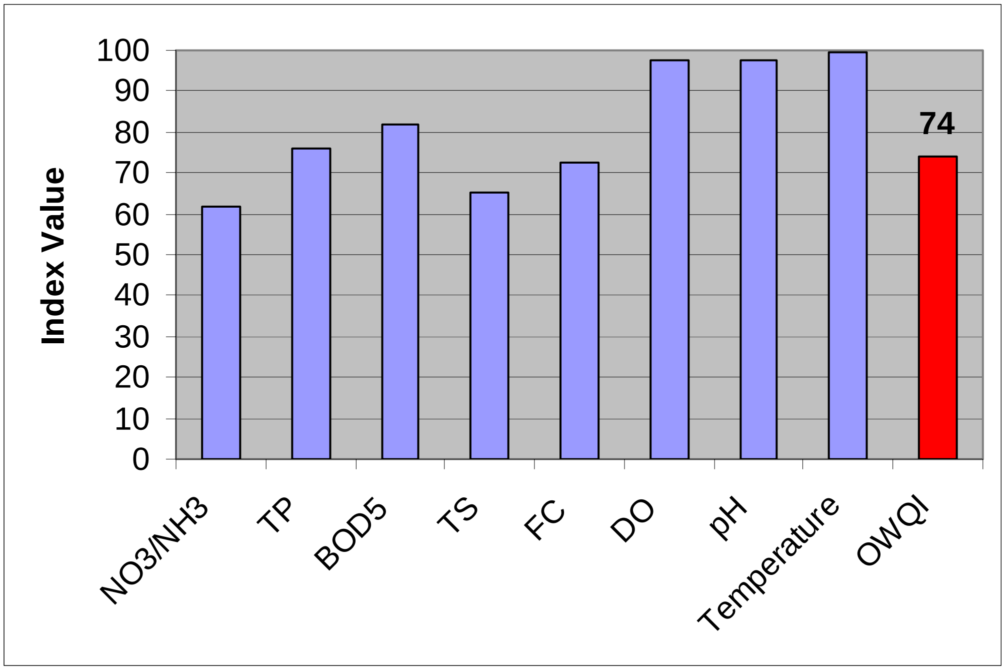
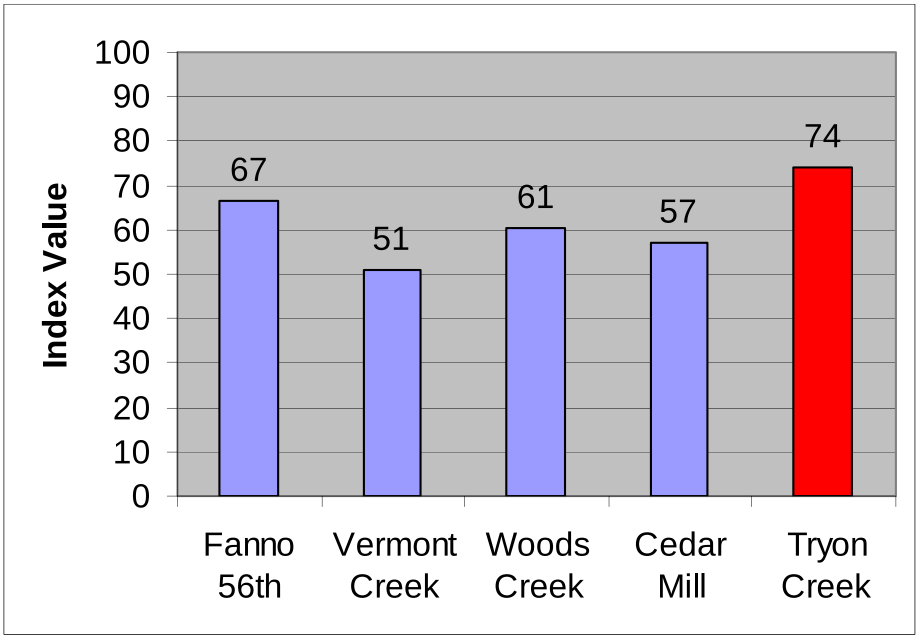


Figure 6-8
Oregon Water Quality Index
Local Urban Streams



Water Quality Standards/TMDLs

Designated Beneficial Uses

Pursuant to Oregon Administrative Rules (OAR), the Oregon Water Resources Commission establishes the beneficial uses of waters of the state. DEQ has identified Tryon Creek as waters of the state, with all designated beneficial uses applicable. Table 6-5 shows the designated beneficial uses for Tryon Creek.

Table 6-5
Tryon Creek Listed Beneficial Uses

Beneficial Uses	**Tryon Creek**
Public Domestic Water Supply	X
Private Domestic Water Supply	X
Industrial Water Supply	X
Irrigation	X
Livestock Watering	X
Anadramous Fish Passage	X
Salmonid Fish Rearing	X
Salmonid Fish Spawning	X
Resident Fish and Aquatic Life	X
Wildlife & Hunting	X
Fishing	X
Boating	X
Water Contact Recreation	X
Aesthetic Quality	X
Hydro Power	X
Commercial Navigation & Transportation	X

Water Quality Standards

Water quality standards and criteria that apply to the Willamette River Basin also apply to Tryon Creek and its tributaries. These standards are described in detail in OAR 340-041-0442. The standards are in place to protect the designated beneficial uses in the basin, including Tryon Creek. Table 6-6 lists the water quality standards and criteria for Tryon Creek.

Table 6-6
Water Quality Standards and Criteria in Tryon Creek Watershed

Parameter	Water Quality Standard	Criteria/Comments
Dissolved Oxygen (DO)	At least 8.0 mg/l	Cold water aquatic life.
	At least 90% saturation	If climate preclude attainment of 8.0 mg/l.
	At least 11.0 mg/l	Active salmonid spawning areas.
Temperature	18° C (64.4° F) maximum	Salmon and trout rearing and migration..
	13° C (55.4° F) maximum	Salmon and steelhead spawning.
Turbidity	Maximum of a 10% cumulative increase (NTU)	Relative to a control point immediately upstream of activity
pH	6.5 – 8.5	All other basin waters except Cascade lakes
Bacteria (E. c*oli*)	126 organisms per 100 ml.	Based on a minimum of 5 samples
	406 organisms per 100 ml.	Maximum for any single sample
Dissolved Gases (CO_2, H_2SO_4, etc.)	No sufficient quantities allowed to cause objectionable odors	Objectionable odors are deleterious to aquatic life, navigation, or recreation
Development of Fungi	No sufficient quantities allowed	No deleterious effects on stream bottoms or aquatic life, or effects that are injurious to health, recreation, or industry
Total Dissolved Solids	100 mg/l	Willamette River and tributaries
Toxic Substances	No exceedence of natural background levels No exceedence of criteria listed in Table 20 from EPA	In waters of the state if amounts, concentrations, or combinations are harmful As published in *Quality Criteria for Water* (1986)

Temperature

Tryon Creek was listed on the State of Oregon 303(d) list in 1998 as water quality limited for temperature, based on exceedances of the 17.8° C (64° F) temperature standard for the protection of salmonid fish rearing and anadramous fish passage during the summer period. (Oregon water quality standard for temperature was revised in 1994 as shown in Table 6.6). Temperature Table 6-7 summarizes the 303(d) listing.

The listing included Tryon Creek between river miles 0 and 5 including the Nettle, Arnold and Falling Creek tributaries. As described previously, BES has maintained a continuous temperature recording monitor at the SW Boones Ferry Road site (at approximately river mile 2.5) since 1998 during the summer period.

Table 6-7
Summary of Tryon Creek 303(d) Listing for Temperature

Waterbody	Tryon Creek
River Mile	0 – 5
Parameter	Temperature
Criteria	Rearing, 17.8° C
Season	Summer
Status	303(d) list[1]
Sample Matrix	Water column
List Date	1998
Beneficial Uses	Salmonid fish rearing Anadramous fish passage

[1] Draft Willamette Basin TMDL, September 2004

Figure 6-9 shows the results of BES temperature monitoring at the SW Boones Ferry Road site for summer periods from 1998 through 2002. The monitoring results are consistent with the 303(d) listing and show that the 7-day average of the daily maximum temperatures frequently exceeds the water quality standard of 18.0° C during the summer period. As summarized in Table 6-8, maximum summer-period daily temperatures ranged from 20.0° to 21.9° C, and the 7-day average temperatures exceeded the standard from 25 to 42 days each summer.

Figure 6-9
7-Day Average of Daily Maximum Temperatures
Tryon Creek at SW Boones Ferry Road

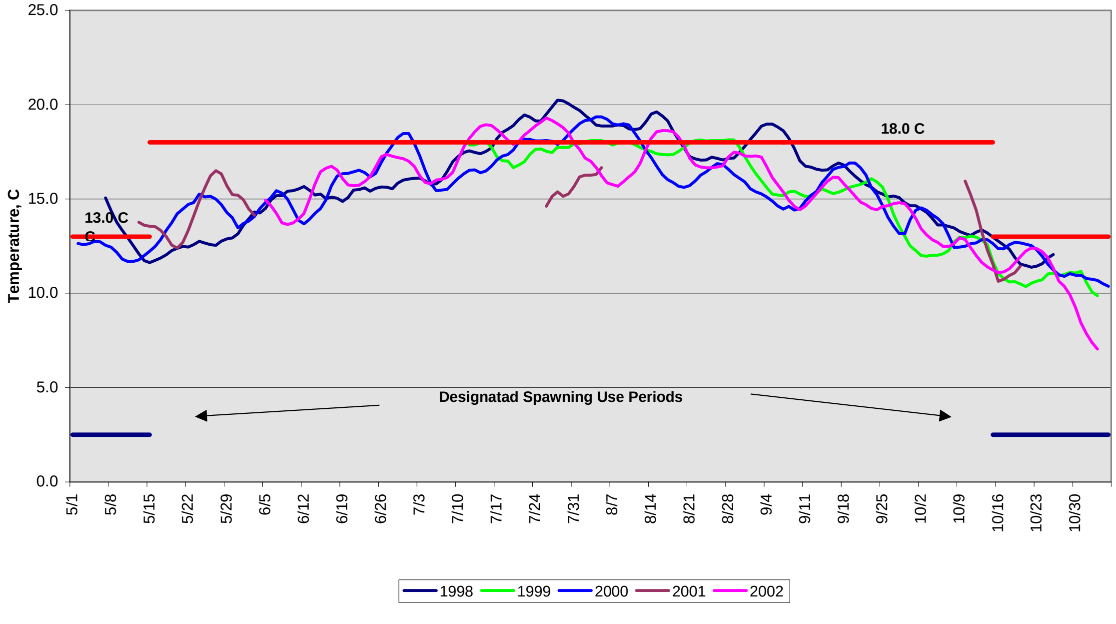


Table 6-8
Summary of Summer Instream Temperature
Tryon Creek at SW Boones Ferry Road

	Year				
	1998	1999	2000	2001	2002
Maximum day	21.9	21.1	20.3	Insufficient data[1]	20.0
Maximum 7-day average	20.2	18.1	19.4		19.3
Number of days > 18.0°	42	25	28		27

[1] Equipment malfunction

Figure 6-9 also shows the temperature standard of 13.0° C for the protection of salmonid spawning, incubation, and fry emergence for the applicable time periods.

Bacteria (*E. coli*)

The water quality standard for *E. coli* bacteria is established to protect the beneficial use of water contact recreation. The water quality standard for bacteria states that organisms of the coliform group commonly associated with fecal sources shall not exceed:

a. A 30-day log mean of 126 *E. coli* organisms per 100 ml, based on a minimum of five samples.

b. No single sample shall exceed 406 *E. coli* organisms per 100 ml.

Figure 6-10 shows the seasonal *E. coli* concentrations for Tryon Creek at SW Boones Ferry Road. The *E. coli* concentrations are from the total of 67 grab samples collected at this sampling location between 1997 and 2002. As shown , the single sample criteria of 406 *E. coli* organisms/100 ml is exceeded at times. This is consistent with monitoring results from other urban streams within Portland. Most of the exceedances of the standard are during periods of precipitation and increased streamflows. The frequency of sampling is not great enough to assess compliance with the standard of 126 *E. coli* organisms/100 ml based on a geometric mean of five consecutive samples.

Figure 6-10
E. coli Concentrations
Tryon Creek at SW Boones Ferry Road
1997-2002

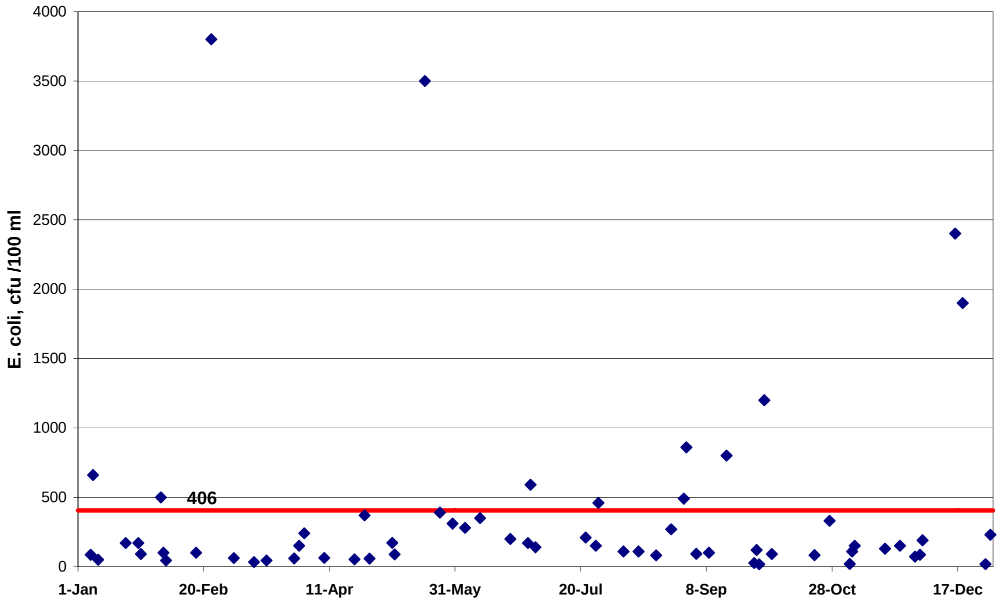


Table 6-9 summarizes the results of *E. coli* monitoring in the Tryon Creek Watershed. It includes results from the routine ambient water quality monitoring at the SW Boones Ferry Road site between 1997 and 2002, as well as monitoring results from the Falling Creek and Arnold Creek tributaries that were monitored between March 2001 and June 2002. The monitoring results are summarized for summer (June through September) and fall-winter-spring (October through May).

Table 6-9
Summary of Tryon Creek *E. coli* Monitoring

	Sampling Location					
	SW Boones Ferry Road		**Falling Creek**		**Arnold Creek**	
	Summer	***FWS***	***Summer***	***FWS***	***Summer***	***FWS***
Samples	22	45	5	11	5	11
Median	160	110	160	150	140	140
Minimum	17	18	74	11	65	11
10th Percentile	83	45	92	22	91	23
50th Percentile	170	110	160	150	140	140
90th Percentile	500	984	436	1,000	264	310
Maximum	860	3,800	580	1,100	320	340
No. > 406	5	7	1	4	0	0
% > 406	23%	16%	20%	36%	0%	0%
Notes: Summer = June-September; FWS (fall, winter, spring) = October – May All concentrations in cfu/100ml						

The monitoring results show that the SW Boones Ferry Road site had a slightly higher frequency of exceeding the *E. coli* standard in the summer period than in the FWS period, with somewhat higher concentrations in the summer period. Tryon Creek is not currently listed on the 303(d) list as being water quality limited for bacteria. However, the results from the SW Boones Ferry Road site would meet the DEQ standard for 303(d) listing (10 percent of samples exceeding 406 *E. coli* organisms/100ml).

The monitoring results for the Falling Creek site were similar to the results from the SW Boones Ferry Road site. The Arnold Creek site did not show any exceedances of the single sample standard.

MODELING RESULTS

As discussed under the Water Quality Monitoring section above, BES has developed a GIS-based model for estimating pollutant loading potential. The model uses a grid system for delineating areas to be evaluated, which is compatible with the DHI MIKE 11 and MIKE SHE hydraulic and water quality models. For the Tryon basin, the grid model breaks the area into 100-foot by 100-foot grids. The model then uses a combination of land use, physical data (e.g., impervious area, vegetation, soils, slope), and rainfall data to predict the potential pollutant loading from each grid. For the Tryon basin analysis, the median pollutant load values from the ACWA stormwater database were used to estimate land use pollutant loads. See Map 12-Tryon Creek Total Suspended Solids Maps by Subwatershed in the Map Atlas.

Findings from analysis of the GIS grid modeling include:

- Because of the homogenous land use within the watershed (80-90 percent residential), the pollutant loading rates tend to be similar throughout the watershed.

- As expected, areas with higher concentrations of commercial and multi-family land uses exhibit higher potential pollutant loads.

- The major transportation corridor (Interstate 5) and associated commercial development show a higher potential pollutant loading.

- In general, the street systems tend to show higher potential loadings.

- The Grid model does not account for changes to pollutant loading caused by effects of flow routing or pollutant decay.

SUMMARY OF FINDINGS

Tryon Creek and its tributaries within the City of Portland exhibit many of the characteristics of many urban streams as a result of changes in hydrology, increased pollutant loadings, and other anthropogenic effects. These characteristics include altered flow patterns and degraded water quality.

The degradation in water quality and resulting impacts on watershed function and health are evident when evaluating the existing conditions using metrics such as the *Framework for Integrated Management of Watershed and River Health* guidelines or Oregon water quality index.

Specific water quality impairment within the Tryon Creek Watershed include 303(d) listing for temperature and elevated levels of bacteria, as summarized below:

TEMPERATURE

- Summer instream temperatures exceed the water quality standard of 64 degrees F for the protection of salmonid fish rearing.
- Shading of the stream is the major factor controlling instream temperature.
- Stream temperatures are elevated despite generally good shade conditions within the watershed.

BACTERIA (*E. coli)*

- E *coli* concentrations frequently exceed the water quality standard (406 counts/100ml) in grab samples.
- Instream bacteria concentrations are higher in the summer than the winter.
- Bacteria concentrations are higher during runoff (rainfall) events.

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CHAPTER 7

Habitat and Biological Communities: Background

This chapter presents the background information that was used to develop the habitat and biological communities characterizations chapters that follow. It includes:

- Habitat Reference Conditions
- Habitat Indicators for Characterization
- Historical Salmonid Use in the Lower Willamette River and Tributaries
- Biological Communities evaluated for Characterization

HABITAT REFERENCE CONDITIONS

Fanno Creek Subbasin

Floodplain Condition

The Tualatin River Basin was historically characterized as “a land of marshes, swamps, and floods, surrounded by mountains” (Cass 1993). Fanno Creek originates from the southeast facing hillslope of the Tualatin Mountains, today known as the West Hills. The steep West Hills (averaging 25 percent) bound the northern side and headwater reaches of Fanno Creek; the southern side is relatively unbound, but lies within incised terraces of the broader south-facing low-sloping hillside of the Tualatin Valley. Stream gradient is low, averaging less than 1 percent, except in the northern headwater reach, where stream gradient steepens to about 5 percent (moderately steep).

Floodplain interactions historically maintained watershed functions in Fanno Creek. Mainstem Fanno Creek was likely seasonally constrained by terraces, varying in width, within a broad alluvial creek bottom (VWI averages 20.0 percent basinwide). The creek likely meandered through these terraces, filling the banks and accessing broad floodplain areas during winter, wet months.

Tributaries to Fanno Creek are divided into low gradient streams in the southern portion of the watershed and steeper streams in the northern reaches. Low to moderately steep tributaries, drain the southern portion of the watershed. These streams were historically bound by alternating terraces and hillslopes, and flowed through a broad floodplain valley. Tributaries draining the northern part of the watershed (from the Tualatin Mountain hillside) are steeper and had a narrower floodplain.

Based on these landform characteristics, one would expect Fanno Creek to meander through an open valley, bound by the Tualatin Mountains on the north. The broader floodplain to south, allowed the Creek to adapt to higher flows (originating from the steeper, headwater reaches) by forming broad open areas of water and emergent wetlands. This allowed the Creek to deposit fine silts and sediments (that characterize the system's soils and geology) along the way, which helped build and form the terraced banks.

Alternating terraces and floodplain wetlands provided important habitat to juvenile salmon, particularly coho and steelhead, for rearing and high flow refugia. Inundation of this broad floodplain, along with springs, seeps and tributary flows provided important off-channel refugia during the winter, and important cool water and base flow throughout the summer.

Riparian Condition

Vegetation in Fanno Subbasin was likely characterized as closed forest canopy and woodland forest.

Common streamside, riparian and upland species (particularly in the headwater area) would have been red alder, big leaf maple, oak, western red cedar, yellow pine cedar, western hemlock, Douglas-fir and grand fir; and common understorey species would have included vine maple, western ash, hazel, dogwood, salal, snowberry, blackberry and Oregon grape (Cass and Miner 1993) (Shively 1993). In addition prairie grasses and forbes were common.

Historically large wetland complexes, created by abundant beaver populations, resided along the Tualatin River and its stream tributary corridors. Areas of heavy clay deposits from the Bretz floods resulted in drier Oak Savanna and seasonally saturated wet praries. Early settlers occupied the more open savannas and prairies of the central county before moving into the more densely wooded areas further east towards Portland (CWS 2002).

Stream Connectivity

Historically, there were no natural barriers on Fanno mainstem that would have impeded anadromy. Natural channel forms such as boulder-steps, beaver dams, and log jams may have temporally impacted fish movement, but did not likely block fish passage year-round. Fish have evolved to either navigate thru interstitial spaces within these types of natural channel forms and structures, or time their migrations to periods when flows allow easier passage above these channel forms.

Refugia

In Fanno Creek off-channel refugia was likely found near tributary junctions, backwater pools, side channels, and secondary channels. In addition, floodplain wetlands would have provided key high flow refugia and seasonal rearing opportunities.

In-stream refugia was most notably associated with wood pieces, clusters and jams. Other habitat features that would have provided substantive protective cover include: beaver ponds and associated wood clusters and debris jams, undercut banks, large cobble and boulders, and deep pools. In addition, seeps and springs likely provided important cool-water refugia and helped augment summer baseflows.

Channel Complexity - Channel Conditions and Habitat Structure

In its natural condition, Fanno Creek had a sequence of pools, pools and riffles, side channels, backwater areas, and oxbows. Three major types of wetlands existed in the Tualatin River basin: 1) freshwater swamps, 2) freshwater marshes, and 3) riparian areas and wetlands (Shively 1993). All three wetland habitats were likely present in the Fanno subbasin. Riparian areas and seasonal wetlands were more common in the upper subbasin. In 1993 Gabriel found that wetland losses throughout the Tualatin River basin totaled 61 percent for areas below 660-ft elevation.

Logs helped form deep pools to shelter adult and juvenile fish while backwaters and off-channel habitats provided areas for juvenile fish to escape during winter peak flows. Shively (1993) noted:

> *"The Tualatin River, along with other streams draining the east slope of the Oregon Coast range (Yamhill, Luckiamute, Long Tom) contained concentrations of large woody debris in the form of drift jams that completely obstructed major channels for a distance of 100-150 meters at some channel locations during the mid 1800s."*

The physiographic characteristics of the watershed and its soil types impact hillslope and channel stability, channel configuration, channel incision and undercutting. Historically, Fanno Creek likely changed directions often, reforming itself within the prevalent clay and silt bed substratum. Loss of vegetation and presence of impervious surfaces results in proportionally higher erosion than expected under historic (or pre-European settlement) conditions. Large wood provided by conifer and deciduous tree boles captured and retained sediment and helped form floodplain terraces and wetlands (via increased hydraulic residence and floodplain expansion) and facilitated nutrient processing and storage.

The Fanno Creek Watershed has an abundance of fine silt (Delena soil type), resulting in a stream system with a high level of naturally occurring suspended solids and settleable organic material. Historically, Fanno Creek had a longer stream channel, and more frequent floodplain interactions. High water events allowed suspended solids to deposit in the floodplain rather than the channel. Although suspended solids were likely common, settleable solids did not dominate stream substrate composition as they do today. Historically, pools were deeper and riffles non-embedded.

Tryon Creek Subbasin

Floodplain and Upland Condition

Tryon Creek is bound by steep valley walls on the northern and southern facing hillsides. Stream gradients in Tryon Creek are low to moderately steep basin-wide. Downstream from Boones Ferry Rd stream gradient is generally below 2 percent, while the upper basin averages from 2.3 percent to 3.1 percent. Lower gradient streams generally have greater riparian and floodplain interactions.

Historically, floodplain interactions helped maintain watershed functions in Tryon Creek. High flows originating from the confined headwaters reaches lead Tryon Creek to flood often. The area in what is now Tryon Creek State Natural Area functioned as a depositional reach, with deep soils and a wide floodplain (WMSWCD, 2003b). This broader floodplain in the Park allowed the creek to adjust to higher flows by meandering from hillside to hillside within the confines of the valley walls.

Alluvial reaches in the Park once provided important summer and winter rearing habitat for juvenile salmon. Eradication and displacement of beavers, beaver dams, debris jams and associated ponds and off-channel pools reduced alluvial stream interactions yielding a less diverse floodway and associated processes:

> *"..portions of the valley floor were likely inundated under beaver impoundments, which, along with silt transport mechanisms, may explain why much of the valley bottom is fairly level with deep soils composed of fine sediment. The annual recharge to shallow aquifers beneath these small floodplain areas likely contributed to summer base flows, helping to moderate stream temperatures".* (PHS, 1997).

Substantive floodplain interactions are severely lacking in Tryon Creek. The creek is incised and straight. Flood flows rarely extend far into the floodway, even within the protected areas of the Park. Frequent flood-flows are not capable of reaching the relatively flat floodplain for energy dissipation, sediment deposition, and periodic flooding of riparian vegetation (WMSWCD, 2003b).

Disconnection of Tryon Creek from its floodplain can be attributed to several interrelated factors. The channel length is shorter, with fewer meanders and less channel complexity. According to the National Riparian Services Team (WMSWCD, 2003b) reductions in resistance-forces (e.g., large wood, and woody, riparian vegetation) and increases in water velocity result in an increase of flow energy that erodes the streambed and streambanks, causing rapid vertical adjustments to the channel network. As a result, the channel is down-cut and widened, so the amount of water that formerly filled the channel and spilled onto the floodplain is now held within the deeper, wider channel. More water remains in the channel and less water infiltrates into the aquifer during moderate storm flows. Only during very high, infrequent floods does flow overtop the creek banks. ODFW field biologists confirmed this in 2002. Their data show floodprone widths greater than active channel widths. This indicates that flood flows periodically top creek banks and interact with the floodway, however, the floodprone width rarely exceeds 1.5 times the active channel width so, flows do not extend far into the floodplain.

Lack of historic floodplain habitat in lower Tryon Creek is a key limiting factor affecting the stream's ability to function dynamically. Given urban constraints within upland and floodplain areas, and the altered hydrograph re-establishment of the full-spectrum of historic stream/floodplain interactions is not likely feasible. However, careful management of existing floodplains in lower Tryon could restore important ecological functions and provide a means to re-establish channel processes. Reconnecting floodplains provides benefits such as slowing velocities, lowering local water surface elevation, and detaining floodwaters.

Riparian Condition

The forest has converted from a mixed conifer-deciduous forest to one dominated by deciduous trees and shrubs. Historically, common streamside, riparian and upland species were red alder, big leaf maple, western red cedar, Douglas-fir and grand fir; and common understorey species were vine maple, western wahoo, and salmonberry.

Riparian condition is relatively good within the Park. Riparian widths average 200 feet or more, tree canopy cover is high, and well-established second growth forest dominates the landscape, averaging 15-30 cm dbh. Red alder and big leaf maple predominate in streamside areas. Large native conifers such as western red cedar, Douglas-fir, and grand fir are rare. Young western red cedar are beginning to predominate above invasive blackberry. An older forest encompasses the lower canyon reach, while a younger forest stand encompasses the middle and upper Park reaches. This is symptomatic of past logging patterns across the landscape.

Stream Connectivity

Marshall Cascade (on mainstem Tryon Creek) and Arnold Falls on Arnold Creek are the only documented natural barriers. Other natural channel forms (steps, beaver dams, and log jams) may have seasonally impacted fish movement, but did not likely block fish passage year-round. Fish evolved to either navigate thru interstitial spaces within these types of natural channel forms and structures, or to time their migrations to periods when flows allow easier passage.

Presently, the HWY 43 culvert most prominently limits anadromous fish from accessing spawning and rearing habitat in Tryon Creek. This concrete box culvert was retrofitted with baffles to improve passage for anadromous adults, however, it remains a partial barrier, particularly for fall spawning coho salmon. Fall flows are not high enough to allow access into the culvert (e.g., the jump height into the culvert remains too high) and passage through the long, baffled culvert is inhospitable. Winter steelhead return to spawn in late winter to early spring when flows are higher, providing more advantageous opportunities for passage, however, passage likely remains impaired.

Other fish passage barriers exist throughout the basin, however this culvert is the most significant because of its closeness to the confluence and its impassability. Improving fish access into Tryon Creek by retrofitting or replacing the HWY 43 culvert could significantly increase anadromous fish productivity and species diversity throughout the watershed (WMSWDC, 2003d).

Refugia

Off-channel refugia was likely found near tributary junctions, backwater pools, side channels, and secondary channels. Floodplain wetlands throughout the Park likely provided substantive high flow refugia.

In-stream refugia was most often associated with wood pieces, clusters and jams. Other habitat features that provided substantive protective cover include: beaver ponds and associated wood clusters and debris jams; undercut banks; large cobble and boulders; and deep pools. Seeps and springs likely provided important cool-water refugia and helped augment summer low flows.

Channel Complexity - Channel Conditions and Habitat Structure

In its natural condition, Tryon Creek should have an array of pools, riffles, side channels and backwater areas created by large amounts of downed wood and trees, and a meandering stream channel. Logs form deep pools to shelter adults and juveniles, while backwaters and off-channel habitats provide areas for juvenile fish to escape during winter flow peaks. Currently, Tryon Creek has little large wood in the stream, even within the Park, and for the most part the creek is confined within a single, simplified channel.

Large Woody Debris

The National Riparian Services Team (WMSWCD, 2003b) characterizes Tryon Creek as a wood dependent system, meaning that it developed in conjunction with a large conifer forest stand. "*Large wood material is the most important attribute in this stream type and the processes associated with it are the most important to the function of the watershed.*" Wood provided by large conifer tree boles historically trapped sediment and formed floodplains, retaining flood flows and promoting rich, diverse riparian vegetation. Large woody material is lacking basin-wide (ODFW 2001), (WMSWCD, 2003a), (WMSWCD, 2003b) (WMSWCD 2003d).

Fine Sediment

The Tryon Creek Watershed is characterized by a natural abundance of fine silt. Land use practices have exacerbated the natural condition of the stream to transport high levels of fine sediment. Fine sediment originating from the steeper, more urbanized upper watershed settles out in the lower gradient reaches (in the Park). Stormwater run-off sediment loading, along with fine silts that slough into the creek during erosive flows results in a constant layer of fine silt and sediment overlaying the stream substrate. High silt loads overlaying spawning and rearing grounds may significantly impair the carrying capacity of Tryon Creek.

Tryon Creek is straight, incised and wide with eroded stream banks. The Creek generally flows through one primary channel; secondary channels and side channels are rare. Important habitats are lacking, such as undercut banks, backwater pools, off-channel habitats, deep pools, and high quality riffle habitats. Lack of these spawning and rearing areas significantly reduces potential population productivity.

INDICATORS OF HABITAT CONDITION

Introduction

This section describes habitat indicators of riverine (stream) health. These indicators were used to characterize present stream and aquatic habitat conditions in the Fanno and Tryon Creek Watersheds

The following indicators were used:

- Floodplain Condition
- Riparian Condition
- Stream Connectivity
- Refugia
- Channel Conditions and Habitat Structure

These indicators are equivalent to ecological functions and are interdependent. Each is briefly described, and associated metrics are identified. The reference conditions or processes indicative of healthy riverine ecosystems are mostly modeled from rural/wildland-type ecosystems. The complexities and nuances of ecosystem dynamics that occur in urban watersheds are not fully understood, however, rural watershed health indicators provide a context from which healthy or normative ecological conditions can be evaluated. The range of conditions presented for Pacific Northwest streams are intended to provide a description of how Tryon and Fanno Creek Watersheds would function under varying aquatic health conditions.

Floodplain Condition

Floodplain and riparian environs help maintain hydrologic connections and provide benefits to aquatic – terrestrial interactions. Floodplain habitats attenuate stream flows, decrease peak flows, store water, and recharge groundwater which maintains base flow during the summer. Floodplains and wetlands filter sediments, moderate stream temperatures (via subsurface and hyporheic flows), and supply organic matter (including large wood) and bed-form substrates to the channel. For example, riparian areas provide shade and source woody material (and leaf matter) to a stream. Trees, shrubs and grasses provide protective cover (overhanging vegetation) to residing aquatic organisms. Vegetated banks stabilize stream banks, and capture and filter sediments. Opportunities for flood flows to top the bank and inundate the riparian area and broader floodplain area are necessary to maintain these aquatic – land interactions.

Floodplain and wetland environs provide important habitat to aquatic and terrestrial wildlife. Floodplain wetlands (or seasonal wetlands), oxbows, and secondary channels, provide important high flow refugia and overwintering habitat to native fish communities. Coho salmon rely on these slack water, low velocity rearing areas during fall, winter and spring. Salmonids may use off-channel habitats as refuge from adverse instream conditions, such as high flows, high sediment loads, or large concentrations of pollutants.

Metrics

Key metrics used to evaluate floodplain conditions were:

- Ratio of floodway to stream width (valley width index, or VWI)
- Stream gradient (%)
- Entrenchment ratio (floodprone width/active channel width)
- Evidence of stream corridor and floodplain connectivity (or lack thereof)

This data was evaluated to determine floodplain function and condition and was gauged according to criteria described in *NMFS Matrix of Properly Functioning Condition* and *Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale* (1996):

> Properly Functioning: Off-channel areas are frequently hydrologically linked to the main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession.
>
> At Risk: Reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession

Not Properly Functioning: Severe reduction in hydrologic connectivity between off-channel, wetland, floodplains and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly

Riparian Condition

Riparian areas are the interface between aquatic-land interactions and provide critical functions to cold water species and other wildlife. Some of the most apparent are temperature moderation (and reduction of peak temperatures), sediment filtration and reduction, bank stability and erosion control, organic inputs, cover (overhanging vegetation), and sources of large wood, gravels, and cobbles. Riparian habitats provide important rearing habitat and migration corridors for different wildlife species.

Riparian integrity criteria are not well defined for urban areas. These criteria often rely on total riparian width, vegetative characterizations (species abundance, density, age structure, and diversity), and percent impervious surface adjacent to the stream bank. Riparian widths vary with local topography, geology, and soils, as well as the type and degree of human use. Optimal riparian widths (necessary to maintain high riparian integrity) therefore vary within each basin, depending on (among other things) stream size, stream gradient, bank slope stability, channel sinuosity, vegetation type and density, and surrounding land use. In Tryon and Fanno Creeks, human uses significantly affect the quantity of effective riparian area and the potential functions the riparian fringe provides.

The importance of wetlands and hyporheic areas in small, low-elevation streams, such as Tryon and Fanno Creeks, has not been substantively evaluated. These area are likely of high significance because seeps and springs augment low flows and cool stream temperatures. Hyporheic flows (near springs, seeps, and the wetted channel perimeter) provide water quality benefits and are often associated with increased macroinvertebrate production.

Metrics

Key metrics used to assess riparian condition were:

- Percent tree canopy cover and riparian width
- Riparian vegetation: species, composition and size
- Riparian fragmentation (or lack of longitudinal continuity)
- Presence of wetlands, springs and seeps
- Predominant land-use

These data were evaluated according to the following criteria:

Criteria	
Zone of Influence: Width of Riparian Vegetative Zone – Least buffered side[1]	Optimal: Vegetative zone > 4 x bank full width (BFW). **NO** impacts in the zone. Sub-Optimal: Vegetative zone > 2 x BFW. Minimal impacts in

Riparian Condition[4]	this zone. Marginal: Vegetative zone > BFW. Serious impacts in the zone up to the stream edge. Poor: Very high disruption of streambank. Vegetation removed to < 2 inches average stubble height. The riparian zone should be at least 30 meters wide and have 65 percent or more forest canopy
Successional Stage (forest only)[1]	Optimal: Old growth-mature: diameter > 53 inches Sub-Optimal: Young: diameter 22 – 53 inches Marginal: Pole saplings: diameter 13 – 22 inches Poor: Seedlings / clearcut: diameter 0-13 inches
Riparian Conifers (30 meters from both sides)[2]	Desirable: > 300 conifers, > 51 cm dbh per 1000 ft stream length **OR** > 200 conifers, > 89 cm dbh / 1000-ft stream length Undesirable: > 150 conifers, > 51 in dbh / 1000 ft stream length **OR** > 75 conifers, > 89 in dbh / 1000 ft stream length
Shade (%) – westside streams[2] Stream width < 12 m	Desirable: > 70% Undesirable: < 60%
Stream width > 12 m	Desirable: > 60% Undesirable: < 50%
Riparian Reserve[3]	Properly Functioning: The riparian reserve system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact): percent similarity of the riparian vegetation to the potential natural community / composition > 50%. At Risk: Moderate loss of connectivity or function (shade, LWD, recruitment) of riparian reserve system, or incomplete protection of habitats and refugia for sensitive aquatic species (~ 70-80% intact): percent similarity of riparian vegetation to the potential natural community / composition 25-50% or better. Not Properly Functioning: Riparian reserve system is fragmented, poorly connected, or provides inadequate protection of habitats and refugia for sensitive aquatic speies (< 70% intact): percent similarity of riparian vegetation to the potential natural community composition < 25%.

1. Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

2. Oregon Watershed Assessment Manual
3. NMFS Matrix of Properly Functioning Condition as described in Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale (1996)
4. May 1997

Stream Connectivity

Pacific Northwest salmonids require a variety of habitat types (and conditions) throughout their life. Adults need opportunities to migrate upstream and spawn (late summer through winter, depending on species), and juveniles (and resident trout) require opportunities to move around while rearing to seek food, avoid predators, and seek unique habitat niches.

Stream connectivity is affected by natural and artificial features (usually hard and fixed) within and along the stream channel and/or conditions occurring in the stream. For example, culverts, dams, sewer lines, and concrete walls can block fish passage via physical obstruction (hydraulic control) or by creating hydrologic conditions that impede fish movement.

High water velocities at a culvert inlet, outlet, or within a culvert may overwhelm prolonged and burst swimming speeds, creating a velocity barrier. Shallow water depths (e.g., below six inches) within a culvert may limit a fish’s ability to swim upstream or downstream, stranding (or isolating) them to specific stream reaches. Depending on the culvert design (high flow versus low flow), stream flows may delay fish from accessing upstream and downstream sites at critical times (such as spawn timing) and may distribute fish into less-than-ideal locations. The height between a culvert outlet and the water surface may exceed maximum jumping heights for adult salmonids during migration and/or for juvenile salmon and trout during freshwater rearing. The number, location, and type of road-crossing barriers in a watershed acts as a filter that determines the amount of habitat available to each species and age-class of fish (ODFW 1999).

Barriers to fish migration can significantly impair a population’s ability to persist and reproduce. Delayed adults may expend a great portion of their energy reserves, resulting in weakened fish more disposed to disease or pre-spawning mortality, or, in females, retention of eggs. Eggs may be deposited during unfavorable environmental conditions for egg and fry survival. Headwater areas may be poorly seeded, while downstream reaches may exceed the stream carrying capacity.

Metrics

The number and impact (e.g., totally impassable, partially impassable, or temporarily impassable) of culverts or other hydraulic breaks (waterfalls, stormwater pipes, irrigation dams, etc.) were inventoried. Criteria described in NMFS *Matrix of Properly Functioning Condition* and *Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale* (1996) were used to evaluate stream connectivity for each surveyed reach:

> <u>Properly Functioning</u>: Any man-made barriers present in watershed allow upstream and downstream fish passage at all flows.
>
> <u>At Risk</u>: Any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at base/low flows.

Not Properly Functioning: Any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at a range of flows.

Refugia

In the Tryon and Fanno Creek Watersheds, refugia occur primarily in (or immediately adjacent to) the channel and are associated with side channels, tributaries (off-channel refugia), and instream channel features. Both instream and off-channel refugia are important to fish, allowing them to respond to environmental changes from season to season, or to behavioral stresses (e.g., predator avoidance) throughout their freshwater residency.

Instream structure (such as overhanging vegetation, undercut banks, boulders and cobbles, deep pools, turbulent flows, and large wood) provides important physical refuge (or cover) to aquatic species. The amount, type, and location of instream cover plays an important role in salmonids' selection of habitat for spawning and rearing (USFWS 1983), and allows fish to occupy portions of the creek they may not otherwise use. The presence of cover can increase the abundance of salmonids if the amount of suitable habitat is limiting fish productivity (Bjornn and Reiser 1991).

Tributaries, side channels, secondary channels, off-channel pools, and seasonally accessed wetlands provide off-channel refugia to salmonids during periods of environmental change or stress. For example, salmonids will move into tributaries for temporary refuge when water temperatures are high, storm flows are high, or to avoid competition with other fish.

Metrics

Key metrics used to evaluate instream and off-channel refugia were:

- Number and size of side channels, off-channel areas and tributaries
- Density of large wood and shelters, such as beaver ponds and debris jams, large substrates (boulders), undercut banks, and engineered structures

Criteria	
Off-channel Habitat[1]	Properly Functioning: Backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.) At Risk: some backwaters and high energy side channels Not Properly Functioning: Few or no backwaters, no off-channel ponds
Instream Cover[2]	Optimal: >50% gravel, cobble, submerged logs, undercut banks: Stable fish habitat Sub-Optimal: 30-50% Stable fish habitat Marginal: 10-30% Stable fish habitat Poor: <10% Stable fish habitat. Lack of habitat is obvious.
Refugia[1]	Properly Functioning: Habitat refugia exist and are adequately buffered (e.g., by intact riparian reserves); existing refugia area sufficient in size, number and connectivity to maintain viable populations or sub-populations. At Risk: Habitat refugia exist but are not adequately buffered (e.g., by intact riparian reserves); existing refugia area insufficient in size, number and connectivity to maintain viable populations or sub-populations. Not Properly Functioning: Adequate habitat refugia do not exist

1. National Marine Fisheries Service. 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. NMFS, Environmental and Technical Services Division, Habitat Conservation Branch: 26 pp.
2. Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Channel Conditions and Habitat Structure

Channel form and complexity can have an important influence on local hydrology. Hydrologic regimes play a critical role in building pool-riffle sequences; creating deep pools; delivering substrate (gravels, cobbles, and boulders), wood, and nutrients; changing channel dimensions, orientation, and stream length; and creating side-channel and off-channel habitats. Flow also affects streambank stability and erosiveness, bank slope, and stream bank form (e.g., undercut banks, incised banks). Flow determines the extent of riparian and floodplain hydrologic connectivity.

Stream structure, habitat sequencing, and the amount of each habitat type significantly affects the carrying capacity of a system. Salmon require different physical environments throughout progressive stages of their life (Hawkins 1993). For example, they require gravels of particular size to successfully spawn and for fertilized eggs to thrive. They also require deep pools, side channels, riffles, and off-channel habitats for sustained rearing and feeding. Without these important key habitats, salmonid productivity may be limited.

Habitat quantity and quality is influenced by a variety of instream features and watershed processes, and is also influenced by macro scale factors such as basin size and shape, elevation, hillslope gradient, stream gradient, parent material and soil structure. Combined, these factors create and maintain instream habitat and affect a system's ability to support sustainable native fish populations. Key attributes that help define channel condition and habitat structure include: 1) **channel form**; 2) **stream bank condition**, 3) **habitat diversity** (and channel complexity); 4) **substrate** and 5) **key habitats**. These habitat attributes are further described below.

1. Channel Form

A one-to-one pool to riffle ratio is believed to be a natural sequencing of habitat type in PNW streams (Platts 1983) and is believed to provide for optimum aquatic health. Generally, streams with a high number of riffles and few pools are low in biomass and species diversity because they do not provide important shelter habitat for fish during high flow velocities. Conversely, streams with a high number of pools and few riffles lack aquatic diversity due to the lack of larger, exposed substrates for fish to spawn and rear on, and for macroinvertebrate to colonize.

Metrics

Criteria	
Pool / Riffle Ratio[2]	Optimal: 5-7 Sub-optimal: 7-15 Marginal: 15-25 Poor: >25
Width / Depth[1]	Properly Functioning Condition: <10 At Risk: 10-12

OR Width / Depth[2]	Not Properly Functioning: >12 Optimal: <7 Sub-optimal: 8-15 Marginal: 15-25 Poor: >25
Channel Shape[2]	Optimal: Trapezoidal Sub-optimal: Rectangular Marginal: Triangle Poor: Inverse Trapezoid

1. National Marine Fisheries Service. 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. NMFS, Environmental and Technical Services Division, Habitat Conservation Branch: 26 pp.
2. Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Stream Bank Condition

Vegetated banks are effective at protecting stream banks during erosive flows. They help hold bank material together and stabilize stream banks. Natural stream banks are considered stable if perennial vegetation covers the stream banks (e.g., vegetative ground cover and roots are evident), and protection is provided by rocks of cobble size, logs and woody material. Stream banks are considered unstable if they show indications of breakdown, slumping, fracture, or vertical erosion (Bauer and Burton 1993). Characteristics of unstable bank conditions are defined below:

> Breakdown: obvious blocks of bank broken away and lying adjacent to the bank breakage.
> Slumping or False bank: the bank has slipped down, cracks may or may not be obvious, but the slump feature is obvious.
> Fracture: a crack is visibly obvious on the bank indicating that the block of bank is about to slump or move into the stream.
> Vertical and Eroding: the bank is mostly uncovered and the bank angle is steeper than 80° from the horizontal.

In addition to these natural features, human-made alterations to a stream bank should be considered. Altered bank conditions may limit channel and floodplain response to watershed processes, for example the delivery and routing of water, sediment and large wood.

Criteria	
Bank Vegetation Protection[2]	Optimal: > 90% covered by vegetation Sub-optimal: 70-80% covered by vegetation Marginal: 50-79% covered by vegetation Poor: <50% covered by vegetation

Lower Bank Stability[2]	Optimal: Stable: NO erosion or failure Sub-optimal: Little erosion, mostly healed Marginal: Erosion moderate in size and frequency Poor: Unstable: Many raw eroded areas
Disruptive Pressures (within Bank Full Width)[2]	Optimal: Vegetative disruption minimal or no evident. Almost all potential plant biomass at present stage of development remains. Sub-optimal: Disruption evident but not effecting community vigor. > 50% potential biomass remains. Marginal: Disruption obvious, some patches of bare soil or closely cropped vegetation; < 50% potential biomass remains. Poor: Very high disruption of streambank. Vegetation removed to < 2 inches average stubble height.
Stream Bank Condition[1]	Properly Functioning Condition: > 90% stable; i.e., on average, less than 10% of banks are actively eroding At Risk: 80-90% stable Not Properly Functioning: <80% stable
Percent actively eroding	30- 60 % indicates moderately unstable banks and signifies high erosion potential

1. National Marine Fisheries Service. 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. NMFS, Environmental and Technical Services Division, Habitat Conservation Branch: 26 pp.
2. Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Habitat Diversity and Channel Complexity

A variety of habitat features characterize channel complexity and channel roughness. For example, undercut banks, overhanging vegetation, deep pools, and large boulder and cobble sized substrate, add different form and functional capacity to aquatic systems. These are all important, however, channel complexity is most easily evaluated by considering the amount, volume, size and distribution of wood instream. Wood provides critical form and function to a stream system, and ultimately helps determine whether other important habitat forms.

Large wood, generally defined as downed wood that intercepts bankfull flow, influences channel hydraulics, creates stream meanders (increasing stream length), and helps form and maintain important habitats such as pools and riffles, undercut banks, deep scour areas, and backwater pools. The presence of wood instream adds channel roughness, protects stream banks and helps capture and retain sediments. Less dynamic wood, such as that buried on the floodplain or embedded along meander belts, stabilize and shape creek beds as they adapt to high flows and build new channels.

Large wood and boulders deflect flows out of the primary channel, resulting in the creation of new channels, the reactivation of old channels (Sedell and Froggatt 1984; Sedell and Luchessa 1982), and the creation and maintenance of wetlands. Channel complexity increases interactions between the stream and its floodplain by slowing the downstream migration of flood flows, temporarily backing up water and forcing it out onto the floodplain area. Lower velocities allow sediments to settle-out in the riparian and broader floodplain area. These areas provide rich soils for plants to establish.

Complex channel forms and features also provide cover to fish, important substratum for macroinvertebrates (a food source for fish), and source organic material into the creek.

Metric

Criteria	
Number of pieces (per 100 meters of stream length)[1]	Desirable: > 20 Undesirable: < 10
Volume of wood (per 100 meters of stream length)[1]	Desirable: > 30 Undesirable: < 20
Number of "Key" pieces (>60 cm and 10 m long per stream length)[1]	Desirable: > 3 Undesirable: < 1
Number of Pieces: > 20 pieces / mile (> 30 cm diameter x 10.6 m long; **AND** adequate sources of woody debris recruitment in riparian areas[2]	Properly Functioning: Meets the criteria At Risk: Meets the standards for properly functioning, but lacks potential sources from riparian areas of woody debris recruitment to maintain that standard Not Properly Functioning: Does not meet standards for properly functioning and lacks potential large woody debris recruitment.

1. Oregon Watershed Assessment Manual defines large wood as 15 cm x 3 m minimum size
2. National Marine Fisheries Service. 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. NMFS, Environmental and Technical Services Division, Habitat Conservation Branch: 26 pp.

Substrate

Substrate composition, type, and location is critically important to fish communities during spawning, egg incubation, and juvenile rearing. Salmonids require an array of substrate sizes (from 1.3 to 14.0 centimeters) for spawning, egg incubation, and habitat for fry.

Gravels and cobbles associated with spawning are found in riffles and in pool tail-outs. For substrates to be functional, they cannot be embedded or extensively covered in fine silts and sediments. They must be relatively free-floating (or loose) in order for salmon to successfully dig redds and lay eggs and for eggs and fry to experience optimal flow and dissolved oxygen levels.

Spawning bed materials and substrate permeability are critical to the development and emergence of salmonid fry. Excess (greater than 20 percent) sand and silt (less than 6.4 mm in size) in gravel can reduce both survival and emergence of Chinook, steelhead and coho fry. Fine sediment (suspended and deposited) should make up less than 40 percent of riffle substrates. Amassed (or deposited) fine sediment and extreme silt loads (greater than 25 milligrams per liter) (Bell 1973) can clog fish gills and affect a fish's ability to "breathe" (or absorb oxygen), and can trap fry attempting to leave the gravel. Cobbles and gravels covered with fine sediment reduce interstitial spaces used by aquatic invertebrates (the primary food organisms of salmonids) and juvenile salmonids for cover in the winter.

Indirect effects on fish of fine sediment in substrate may include reduced feeding, avoidance reactions and delayed (or ceased) migrations (if a silt curtain persists), destruction of food supplies (via limiting production of benthic invertebrates), and altered habitats (covering of critical spawning or rearing areas). Salmonids often rise to the surface during high-turbidity events, where they are more vulnerable to avian predators. This is especially important in river reaches lacking adequate riparian vegetation and associated overstory cover.

Metrics

Criteria	
Substrate Composition[1]	Properly Functioning: Dominant substrate is gravel or cobble or embeddness is <20% At Risk: Gravel and cobble is subdominant, or if dominant embeddness is 20-30% Not Properly Functioning: Bedrock, sand and silt or small gravel dominant, or if gravel and cobble dominant, embeddness >30%
Bottom Substrate - % Fines[2]	Optimal: <10% fines Sub-optimal: 10-20% fines Marginal: 20-50% fines Poor: >50% fines

1. National Marine Fisheries Service. 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. NMFS, Environmental and Technical Services Division, Habitat Conservation Branch: 26 pp.
2. Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Key Habitats

The amount and type of habitat available is significantly affected by flow volume and channel hydraulics. The depth of water at each cross section of creek determines how that habitat can be used. For example, migratory fish need water of sufficient depth at critical seasons throughout the year. Adult steelhead and Chinook require a water depth of 0.24 meters or greater, and coho adults require depths of 0.18 meters or greater to successfully navigate upstream and spawn (Bjorn and Reiser 1991). Some salmon prefer deeper areas with higher velocities (or turbulent flow) to rear and seek cover; juvenile coho often seek deep waters (0.3 to 1.2 meters) in submerged riffle habitats (USFWS 1983).

However, if key functional habitats are not available, flow volume and velocity will be inconsequential. Key habitats to Pacific Northwest salmon include riffles, deep pools, side channels, and off-channel areas. These habitats provide important functions during different stages of life. For example, migratory adults require deep pools for resting and to generate swimming speeds (prolonged or burst) to navigate above natural or artificial barriers. If a channel section is dewatered or lacking adequate depth at the base of a falls, culvert or large debris jam, then upstream migrations will be hindered. In addition, spring Chinook (and winter steelhead) enter their natal stream months before spawning. During this interim, they seek deep pools to rest prior to spawning. Deep pools also provide important refuge habitat to juvenile salmon during high storm flows and provide refuge from predators.

Slack water, and shallow water areas also provide important function to juvenile salmon during the winter and during high storm flows. Slack water and/or shallow water habitats are especially important for coho salmon. Coho often migrate to lower river reaches during their juvenile maturation, and seek slack water, side channels, and backwater pools to overwinter. These environs provide year-round food sources and cover, and are generally devoid of other competing salmonids. Co-occurring steelhead, Chinook and cutthroat generally overwinter in deep pools.

Pool habitats, both deep and shallow provide important function during different times of the year, to different species, and to different age classes of fish. The National Oceanic and Atmospheric Administration considers habitat structure properly functioning (for salmonids) if there is approximately 70 pools per mile, a prevalence of high-quality pools (over 0.91meters deep), and a prevalence of backwater pools and off-channel areas (tributaries and side channels).

Riffles provide substrate for spawning beds, an environment for eggs to incubate, and key habitat for fry and juvenile salmon. In the absence of riffle habitat, spawning area will be limited which fundamentally limits the system's ability to support sustainable populations of fish.

Metrics:

Pool area and Quality

Criteria	
Pool Area (% total stream area)[1]	Desirable: > 35 percent Undesirable: < 10 percent

<table>
<tr>
<td>Pool Frequency
Channel widths between pools[1]

OR

<table>
<tr><th>Channel Width (ft)</th><th># Pools / Mile[5]</th></tr>
<tr><td>5</td><td>184</td></tr>
<tr><td>10</td><td>96</td></tr>
<tr><td>15</td><td>70</td></tr>
<tr><td>20</td><td>56</td></tr>
<tr><td>25</td><td>47</td></tr>
<tr><td>50</td><td>26</td></tr>
<tr><td>75</td><td>23</td></tr>
<tr><td>100</td><td>18</td></tr>
</table>
</td>
<td>Desirable: 5-8
Undesirable: >20

Properly Functioning: Meets pool frequency standards and large woody debris recruitment standards for properly functioning habitat.
At Risk: Meets pool frequency standards but large woody debris recruitment inadequate to maintain pools over time
Not Properly Functioning: Does not meet pool frequency standards.</td>
</tr>
<tr>
<td>Average residual pool depth[1]
Small streams, <7 meters wide

Medium streams (> 7 m and < 15 m wide)
▪ <i>Low gradient (slope < 3%)</i>
▪ <i>High gradient (slope > 3%)</i>

Large streams (> 15 m wide)</td>
<td>Desirable: > 0.5 m
Undesirable: < 0.2 m

Desirable: > 0.6 m
Undesirable: < 0.3 m

Desirable: > 1.0 m
Undesirable: < 0.5 m

Desirable: > 1.5 m
Undesirable: < 0.8 m</td>
</tr>
<tr>
<td>Relative pool depth[4]</td>
<td>Pools 75-100 percent deeper than the prevailing channel depth provide protective cover</td>
</tr>
<tr>
<td>Complex Pools (with wood complexity > 3 km)[1]</td>
<td>Desirable: > 2.5 pools
Undesirable: < 1.0 pools</td>
</tr>
<tr>
<td>Fines (% silt-sand and organics)[2]</td>
<td>20-50 percent deposited fines signifies slight deposition</td>
</tr>
<tr>
<td>Number of deep pools (>1.0 meter deep) AND pools with good cover and cool water, minor reduction in pool volume by fine sediment[5]</td>
<td>Properly Functioning: Meets pool quality standard
At Risk: Few deep pools present or inadequate cover/temperature, moderate reduction in pool volume by fine sediment
Not Properly Functioning: No deep pools and inadequate cover/temperature, major reduction of pool volume by fine sediment</td>
</tr>
</table>

1. Oregon Watershed Assessment Manual
2. Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.
3. Moore, K., Jones, K. and Dambacher, J. Oregon Department of Fish and Wildlife. 1999. Methods for Stream Habitat Surveys Aquatic Inventory Project. Natural Production Program: Oregon Department of Fish and Wildlife.
4. NRCS 1999
5. National Marine Fisheries Service. 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. NMFS, Environmental and Technical Services Division, Habitat Conservation Branch: 26 pp.

Riffle Area and Quality:

Criteria	
Riffle Area (percent of total stream area)[1]	Qualitative assessment
Width / Depth (active channel) – riffles only, West side streams[2]	Desirable: < 15 Undesirable: > 30
Gravel (% area)[2]	Desirable: ≥ 35 % Undesirable: < 15%
Fines (% area) - silt-sand and organics[2]	
Volcanic Parent Material	Desirable: < 8 % Undesirable: > 15 %
Sedimentary Parent Material	Desirable: < 10 % Undesirable: > 20 %
Channel Gradient < 1.5%	Desirable: < 12 % Undesirable: > 25 %
OR	
Embeddedness[4]	Optimal: < 25% covered Sub-optimal: 25-50% covered Marginal: 10-30% covered Poor: >75% covered

1. Moore, K., Jones, K. and Dambacher, J. Oregon Department of Fish and Wildlife. 1999. Methods for Stream Habitat Surveys Aquatic Inventory Project. Natural Production Program: Oregon Department of Fish and Wildlife.
2. Oregon Watershed Assessment Manual
3. National Marine Fisheries Service. 1996. Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Watershed Scale. NMFS, Environmental and Technical Services Division, Habitat Conservation Branch: 26 pp.
4. Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

BIOLOGICAL COMMUNITIES

Salmonids are the focal species for this characterization because they indicate ecosystem health, are native to the Pacific Northwest and the Willamette Basin, and are believed to be surrogates for other aquatic species that inhabit the same (or similar) habitat niches. Other fish native to Pacific Northwest streams include Pacific lamprey, brook lamprey, and sculpin. Lamprey are declining (in population numbers) throughout their historic range and are petitioned for listing under the federal ESA. Torrent sculpin are also an indicator species for habitat degradation and poor water quality. They prefer pristine habitats so are found in rural streams more often than urban streams. Both these species are considered species of interest for this characterization.

- **Tryon Creek**: Target species include those inhabiting the Lower Columbia River and Lower Willamette River evolutionarily significant units (ESUs)*: steelhead/rainbow (*Onchorynchus mykiss*), Chinook salmon *(O. tshawytscha*), and coho salmon (*O. kisutch*). Cutthroat trout (*O. clarki*) are also considered a target species. Lamprey (*Lamperta spp*.) and torrent sculpin (*Cottus rhotheus*) are considered species of interest.

- **Fanno Creek**: Target species include those inhabiting the Upper Willamette River and Lower Columbia River evolutionarily significant units (ESUs): steelhead/rainbow (*Onchorynchus mykiss*), Chinook salmon *(O. tshawytscha*), and coho salmon (*O. kisutch*). Cutthroat trout (*O. clarki*) are also considered a target species.

To characterize present status of salmon communities in Tryon and Fanno Creek, it is necessary to know historic fish presence and distribution by subbasin. Historic data documenting fish communities in Tryon and Fanno Creeks are lacking. However, data exists showing historic salmonid use in the lower Willamette Basin and tributaries. Based on that information and on particular life history traits and habitat preferences (described below), it is possible to surmise which species populated Tryon and Fanno Creeks. The summary below describes historic salmonid use of the lower Willamette River and tributaries and key species and life history characteristics; this information suggests which species populated Tryon and Fanno Creek subbasins. Chapters 8 and 9 provide more detailed characterizations of the biological communities as they exist today.

Historical salmonid use in the lower Willamette River and tributaries

As early as 1903, Oregon state fish biologists noted that Willamette River salmon entered the Columbia River system early in the season to navigate above Willamette Falls and access remote areas of the upper Willamette River (and its tributaries) (Department of Fisheries 1905).

Large portions of the Willamette River's anadromous fish runs entered the basin via Multnomah Channel (Hutchison and Aney 1964). Coho, steelhead and cutthroat historically occupied small tributaries to the channel (Willis et al. 1960). In 1999, residents of the Miller Creek

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* An ESU is a distinct group of Pacific salmon, steelhead, or sea-run cutthroat that is substantially reproductively isolated and represents an important component in the evolutionary legacy of the species.

subwatershed noted that both resident and anadromous fish resided in the creek over the past 40 years (ODFW 2000).

In 1952, the Oregon State Game Commission (1952), as part of their fish salvage activities, collected 1400 salmon from Sauvie Island from July 1 through September 4. Most salmon were of yearling size.

Prior to hydrologic changes in the upper Willamette River Basin, and fish passage improvements at Willamette Falls (beginning in the 1880s), winter steelhead, spring Chinook, and Pacific lamprey are believed to be the only anadromous fish to access and populate areas in the middle and upper Willamette River Basin (ODFW 2000(b)). Changes to the hydrologic regime and improved fish passage over the falls allowed historically absent anadromous fish runs of summer steelhead, coho and fall Chinook to naturalize in subbasins above Willamette Falls (ODFW 1990b).

Important anadromous fish streams of the lower Willamette River (below Willamette Falls) include Johnson Creek, Crystal Springs Creek, Milton Creek, and Scappoose Creek (Hutchinson et.al. 1964) (Willis 1960). Tryon Creek was historically considered valuable to anadromous fish (Willis 1960). Coho, fall Chinook, spring Chinook and steelhead populated the Tualatin River Basin.

The Willamette River served as a transportation corridor to migrating anadromous fish, and provided rearing habitat to salmonids, such as Chinook, coho, steelhead, and cutthroat.

SPRING CHINOOK

The Willamette River Basin historically provided important spawning and rearing grounds to Chinook salmon in the Columbia River Basin. In 1946, 55,000 spring Chinook passed over Willamette Falls in April, May, and June. During that same period, 97,543 spring Chinook passed over Bonneville Dam (Fish Commission of Oregon 1948). From 1946 to 1951, annual Chinook runs, (including the mainstem Willamette River sport catch, escapement above Willamette Falls, and escapement to the Clackamas River) averaged 25,100 to 96,800 fish (Mattson 1963); the mean annual run size for this period was 55,600. The largest run on record was 156,033 adults in 1953 (ODFW 2000b). In the early 1920s, an estimated 2.5 million spring Chinook passed over Willamette Falls; historically, this run ranked second in the Columbia River Basin for spring and summer Chinook (Fulton 1968).

Wild spring Chinook have declined as a result of the construction (and ongoing operations) of Willamette Basin dams. State biologists estimated that construction of the dams would cause the loss of nearly 48 percent of spring Chinook spawning habitat (Fish Commission of Oregon 1948). Based on historic spawning information, only 400 miles of riverine habitat now remain available to spring Chinook (ODFW 2000a).

The spring Chinook sampled from 1946 through 1951 had the following age composition (Mattson 1963):

- 3 year age fish: 4 percent
- 4 year age fish: 24 percent;

- 5 year age fish: 62 percent
- 6 year age fish: 10 percent

These observations are generally consistent with observations made a quarter century earlier by Rich and Holmes (1929): “5 year old adults predominated, 6 year old salmon returned in larger numbers than 4’s, and only a few 3 year olds were recovered.”

Spring Chinook reared predominantly in the mainstem Willamette River and east side tributaries (ODFW 1990a). Adult Chinook were occasionally reported in the Tualatin River, but were believed to be “accidental” strays (Dimick and Merryfield 1945). Spring Chinook continue to spawn and rear in the Tualatin River. In 2000, the Oregon Department of Fish and Wildlife (ODFW) found Chinook up to the mouth of Gales Creek in river mile 56.0 to 56.5 (Leader 2002).

Native spring Chinook entered the Willamette River in February, peaked in April, and completed their migration to natal spawning grounds from late May through July. Passage over Willamette Falls was related to flow and temperature: passage increased when the river level dropped and water temperatures exceeded 53 degrees Fahrenheit (ODFW 1990a). Although a large portion of the spring run passed and occupied reaches above the falls, historic records show that a run of spring Chinook entered the Clackamas subbasin in March, prior to the upper Willamette fish run.

Spawning generally begins in early September and extends through mid-October. However, Dimick and Merryfield (1945) reported spawning activity in the Clackamas and Molalla Rivers as early as July. Residents of both basins substantiated these findings. Clackamas residents noted that hatchery staff took eggs in early July and August. These findings are consistent with the belief that spawning generally begins earlier in colder headwaters, and progresses later in the lower stream reaches. Spawning coincides with a slight drop in water temperature, following the first few cool nights (Dimick and Merryfield 1945; Mattson 1963).

Most Chinook fry emerge in February and March. Mattson (1962) observed that it is quite probable that some do not emerge until late spring, yielding a span of four to five months when fry actively emerge from spawning gravels.

Based on field observations and scale analysis of adult returns from 1946 to 1951, Mattson (1962 and 1963) reported three distinct emigration periods for Willamette Basin spring Chinook. The first downstream migration of fry occurred during the first spring and summer (soon after emergence). Fry were noted as early as January and as late as August, peak movement occurred in April. This group was frequently the largest in numbers and constituted a maximum 55 percent of the year class. The second period of peak emigration occurred in late fall and early winter (October and November) and coincided with high stream flows and reduced stream temperature. This group was the second largest in numbers and constituted a maximum 50 percent of the year class. The third and final peak movement occurred the following spring (March through May) and constituted the smallest of the year class, with an upper magnitude of 35 percent. Mattson reported presence of spring Chinook emigrants in every month of the year near Lake Oswego, indicating year-round movement into the lower river.

Nearly 20 years earlier Dimick and Merryfield (1945) noted similar use of the mainstem Willamette River by young of the year fry. In the early 1940s, large numbers of fry were found from Harrisburg to Independence in February, March, and April. In 1945, many fry were collected from Corvallis to the Sellwood Bridge in Portland. Chinook fry continue to express this behavior; they pass Leaburg Dam on the McKenzie River beginning in January and are regularly observed throughout the year at Willamette Falls (Baker and Miranda 2003).

Of the emigrants observed by Mattson (1962) from 1946 to 1951, fork lengths ranged from 37 to 100 millimeters (mm) for fry and fingerling in late winter to spring; 100 to 130 mm for the late fall/early winter yearling group; and 100 to 140 mm for yearlings the second spring. Field observations showed that as larger fish moved out of the tributary reaches, smaller, newly emerged fry replaced them on rearing grounds. Based on scale analysis of returning adults, Mattson concluded that growth rates of fry and fingerling residing in the lower Willamette River (first group of emigrants) exceeded freshwater growth rates of yearling migrants that remained in their natal streams. Mattson further concluded that a small number of yearling spring migrants (the third group of emigrants) experienced superior freshwater growth in the lower Willamette. Howell et al. (1985) found similar results, noting that juveniles rearing in the lower mainstem Willamette have an accelerated growth pattern and may emigrate seaward up to two months earlier than those reared in upper Willamette Basin tributaries. The combination of these studies over a 40 year period suggests that Chinook emigrants encounter favorable environmental and feeding conditions in the lower Willamette River.

The number of yearling migrants increased proportionally with the age of returning adults (Mattson 1963), indicating that older-age adults rear in fresh water (either in natal streams or the lower Willamette River) at least a year before emigrating seaward. Conversely, fry and fingerling emigrants accounted for a higher proportion of three year age adults. Therefore, the older-age adults included larger-size and older-age juveniles, while the younger-age adults included more smaller, younger-age migrants.

SUMMER CHINOOK

Summer-run Chinook may have populated tributaries of the Willamette River. Fisherman in the lower Willamette claimed that before 1927, a run of large salmon passed through the lower river each June. The last sizeable run of June migrants passed Willamette Falls in 1934, coinciding with the loss of the Clackamas River fall-run Chinook (Mattson 1963). A number of destructive activities in the 1880s and 1890s, along with poor water quality conditions in the lower Willamette River (e.g., low dissolved oxygen) in the 1920s, are believed to have significantly affected these native Chinook runs.

The summer run may have been the later part of the spring-run population. These fish averaged 25 to 30 pounds and are believed to be mostly six-year age fish. Spring Chinook and summer Chinook spawn in similar areas. However, spring-run Chinook are more abundant in upper mainstem reaches (and tributaries), while summer Chinook are more abundant in middle and lower mainstem reaches (Fulton 1968). This observation is consistent with the behavior of fall run Chinook that tend to spawn in lower mainstem reaches.

FALL CHINOOK

Most, if not all, fall Chinook native to the Willamette Basin populated reaches below Willamette Falls, including the lower Clackamas River, Sandy River, Tanner Creek, and Scappoose drainage (Hutchinson and Aney 1964). In 1945, Dimick and Merryfield reported that "At least up to fifty years ago, an annual run of salmon occurred in the Willamette River during September and October. Most of these fish that escaped the commercial fishery of the Willamette at that time spawned soon after entering the Clackamas River." The Clackamas River fall Chinook run was believed to be quite large, and used the lower 18 kilometers of stream. Fall Chinook also spawned in the mainstem Willamette River below the mouth of the Clackamas River (Fulton 1968). A number of destructive activities in the 1880s and 1890s, along with poor water quality conditions in the lower Willamette River (e.g., low dissolved oxygen), particularly during adult migrations, are believed to have significantly affected native fall-run populations. By the late 1920s and early 1930s, the native fall Chinook population was believed to have disappeared (Mattson 1963).

In 1964, fisheries managers introduced an early spawning (tule) and a last spawning (Cowlitz) fall chinook stock into streams above Willamette Falls. Currently, fall Chinook spawn and rear in the mainstem Willamette River and lower reaches of eastside tributaries (ODFW 2000a). Spawning surveys conducted from 1976 through 1988 show 60 percent of the fall run spawning between Corvallis (river mile 132) and Coburg (river mile 175) (ODFW 2000b). Of the fish passing above the falls, 95 percent were three and four year olds. Adults generally spawn shortly after returning to freshwater, from mid-September through early October. Fry emerge from gravels beginning in late December, with peak emergence in mid-January. Juveniles emigrate from tributary reaches from mid-April to late June, and are believed to enter the lower Willamette River at five months of age.

STEELHEAD

Two life-history phases of steelhead are native to the Willamette Basin: anadromous steelhead and resident rainbow trout. Both life histories inhabit eastside and westside tributaries of the Willamette River Basin (Dimick and Merryfield 1945). Upstream of Willamette Falls, winter steelhead are believed to be native mostly to eastside tributaries and to the Tualatin River on the west side (ODFW 2000a; Fulton 1970). Small wild winter steelhead are also native to eastside tributaries below the falls, most notably the Clackamas River and Johnson Creek. Small wild runs have populated Johnson Creek since the 1950s (ODFW 2000a). Fulton reported that steelhead spawned and reared in lower Johnson Creek before the mid-1960s, but since then have extended their distribution up to the middle section. Winter steelhead populating the Tualatin River Basin yielded an average annual run size of 500 (Hutchison and Aney 1964).

Winter steelhead enter the Willamette River from October through May (Dimick and Merryfield 1945), with peak passage above Willamette Falls in February and March (Howell et al.1985; ODFW 1990a). Willamette winter steelhead return to spawn in their fifth or sixth year. Spawning begins as early as March with peak spawning in April in westside tributaries and May in eastside tributaries. Resident rainbow trout spawn in March, April, and May. Juveniles generally spend two years in fresh water before smolting, with peak juvenile emigration beginning in early April and extending through early June with larger steelhead emigrating earlier than smaller ones (ODFW 2000a).

Summer steelhead are not native to the Willamette Basin. They were introduced into several subbasins in the late 1960s, but have not substantively reproduced naturally (ODFW 2000a).

COHO

Fulton (1970) noted that the Willamette River (and its tributaries) provided the third most important spawning grounds for coho salmon throughout the entire Columbia River Basin.

Coho are believed to be native only to subbasins below Willamette Falls. Although coho were not reported in the Tualatin River Basin before 1931, they were found rearing in the basin up to and including Scoggins Creek in 1945 (Dimick and Merryfield 1945). These fish are believed to be progeny of hatchery coho released in the 1920s (Fulton 1970). A formal hatchery program did not begin until 1952. Some populations naturalized, such as those in the Tualatin River Basin, while others did not. Coho populating the Tualatin River Basin had an average annual run size of 6,000 (Hutchinson and Aney 1964). By 1970, the Tualatin River supported the largest run of coho above Willamette Falls (Fulton 1970). Although hatchery-reared coho are no longer released into the Tualatin River Basin, remnant fish continue to persist and occupy the basin. In fall 1999, Oregon state fish biologists observed coho in the upper mainstem, near the mouth of Gales Creek (river mile 56.0 to 56.5) (Leader 2002).

Coho are native to the Clackamas River and Johnson Creek (Fulton 1970) and were observed in tributaries to Multnomah Channel from 1951 to 1959 (Willis 1960). Coho spawned and reared throughout all of mainstem Johnson Creek. However, the best spawning areas were believed to be in the upper watershed (Fulton 1970).

Early-run coho pass Willamette Falls from late August through early November, with peak migrations in middle to late September, following periods of considerable rainfall. Coho return as three-year age adults and two-year age jacks. Peak spawning generally occurs from September through December, within days after reaching their spawning ground. Fry emerge during a four month emergence period from mid-January through April. A small proportion of fry may emigrate during the first year, but most fingerling are believed to emigrate during the second spring (as yearlings), beginning in March and extending through mid-July.

CUTTHROAT

Coastal cutthroat had the greatest overall distribution of any of the salmonids in the Willamette River Basin, and populated most streams in the basin (Hutchinson and Aney1964). Dimick and Merryfield (1945) reported that “few tributaries of the Willamette system is without cutthroat trout unless blocked by natural barriers.”

Two life-history phases of cutthroat trout resided in Portland area streams: migratory and non-migratory. Non-migratory, or resident, cutthroat historically did not migrate far from upper tributary reaches (Hutchison and Aney 1964), remaining in fresh water for their entire lifespan. Migratory, or sea-run, cutthroat are believed to drop down into the mainstem Willamette River in the spring, rear throughout the summer, then migrate to the ocean in the fall or early winter. They did not use mainstem reaches for spawning; rather, they used them for spring, summer, fall, and early winter rearing. Sea-run cutthroat resided predominantly near tributary confluence regions with the Willamette.

In 1945, Dimick and Merryfield found no morphological differences between the two races of cutthroat, except for differences in the size of adults. However, they found that sea-run cutthroat spawned in January, February, and March (much like native winter steelhead), while resident cutthroat spawned in May, June, and July. Sea-run cutthroat return to their natal freshwater streams (and move out of the mainstem Willamette) before juvenile Chinook emigrate seaward and use lower mainstem habitats.

Tryon Creek Subbasin

Tryon Creek Winter Steelhead

POPULATION DESCRIPTION

The life history of this population is based on other lower Willamette winter steelhead populations, specifically the Clackamas and the Tualatin River populations, that took advantage of high flows and cool temperature to access upper reaches of the subbasin. Both are believed to be a late-run population returning to freshwater to spawn during their fifth and sixth year. Native, late-run winter steelhead entered the Willamette River from October through May (Dimmick 1945), with spawning beginning in March and peaking in April thru May. Steelhead spawn in cool, clear, and well-oxygenated streams with small to large gravel (1.3 to 11.4 cm) and suitable flow (0.76 meters/second) (USFWS 1983). These conditions are found in riffle-type habitats and are typical of habitat found in the upper parts of tributaries. After spawning, some steelhead will re-enter the ocean, returning to their natal stream for a second time to spawn again.

Eggs hatch and fry emerge in winter or early spring, depending on habitat, water temperature, and spawning season. After emergence, fry continue to rear in riffle-type habitats through the summer, then move into pools in the winter. Generally, steelhead become inactive in winter months, often burrowing into stream-bottom substrates and other available instream cover. Steelhead, like Chinook, rely on an abundance of instream structure for cover during overwintering months.

Juvenile steelhead generally spend two years in freshwater before smolting, with peak emigration beginning in early April and extending through early June. Smoltification is initiated by a combination of environmental factors including photoperiod, water temperature, and water chemistry. Larger steelhead generally emigrate sooner than their smaller cohorts (ODFW 2000a). Marine survival is correlated with smolt size, with the critical minimum size ranging from 14 to 16 cm upon saltwater entry. Steelhead rear in the ocean for one to four years before returning to their natal streams.

RELATIONSHIP TO ESU OR OTHER POPULATION DESIGNATIONS

Tryon Subbasin winter steelhead are part of the lower Willamette River ESU and are believed to be most closely associated with populations below Willamette Falls in the Clackamas River and Johnson Creek.

HISTORIC ABUNDANCE AND PRESENT STATUS

Winter steelhead once populated the Tryon Creek Basin (WMSWCD 2003(d)). The upstream extent of their anadromy is not known. Based on channel geomorphology and valley hillslope, they likely spawned upto (and perhaps beyond) Marshall Cascades on mainstem Tryon Creek and perhaps upto Arnold Falls on Arnold Creek (RM 0.4).

Tryon Creek Coho

POPULATION DESCRIPTION

Life history of this population is based on similar populations in the Lower Willamette River specifically the Clackamas River and Johnson Creek populations. Native lower Willamette Basin coho return as three year age adults and two year age jacks. They are an early run population, reaching Willamette Falls from late August through early November. Peak migrations occur from middle to late September, following periods of considerable rainfall. Peak spawning generally occurs from September through December. Coho commonly use tributaries to lower river reaches, and spawn in small, low-gradient areas, however, they will spawn in mainstem reaches. They prefer fast-flowing waters with small to large gravel substrates (1.3 to 10.2 cm).

After eggs are deposited, they incubate for 80 to 150 days, depending on stream temperatures. Fry emerge during a four month period from mid-January through April. During this period they seek shallow water areas before dispersing downstream into deeper habitats. A small proportion of fry emigrate during the first year, but most fingerling smolts emigrate during the second spring, from March and through mid-July. Those that remain in their natal streams migrate upstream or downstream, seeking slack water habitats often found in side channels, backwater pools, and beaver ponds. These habitats are important during overwintering months because they harbor insects and provide a continual source of food for coho. Yearling juvenile coho emigrate seaward in early spring, with peak migrations in April and May. Generally, coho will rear for two years in the ocean and return to their natal streams as three and four year age adults in the fall.

RELATIONSHIP TO ESU OR OTHER POPULATION DESIGNATIONS

Lower Columbia River coho salmon were listed on the state ESA in July 1999. This population was previously considered for federal listing. On July 25, 1995, NMFS determined that the listing was unwarranted, but the population remains a “candidate” for listing on the federal ESA. The Willamette River Basin up to Willamette Falls, including the Clackamas, contains major spawning and rearing habitat for this population.

HISTORIC ABUNDANCE AND PRESENT STATUS

Willamette Basin coho are believed to be native only to subbasins below Willamette Falls, including, the Clackamas River, Johnson Creek (Fulton 1971) and Tryon Creek (WMSWCD 2003d). They were reported occupying tributaries to Multnomah Channel from 1951 to 1959 (Willis 1960). The lower Willamette River Basin provided the third most important spawning grounds for coho salmon, throughout the entire Columbia River Basin (Fulton 1970).

In Tryon Creek adults generally occupied the lower and middle basin. The upstream extent of their anadromy is not known. Based on channel geomorphology and valley hillslopes, they likely migrated upto the confluence of Tryon and Arnold Creek and possibly upto the bottom of Marshall Cascades, a natural fish barrier, during high water years.

Tryon Creek Cutthroat

POPULATION DESCRIPTION

In Oregon and Washington, sea-run cutthroat return home to their natal stream from July through March (peaking in September through October). Generally, they migrate to reaches upstream of coho and steelhead (to avoid competition), but will reside sympatrically with resident cutthroat populations. Their preference for upstream reaches spatially segregates them from other co-occurring salmonids to avoid competition for rearing and spawning areas. Some female cutthroat do not spawn in the first winter after returning to freshwater (Johnston 1982). Rather, they overwinter in freshwater, then return to the ocean the following spring.

Cutthroat prefer small to moderate size gravel for spawning (depending on their body mass and size) and seek pool tail-outs. They are repeat spawners; fish that survive post-spawning overwinter in fresh water and emigrate downstream from early to late spring. This migration generally begins prior to smolt emigrations.

Eggs incubate for four to six weeks in gravel. Fry emerge and immediately seek shallow stream margins, with low-velocity flow. During early life history rearing cutthroat are opportunistic feeders, feeding predominately on aquatic invertebrates suspended in the water column. If other salmonids are present, fry are easily displaced. Their distribution and habitat use is therefore highly dependent on interspecific competition with other native fish.

Juveniles (and adults) prefer to rear in deeper pools and slower-velocity water, but display transitory behavior, moving upstream and downstream into differing habitats (e.g., pools, riffles), depending on local habitat conditions (e.g., food availability, flow, temperature) and competition.

Cutthroat smolt from age one to four (and sometimes later). Most smolt at age three or four, when they reach a size of 20 to 25 cm (fork length). Downstream emigrations occur from March to June, peaking in mid-May. A unique characteristic that cutthroat exhibit (different from other salmonids) is that they form schools before saltwater entry and remain schooled throughout their saltwater migrations and rearing.

Generally, cutthroat remain close to shore and occupy shallow waters while rearing in the marine environ. Although salt-water residence time varies among populations, cutthroat tend to re-enter freshwater in the same year they migrate to sea, returning to their natal stream during the subsequent fall season.

RELATIONSHIP TO ESU OR OTHER POPULATION DESIGNATIONS

The USFWS considered Southwest Washington/Columbia River coastal cutthroat trout a “candidate” species for federal ESA listing. In June 2002, the USFWS determined that the population did not warrant protection under the ESA, based on trends in population abundance and recently enacted fish and habitat protections (including protections by the City of Portland).

HISTORIC ABUNDANCE AND PRESENT STATUS

Sea-run cutthroat had the greatest over-all distribution of any of the salmonids in the Willamette River basin, and populated most streams (Hutchinson 1964). Dimmick (1945) reported that "*few tributaries of the Willamette system is without cutthroat trout unless blocked by natural barriers*". Sea-run cutthroat and resident cutthroat likely populated Tryon Creek subbasin at least upto Marshall Cascades on mainstem Tryon Creek and Arnold Falls on Arnold Creek. Cutthroat likely populated upper reaches of the Tryon Creek subbasin (above Marshall Cascades). These areas were likely accessed during high flows, which allowed trout to navigate through the high gradient cascade reach, by jumping from one pool to the next.

Fanno Creek Subbasin

Chinook and coho did not likely populate Fanno Creek prior to Willamette Falls fish passage improvements in the late 1800s. Only since fish passage improvements at W.F. have coho populated the Tualatin. Chinook are often documented in the Tualatin basin, but are rarely found in Fanno Creek. Although salmon and steelhead now navigate above Willamette Falls, it is not known if salmon were able to leap the falls prior to 1880: "…it seems that any salmon in the Tualatin River were insufficient because yearly treks (*by the Kalapuya)* were made to the Falls, to the annoyance of the Clackamas tribe…" (Benson 1975). Regardless, anadromous fish numbers have declined as a result of low, warm rearing flows in the river and its tributaries:

> *"It has been reported that poor summer conditions are suspected to have been a major cause for spring Chinook salmon extinction in the drainage. Coho (silver) salmon and steelhead have maintained runs largely because the adults do not require summer residency, and a number of their progeny, either by adaptation or necessity, rear in headwater streams."*(Hutchison and Aney, 1964).

Anadromous steelhead (winter-run), and sea-run cutthroat likely populated the Fanno Creek Basin, and resident trout (rainbow and cutthroat) likely populated most subbasins. Sea-run and resident cutthroat likely had the greatest distribution, populating most reaches of the subbasin.

Fanno Steelhead

POPULATION DESCRIPTION

Remnant Fanno Creek winter steelhead are most closely related to the larger Tualatin River Basin steelhead, are part of the Upper Willamette River ESU and are believed to be most closely associated with populations above Willamette Falls: North Santiam, South Santiam and Calapooia watersheds. These populations are a late, winter-run population, entering the Willamette River from October through May (Dimmick 1945), with spawning beginning in March and peaking in April thru May. Steelhead spawn in cool, clear, and well-oxygenated streams with small to large gravel (1.3 to 11.4 cm) and suitable flow (0.76 meters/second) (USFWS 1983). These conditions are found in riffle-type habitats and are typical of habitat found in the upper parts of tributaries. After spawning, some steelhead will re-enter the ocean, returning to their natal stream for a second time to spawn.

Eggs hatch and fry emerge in winter or early spring, depending on habitat, water temperature, and spawning season. After emergence, fry continue to rear in riffle-type habitats through the summer, then move into pools in the winter. Generally, steelhead become inactive in winter months, often burrowing into stream-bottom substrates and other available instream cover.

Steelhead, like Chinook, rely on an abundance of instream structure for cover during overwintering months.

Juvenile steelhead generally spend two years in freshwater before smolting, with peak emigration beginning early April and extending through early June. Smoltification is initiated by a combination of environmental factors including photoperiod, water temperature, and water chemistry. Marine survival is correlated with smolt size, with the critical minimum size ranging from 14 to 16 cm upon saltwater entry. Steelhead rear in the ocean for one to four years before returning to their natal streams.

RELATIONSHIP TO ESU OR OTHER POPULATION DESIGNATIONS

Remnant Fanno Creek steelhead are part of the Upper Willamette River ESU and are believed to be most closely associated with populations above Willamette Falls: North Santiam, South Santiam and Calapooia subbasins.

HISTORIC ABUNDANCE AND PRESENT STATUS

It is believed that steelhead historically populated the Tualatin River Basin. In 1964, Hutchison and Aney reported that the average annual run size entering the Tualatin River was less than 500 fish. Adult steelhead were widespread and were known to spawn upto rivermile 75 (Lee Falls) and in tributaries East Dairy, Gales, and Scoggins Creek. It is believed that poor summer rearing habitat led to the decline of this native population.

The upstream extent of winter steelhead anadromy in Fanno Creek is not known. Based on channel morphology and hillslope and valley characteristics, they likely spawned at least upto the headwater reach, just upstream of the confluence with Ivey Creek (ODFW 2002). Although adults may not have spawned above this mainstem reach, juveniles likely moved into these upper areas in the summer to find cooler water.

Winter steelhead continue to spawn and rear throughout the Tualatin River Basin and are believed to spawn and rear in Fanno Creek up to Ivey Creek (ODFW 2005). A population assessment of the Tualatin River winter steelhead population concluded that they continue to spawn and rear in mainstem reaches of Fanno Creek. Data were evaluated based on accessible habitat, suitable habitat, potential use (migration, spawning and rearing) and adult and juvenile observations (ODFW 2005, ODFW Fish Distribution Maps - 2002). From 1999 thru 2001, ODFW found steelhead and unidentified trout (cutthroat or steelhead) in a reach of upper Fanno Creek, they are presumed to inhabit reaches up to the headwaters.

Unidentified trout (steelhead and/or cutthroat) were observed in Ash Creek during 2001 (ODFW 2002). Anadromous steelhead are not believed to persist here, or in any other tributaries of Upper Fanno Creek basin.

Because steelhead are not believed spawn and rear in Upper Fanno Creek, an assessment of their population potential is not included in this report.

Fanno Creek Coho

POPULATION DESCRIPTION

The Fanno Creek coho population did not historically navigate above Willamette Falls. The combination of fish passage improvements made to the Falls in the late 1800s, and hatchery coho releases into the subbasin in the early 1900s, created naturalized populations of coho salmon in different subbasins of the larger Tualatin River Basin.

Life history of this population is based on native populations in the lower Willamette River, specifically Clackamas River and Johnson Creek populations. Native lower Willamette Basin coho return as 3 year age adults and 2 year age jacks. They are an early run population, reaching Willamette Falls from late August through early November. Peak migrations occur from middle to late September, following periods of considerable rainfall. Peak spawning generally occurs from September through December. Coho commonly use tributaries to lower river reaches, and spawn in small, low-gradient areas, however, they will spawn in mainstem reaches. They prefer fast-flowing waters with small to large gravel substrates (1.3 to 10.2 cm).

After eggs are deposited, they incubate for 80-150 days, depending on stream temperatures. Fry emerge during a four month period from mid-January through April. During this period they seek shallow water areas before dispersing downstream into deeper habitats. While a small proportion of fry emigrate during the first year, most fingerling smolts emigrate during the second spring, beginning in March and extending through mid-July. Those that remain in their natal streams will migrate upstream or downstream, seeking slack water habitats often found in side channels, backwater pools, and beaver ponds. These habitats are especially important during overwintering months because they harbor insects and provide a continual source of food for coho. Yearling juvenile coho emigrate seaward in early spring, with peak migrations in April and May. Generally, coho will rear for two additional years in the ocean and return to their natal streams as three and four year age adults in the fall.

RELATIONSHIP TO ESU OR OTHER POPULATION DESIGNATIONS

Because coho did not likely populate subbasins above Willamette Falls, the current Tualatin Basin population is not part of a recognized evolutionarily significant unit (ESU), as defined by the federal ESA. However, naturalized coho in the Tualatin are believed to be the closest genetically related species to Lower Columbia River coho salmon. This population was listed as endangered on the state ESA in July 1999 and was considered for federal listing. On July 25, 1995, NMFS determined that the listing was unwarranted. However, the population remains a “candidate” for listing on the federal ESA.

HISTORIC ABUNDANCE AND PRESENT STATUS

Historically, the lower Willamette River Basin provided the third most important spawning grounds for coho salmon, throughout the entire Columbia River Basin (Fulton 1970). Although coho were not reported in the Tualatin Basin, prior to 1931, they were found rearing in the basin, up to and including Scoggins Creek in 1945 (Dimmick, et.al. 1945). These coho are believed to be progeny of hatchery coho released in the 1920s (Fulton 1970). A formal hatchery program did not begin until 1952. By the early 1960s coho populating the Tualatin River Basin had an average annual run size of 6,000, and were the most numerous and widespread anadromous fish in the Tualatin River Basin (Hutchinson et.al. 1964). By 1970, the Tualatin River supported the largest run of coho above Willamette Falls (Fulton 1970).

Coho were not observed during ODFW fish surveys from 1999 through 2001 (ODFW 2002b). However, ODFW biologists and other natural resource biologists believe that coho currently inhabit mainstem habitat in lower and middle Fanno Creek (up to rivermile 11.5), or have at some time during the past five reproductive cycles (ODFW 2002, ODFW Fish Distribution Maps - 2002). Fish distribution is based on the current distribution of available, potentially suitable habitat for migration spawning and rearing. Coho may use mainstem Fanno Creek from rivermile 0.0 to 5.3 (38 percent of mainstem Fanno Creek habitat) for adult rearing and migration, and river mile 5.3 to 11.5 (45 percent of mainstem Fanno Creek habitat) for spawning and rearing. Note - their range does not extend above the Beaverton-Hillsdale Shopping Center. Coho have not been observed using any tributary to Fanno Creek and are not believed to currently occupy tributary habitat.

Because coho salmon are not believed to spawn or rear in Upper Fanno Creek, an assessment of their population potential is not included in this report.

Fanno Creek Cutthroat

POPULATION DESCRIPTION

In Oregon and Washington, sea-run cutthroat return home to their natal stream from July through March (peaking in September through October). Generally, they migrate to reaches upstream of coho and steelhead (to avoid competition), but will reside sympatrically with resident cutthroat populations. Their preference for upstream reaches spatially segregates them from other co-occurring salmonids and avoids competition for rearing and spawning areas. Some female cutthroat do not spawn in the first winter after returning to freshwater (Johnston 1982). Rather, they overwinter in freshwater, then return to the ocean the following spring.

Hutchison and Aney (1964) noted:

> *"Cutthroat trout enter the Tualatin River each winter to spawn. These fish are both sea-run and Willamette River resident forms. Runs are normally moderate. Smaller resident cutthroat occur throughout the year in most streams in the moderate to high numbers. They are most plentiful in the headwater streams possessing cool summer temperatures."*

Cutthroat prefer small to moderate size gravel for spawning (depending on their body mass and size) and optimally seek pool tail-outs. They are repeat spawners; if they survive post-spawning, they overwinter in fresh water and emigrate downstream from early to late spring. This migration generally begins prior to smolt emigrations.

Eggs incubate for four to six weeks in gravel. Fry emerge and immediately seek shallow stream margins, with low-velocity flow. During early life history rearing cutthroat are opportunistic feeders, feeding predominately on aquatic invertebrates suspended in the water column. If other salmonids are present, fry can be easily displaced; their distribution and habitat use is therefore highly dependent on interspecific competition with other native fishes.

Juveniles (and adults) prefer deeper pools and slower-velocity water to rear in, but display transitory behavior, moving upstream and downstream into differing habitats (e.g., pools, riffles), depending on local habitat conditions (e.g., food availability, flow, temperature) and competition.

Cutthroat smolt from age one to four (and sometimes later). Most smolt at age three or four, when they reach a size of 20 to 25 cm (fork length). Downstream emigrations generally occur from March to June, peaking in mid-May. A unique characteristic that cutthroat exhibit (different from other salmonids) is that they form schools before salt-water entry and remain schooled throughout their saltwater migrations and rearing.

Generally, cutthroat remain close to shore and tend to occupy shallow waters while rearing in the marine environ. Although salt-water residence time varies among populations, cutthroat tend to re-enter freshwater in the same year they migrated to sea, returning to their natal stream during the subsequent fall season.

RELATIONSHIP TO ESU OR OTHER POPULATION DESIGNATIONS

The USFWS considered Southwest Washington/Columbia River coastal cutthroat trout a “candidate” species for federal ESA listing. In June 2002, the USFWS determined that the population did not warrant protection under the ESA, based on trends in population abundance and recently enacted fish and habitat protections (including protections by the City of Portland).

HISTORIC ABUNDANCE AND PRESENT STATUS

Sea-run cutthroat had the greatest over-all distribution of any of the salmonids in the Willamette River Basin, and populated most tributary streams (Hutchinson 1964). Dimmick (1945) reported that “*few tributaries of the Willamette system is without cutthroat trout unless blocked by natural barriers*”.

Today, resident cutthroat trout populate middle and upper reaches of Upper Fanno Creek and lower reaches of Vermont Creek. They are present year-round; abundance is highest in winter and lowest in fall. The culvert at SW 39th Place is impassable and prevents fish from moving upstream into upper reaches of mainstem Fanno Creek. Cutthroat spawn and rear above this culvert, but if an event ever killed-off a substantive portion of this population there would be little chance to recolonize the area, absent reintroduction. Unidentified trout have also been documented in Ash Creek (ODFW 2002).

Because cutthroat trout are known to spawn and rear in Upper Fanno Creek, they were selected as a primary indicator species for other biological communities inhabiting aquatic habitats in Fanno Creek.

Life History Characteristics of Salmonids

Key life history characteristics (age at maturity and spawning, egg incubation, fry emergence, juvenile rearing, and smolt emigration) and associated freshwater habitat needs (e.g., instream structure and channel form or condition) are provided below. The life history characteristics are described in general terms per species.

Spring Chinook

Spring Chinook generally inhabit larger river reaches than steelhead, and enter freshwater at age two to five during spring freshets (April-June). They migrate slowly upstream and hold in deep pools, then spawn in mid to upper reaches of their natal stream in late summer and fall (between August and November). They typically spawn in coarse gravel and cobble substrates (up to 14 cm diameter) and in pools at least 0.24 meters deep (Reiser and Bjornn 1979; Hutchison and Aney 1964). Chinook seek pool-riffle channel areas versus plane bed or step pool channels (Montgomery et al. 1999).

Eggs usually incubate for 90-150 days and emerge in March through April. Fry rear in fresh water for one to two years, and gradually move downstream to deeper waters as they grow to smolt condition.

Juvenile spring Chinook overwinter in large, deep pools and rely on instream structure such as large boulders and woody debris complexes for cover and refuge. During freshwater rearing, juveniles prefer bank edges of deep (greater than 0.5 m), fast flowing waters that enable opportunistic feeding (e.g., they are characterized as drift, benthic feeders that feed primarily on insects).

Juvenile spring Chinook experience an accelerated growth rate in early spring, smolt in April and May, then emigrate to lower river estuarine habitats. They then enter the ocean and begin their northwesterly migrations. They continue to rear for an additional two to four years in the marine environ before re-entering freshwater.

Fall Chinook

Fall Chinook adults enter fresh water from late summer through fall. They rapidly swim upstream into lower mainstem river reaches and tributaries to briefly hold, and spawn between October and December.

Like spring Chinook, fall Chinook typically spawn in coarse gravel and cobble substrates (up to 14 cm diameter). They prefer to spawn in pools greater than 0.24 meters deep (Reiser and Bjornn 1979), and seek pool-riffle channel areas versus plane bed or step pool channels (Montgomery et al. 1999).

Eggs usually incubate for 90-150 days and emerge in March through April. Fall Chinook fry begin their downstream migration within several weeks of emergence, but may extend their migrations through the summer. Juvenile fall Chinook generally enter estuary environs in late winter (February) through early summer (July) (Beamer et al. 2000).

Potential Interspecific Competition among Target Species

Competition can occur among (intraspecific) and between (interspecific) salmonid populations. This characterization evaluates interspecific competition between differing species. Individuals may compete for resources (or overlap in their resource use) during varying stages of their freshwater life: adult freshwater entry, adult spawning, freshwater rearing, and smolt emigration.

Freshwater Entry (Timing)

Spring Chinook, winter steelhead, and coho enter freshwater as adults during different seasons of the year. Spring Chinook enter freshwater in the spring, followed by coho during late summer/early fall, and finally winter steelhead from early to late winter. Cutthroat adults migrate to fresh water from fall through winter, peaking in September to October; their adult migrations may temporally overlap with coho and steelhead residing in the same stream reach. Adult migrations are closely associated with freshets of high flows and optimum temperature regimes.

Spawn Timing, Location and Habitat Use

Anadromous salmonids are considered segregate either spatially (in terms of preferred spawning conditions and locations) or temporally (in terms of optimal spawn timing). Spring Chinook prefer upper mainstem pools (greater than 0.24 meters deep) that contain coarse gravels and cobbles, and spawn from August through November. Winter steelhead prefer small tributary and headwater reaches and seek riffle-type habitats (or pool tail-outs) that contain small to large sized gravels. Coho similarly prefer small mainstem reaches and tributaries and small to large sized gravels (often found in riffles and pool tail-outs). However, coho spawn in late fall to early winter (late September to early January), while winter steelhead spawn in late winter through early spring (February through May). Although coho and winter steelhead may seek and occupy similar spawning areas, their spawn timing is relatively segregated.

Cutthroat migrate to upper stream reaches, generally above Chinook, steelhead, and coho spawning grounds. It is believed that cutthroat exhibit this behavior specifically to avoid antagonistic interactions and competition for food and space. Cutthroat prefer small to moderate sized gravels often found in pool tail-outs and riffles, and spawn from late winter to early spring, similar to winter steelhead spawn timing.

Although cutthroat are believed to seek upper stream reaches, away from other salmonids, they are known to interbreed with steelhead. Hybridization between cutthroat and steelhead (especially in areas with limited carrying capacities and available habitat) may significantly affect the recovery and persistence of independent steelhead and cutthroat populations.

Freshwater Rearing and Habitat Use

Steelhead tend to occupy upper river reaches with steep gradients (headwater and tributary reaches), while Chinook tend to occupy mainstem river reaches. If steelhead and Chinook co-exist, they likely partition into available habitat. Juvenile steelhead seek rubble substrate with low water velocities and shallow depth (0.15 meter), while juvenile spring Chinook seek deep pools or mainstem reaches (greater than 0.5 meter deep) with fast flowing water. Although steelhead occupy riffle-type habitats more during the summer, they often migrate into pool habitats to overwinter where they may co-exist with Chinook. However, each species inhabits different habitats, steelhead seek stream bottom areas and will often burrow into substrates for additional cover and refuge, while Chinook juveniles occupy the water column. Both species rely heavily on instream structure, such as large boulders and trees for cover and refuge, especially during the winter.

Juvenile coho occupy slack-water habitats such as deep pools, backwater pools, beaver ponds, and side channels year-round especially in the winter.

Steelhead, Chinook, and coho occupy different niches in shared habitats. Coho tend to form groups in open waters and occupy space near large stones and boulders, above the stream bottom. Steelhead seek stream bottom areas, often burrowing into (and beneath) cobbles and stones. Coho will migrate to downstream, freshwater reaches throughout the year, seeking optimal overwintering habitat. If coho and Chinook co-occur, coho are more likely to form strong intraspecific social interactions and defend their habitats more aggressively than Chinook. As a result, Chinook juveniles may be displaced.

Cutthroat reside in isolated headwater streams with sloping stream gradient and small drainage area (generally less than 13 square km). Cutthroat optimally reside in stream reaches upstream of co-occurring steelhead and coho. Juvenile cutthroat prefer deep pools with low flows, but will disperse to other habitats if other salmonids are present or if local environmental conditions are suboptimal (e.g., food source, space, cover). If displaced by interspecific competition, cutthroat will often return to their preferred pool environs as winter approaches, temperatures lower, and flows displace them from faster-flowing riffles.

Of the salmonids being considered, cutthroat are most likely to interact with steelhead and coho because of similar habitat preferences, especially during the winter or when food sources are limited. Cutthroat are most likely to overlap with steelhead and rainbow distributions in the Willamette River Basin. Habitat use among the distinct populations appears to be relatively segregated. Antagonistic competition will not occur unless stream carrying capacities are compromised and/or suitable habitat is limited. For example, existing pools may not provide critical functions including suitable substrate composition (small to large sized gravels), adequate cover (boulders, wood, vegetation), or available food sources (invertebrate populations).

Smolt Emigration Timing

Salmonid smolts emigrate throughout the spring, with peak migrations in April and May. Coho, Chinook, steelhead and cutthroat emigrations may overlap, but emigration timing and patterns are not believed to be antagonistic among species.

INDICATORS OF BIOLOGICAL COMMUNITIES

Fish Populations

To date, detailed data that quantify fish population abundance and distribution throughout the Portland metropolitan area are limited. In Tryon Creek and Fanno Creek, biological community structure was characterized by evaluating results from ODFW aquatic inventory surveys from 1999 through 2001. The surveys included extensive summer surveys and intensive seasonal surveys (spring, summer, and fall). The following biological parameters and relationships were evaluated from these data: index of biotic integrity (IBI), fish presence/absence data, and expanded population estimates (based on multiple pass electrofishing surveys). Where data and information gaps exist, anecdotal information and personal communications with expert professionals were considered.

Salmonid populations were characterized according to four interrelated factors: abundance, productivity, spatial structure, and diversity (NMFS 2000). In the absence of robust, long-term data sets that quantify population status and trends, these parameters were only qualitatively assessed (and inferred) where feasible. Each parameter is briefly described below:

Abundance: Also referred to as population size, abundance is an important measure of a population’s health and fitness at various life stages. All else being equal, small populations are at greater risk of extinction than large populations because of processes such as environmental variation, genetic variation, demographic stochasticity, and catastrophic events. Viable populations should be large enough to adapt with these processes (over a period of time) and still sustain a healthy population.

Productivity: Also referred to as population growth, productivity provides information about how well an individual population is performing (e.g., number of returning adults produced by the parent spawner) in response to its environment. A population’s natural productivity should be sufficient to maintain its abundance above the viable level in the absence of hatchery fish, during poor ocean conditions, and across multiple generations.

Spatial Structure: Spatially structured populations are often referred to as metapopulations. A population’s spatial structure is made up of both the geographic distribution of individuals in the population and the processes that generate that distribution (NMFS 2000). It depends on habitat quality, spatial configuration, and dynamics, as well as dispersal behaviors.

Diversity: Salmonids exhibit diverse life history traits within and among populations that significantly affect population viability and persistence. Diversity allows a species to inhabit varying environs, protects a species against short-term catastrophic loss, and provides the genetic makeup to sustain long-term environmental change. Specific traits include anadromy, morphology, fecundity, run timing, spawn timing, juvenile behavior, age structure, size, developmental rate, ocean distributions, and molecular genetic characteristics (NMFS 2000).

BIOTIC INTEGRITY: Biotic integrity is often used to evaluate human effects on fish assemblages. Biotic integrity has been defined as the ability to support and maintain a balanced, integrated, adaptive community of organisms having a composition, diversity, and functional organization comparable with that of the natural habitats or the region (Frey 1977). A widely used indicator of fish assemblage integrity is the index of biotic integrity, or IBI (Karr et al. 1986). IBI reflects important components of an ecosystem:

- **Taxonomic richness** (number of native families and number of native species present)
- **Habitat guilds** (benthic species, native water column species, hider species, sensitive species, nester species, and proportion of tolerant individuals)
- **Trophic guilds** (percent filter-feeding individuals and percent omnivores)
- **Individual health and abundance** (percent of target species and percent of individuals with anomalies)

Fish survey data are queried to make up the IBI rankings and subsequent scores. In addition to absolute IBI scores and what they imply (in terms of biotic integrity), fish presence/absence data can be evaluated to determine relative water quality conditions, based on individual families' tolerance for silty, warm, polluted waters. In general, salmonids tend to be sensitive to water quality condition, while non-native species tend to be more opportunistic and tolerant of degraded water quality.

IBI scores were evaluated to consider biotic health in Tryon and Fanno Creeks. Streams with scores less than or equal to 50 are considered severely impaired; streams with scores of 51-74 are considered impaired; and streams with scores greater than or equal to 75 are considered acceptable. In addition to the composite score, fish assemblages were evaluated to determine relative proportions of community dominance and makeup, based on sensitive, intermediate, and tolerant species.

Macroinvertebrate Production

Macroinvertebrates are observed for two primary reasons: they provide a direct food source for salmonids, and their presence indicates general stream conditions. Presence, abundance, and diversity of macroinvertebrate communities provide an integrated assessment of general stream conditions, including physical, chemical, and biological conditions. To attract and retain these aquatic insects it is important to have dead and dying organic matter, salmonid carcass, etc. present instream. Good stream conditions and an adequate food supply give young fry and juveniles the sustenance (and growth development) needed to successfully emigrate downstream, fend off predators, and survive in the marine environ.

Water quality and nutrient loads are major considerations in Tryon Creek and Fanno Creek. Because Ephemeroptera-Plecoptera-Trichoptera (EPT) taxa are sensitive to water pollution, their presence and taxa richness are used as biological indicators of poor water quality, pollution, and general stream health (e.g., sedimentation). The number or proportion of EPT taxa is expected to decrease as environmental disturbances increase.

Past studies of the lower Willamette Basin showed that aquatic and terrestrial insects such as mayflies, stoneflies, caddis flies, midges, blackflies, and crayfish are important organisms in the diets of Chinook, steelhead, rainbow, and cutthroat trout (Dimick and Merryfield 1945). Field investigations surmised that the scarcity of fish in species and numbers from the mouth of the Yamhill River downstream to the Sellwood Bridge could be the result of food depletion in amount and kinds, resulting from the effects of pollution in that area.

Metrics for Macroinvertebrate Production

EPT evaluations were used to evaluate macroinvertebrate species richness and abundance.

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CHAPTER 8

Habitat: Fanno Creek Watershed

This chapter characterizes habitat conditions in the Fanno Creek Watershed. It includes:

- Reach Descriptions
- Habitat Characterization by Reach
- Habitat Characterization Summary

REACH DESCRIPTIONS

Reach breaks in Fanno Creek are based on tributary confluences and major culverts. Bureau of Environmental Services (BES) reaches generally match reach breaks identified by the Oregon Department of Fish and Wildlife (ODFW) during its 2001 habitat surveys. All reaches are described downstream to upstream. River miles per reach are approximate and based on Portland BES aerial photograph interpretations of channel location. Reaches that lie outside the study area are noted and are not described in this characterization.

Mainstem Fanno Creek Reaches

The upper reaches of Fanno Creek are primarily steep and forested, and in private ownership. As the creek passes through west Portland, residential development is denser, and areas of commercial and industrial use are more common.

The following mainstem reaches that lie west of Multnomah County are outside the current study area and are not included in this characterization:

- **Fanno a** (Ball Creek): River mile (RM) 0.0 – RM 2.5
- **Fanno b** (Red Rock Creek): RM 2.5 – RM 4.0
- **Fanno c** (Ash Creek): RM 4.0 – RM 6.5
- **Fanno d** (Woods Creek): RM 6.5 – RM 9.5)
- **Fanno e** (Vermont Creek): RM 9.5 – RM 10.7

Fanno 1: Oleson Road (RM 10.7 – RM 12.14)

This reach begins at the confluence of Vermont Creek and extends upstream to the Beaverton/Hillsdale Shopping Center. The reach parallels SW Oleson Road for much of its length and is the lowest reach evaluated by ODFW (lower half of ODFW Reach 1). A substantial portion of the stream corridor is in commercial land use.

Two tributaries enter this reach: Pendleton Creek and Sylvan Creek. Pendleton Creek enters near the radio tower/sewage treatment plant site. Sylvan Creek enters at the upper end of the reach through a buried culvert near the junction of SW Beaverton-Hillsdale Highway and Scholls Ferry Road. This piped stretch is approximately 800 feet long.

Fanno 2: 59th Avenue (RM 12.14 – RM 12.46)

This reach begins at the SW Beaverton-Hillsdale/Scholls Ferry Road interchange and ends at the confluence of Columbia Creek (below SW 59th Avenue). The reach is approximately 0.3 miles long and drains portions of Multnomah County and Portland in the Green Hills area. Much of the stream corridor is bounded by medium to high density residential use.

Fanno 3: Shattuck Road (RM 12.46 – RM 12.88)

This reach begins at the confluence of Columbia Creek and extends upstream to Patton Creek, which enters Fanno Creek just above SW Shattuck Road. This reach is approximately 0.42 miles in length. Land use is medium to high density residential and commercial. Patton Creek drains portions of the Southwest Hills and Bridlemile neighborhoods in Portland and Multnomah County.

Fanno 4: 45th Avenue (RM 12.89 – RM 13.39)

This reach begins at the confluence of Patton Creek and ends at Ivey Creek, just upstream of SW 45th Avenue. This reach is approximately 0.55 miles in length. Land use is mixed residential, utilities, and commercial; several privately owned undeveloped lots bound the creek.

Fanno 5: 39th Drive (RM 13.39 - 13.71)

This reach begins at the confluence of Ivey Creek and ends immediately above Kelly Creek, at SW 39th Drive. Reach length is short: 0.32 miles. Land use is predominantly low and medium density residential. There are several large undeveloped parcels and two undeveloped street rights-of-way (SW 43rd Avenue and SW 42nd Avenue) in this reach. Kelly Creek drains the Kelly Park area.

Fanno 6: 30th Avenue (RM 13.71 – 14.39)

This reach begins at SW 39th Drive and ends at SW 30th Avenue. The reach is approximately 0.68 mile in length. High-density residential development (apartments), roads, and SW Beaverton-Hillsdale Highway dominate the landscape. The majority of parcels that constitute the riparian zone are undeveloped and in private ownership.

Fanno 12: Headwaters (RM 14.39 -14.66)

This reach begins at SW 30th Avenue and extends upstream through the Beaverton-Hillsdale Shopping Center. Headwater creeks enter Fanno Creek mainstem near the downstream portion of this reach. ODFW and Clean Water Services (CWS) identified the southeast channel (at the upper end of this reach) as a tributary to Fanno Creek and identified the northern reach originating from Gray Middle School as mainstem Fanno Creek. This interpretation is counter to previous surveys conducted by BES, which refer to the southeast tributary as mainstem Fanno Creek (and headwaters). The BES convention is used in this characterization to remain consistent with past survey efforts and references. Because ODFW and CWS did not survey the southeast channel as part of mainstem Fanno Creek, few data are available to characterize habitat elements in that portion of the reach. Medium-density residential use and SW Beaverton-Hillsdale Highway dominate land use in reach 12, with some commercial use in the uppermost reaches at the shopping center.

Tributaries of Fanno Creek Reaches

This characterization includes Red Rock Creek, Ash Creek, Woods Creek, Vermont Creek, Pendleton Creek, Columbia Creek, Ivey Creek, and Patton Creek. Ball Creek and Sylvan Creek lie partly within Multnomah County, but are not included in this characterization.

Red Rock Creek

RED ROCK 3

Red Rock Creek is divided into three reaches, but only the uppermost reach (Red Rock 3) is within the City of Portland. The reach begins at SW 68th Avenue, approximately 1,000 feet west outside of the Multnomah County line. This reach parallels SW Pacific Highway (Barbur Boulevard) in Washington County. The upper basin drains the northwest slopes of Mt. Sylvania and the Portland Community College campus in the southwest corner of Multnomah County. Land use is primarily low-density residential (BES 1999). Data sources are limited to one CWS survey location and field observations.

Ash Creek

This characterization evaluates two headwater reaches: Ash Creek (mainstem) and North Ash Creek. The characterization is based on ODFW 2001 reach surveys, several site surveys by Harza in 1997, and CWS surveys of two sites on mainstem Ash Creek and one site on North Ash Creek in 2000.

SOUTH ASH CREEK (1G) – HEADWATERS

This reach of mainstem Ash Creek begins at SW 77th Avenue and extends upstream to the headwaters near SW 52nd Avenue and SW 55th Avenue. It drains an area south of SW Taylors Ferry Road and Interstate 5 (I-5). The Multnomah County line crosses the creek about midway through this reach. Although the lower portion of the reach is not within the City of Portland’s jurisdiction, it is included in this characterization (and follows ODFW reach breaks). Land use is primarily low-density, single-family, residential (BES 1999).

NORTH ASH CREEK (1E)– HEADWATERS

North Ash Creek is approximately 720 meters long. This reach matches the ODFW stream habitat survey. It begins 100 meters downstream of SW Dolph Drive (at the Multnomah County line) and ends 10 meters upstream of SW 55th Avenue (north of SW Brugger Street.). Land use is predominantly low-density residential, with no commercial or industrial properties (BES 1999).

Woods Creek

Woods Creek runs through both Beaverton and Portland. Approximately 60 percent of it (middle and upper Woods Creek) is within incorporated Portland. Because ODFW surveys document conditions throughout all of Woods Creek, this characterization evaluates the entire creek. Land use is primarily low-density residential, with some commercial development concentrated along Multnomah Boulevard.

WOODS 1A AND 2A – LOWER AND MIDDLE WOODS CREEK

Lower Woods Creek begins at the confluence of Woods Creek and Fanno Creek, within City of Portland jurisdiction. Middle Woods Creek begins at Oleson Road, at the city boundary, and extends upstream to approximately 500 feet below SW Multnomah Boulevard. The stream segment is approximately 5,500 feet long. Surveys were conducted along this reach by: BES and Brown and Caldwell (1998) in 1197; CWS (2000) in 2000; and ODFW (2001) in 2001. A water quality monitoring station is located at Oleson Road.

WOODS 3A – HEADWATERS OF WOODS CREEK

The upper Woods Creek reach begins approximately 500 feet below SW Multnomah Boulevard, extends upstream into Woods Creek headwaters, and ends at SW Taylors Ferry Road. The headwaters are located in Woods Creek Memorial Park. The lower part of the reach is flows through residential development. The reach is approximately 6,350 feet long. South Fork Woods Creek runs along SW 45th Avenue near the entrance of Woods Memorial Park, and mainstem Woods Creek originates just above SW Capitol Highway, near I-5.

Vermont Creek

The Vermont Creek subbasin is heavily developed with low-density residential and commercial land uses. Upper Vermont Creek begins in a residential area upstream of Gabriel Park and continues through residential developments to its confluence with Fanno Creek. This characterization includes approximately 85 percent of the subbasin. The confluence of Vermont Creek and Fanno Creek (Bauman Park) is not within the study area and is not included in the characterization.

VERMONT 1A – LOWER VERMONT

This reach extends from the confluence of Vermont Creek and Fanno Creek (and Bauman Park) upstream to a tributary approximately 900 feet downstream of SW 45th Avenue. The lower 200 feet of this reach (Bauman Park) are outside the study area and are not included in this characterization.

VERMONT 2A – UPPER VERMONT

This reach begins at a tributary approximately 900 feet downstream of SW 45th Avenue and extends upstream to the headwaters of Vermont Creek that drain Gabriel Park. The mainstem is 3,620 feet long and originates upstream of Gabriel Park, along SW Caldwell Street near SW 36th Avenue. The north fork originates near SW Vermont Street and SW 37th Avenue. The south fork originates near the Garden Home/Multnomah Road intersection and enters mainstem Vermont Creek approximately 100 feet below SW 45th Avenue. Few data are available to evaluate the south fork, which is the longest reach of the three headwater creeks and is believed to provide perennial flow during the summer.

Pendleton Creek

PENDELTON 1A

Pendleton Creek passes through residential developments with some open space and then through a commercial area near its confluence with Fanno Creek. It joins Fanno Creek immediately downstream of the Multnomah County boundary (just below the Beaverton-Hillsdale Shopping Center) and extends upstream to above SW Fairvale Court, near SW 48th Avenue. The tributary is approximately one mile long. The subwatershed drains approximately 240 acres. Land use is primarily low-density residential. Data are limited for Pendleton Creek. Neither ODFW (2001) nor CWS (2000) included Pendelton Creek in their surveys. The 1998

BES and Brown and Caldwell resource inventory evaluates six short segments of the creek. Habitat assessments are therefore based largely on anecdotal field observations, aerial photographs, and topographic map evaluations.

Columbia Creek

Columbia Creek flows into mainstem Fanno Creek near SW 59th Avenue (Fanno 2). The creek is spring fed and originates in the Sylvan Hills.

Ivey Creek

Ivey Creek flows into Fanno Creek just upstream of SW 45th Avenue (Fanno 4/Fanno 5) and drains the Bridlemile neighborhood.

HABITAT CHARACTERIZATION BY REACH

Mainstem Fanno Creek

Fanno 1 – Oleson Road

FLOODPLAIN CONDITION

The floodplain contains multiple terraces within a broad valley. The ratio of floodway to stream width (valley width index, or VWI) is 20.0. However, the stream channel is relatively constrained within the floodway, with high terraces bounding both sides of the creek. Data suggest that flood flows overtop terraces enough to interact with the 50 year floodplain (ODFW 2002b). Land use in the area is urban and rural residential. Stream gradient is low (0.5percent). In the lower portion of the reach, floodplain connectivity is fair to good, but decreases toward the upper end as commercial development dominates the immediate landscape.

RIPARIAN CONDITION

Riparian condition is good in the lower portion of the reach, with the exception of some houses near the stream bank. Upstream of Oleson Road, the riparian corridor narrows, and riparian integrity diminishes to poor (ODFW 2001). Remnant forest surrounds the riparian zone. Recent surveys show riparian vegetation as deciduous trees (15-30 centimeters diameter breast height (dbh)), shrubs and vines (ODFW 2002b). Blackberry is common and spans the creek.

Large trees found in the riparian area are most frequently coniferous (>30 centimeters diameter breast height (dbh)). Tree canopy cover averages 41 percent in zone 1 (0-10 meters from the stream bank), 19 percent in zone 2 (10-20 meters from the stream bank), and 18 percent in zone 3 (20-30 meters from the stream bank).

The upper portion of the reach has little or no remaining riparian zone; parking lots, bridges, and roads surround the creek. Predominant landforms include high terraces and transportation corridors. The Beaverton-Hillsdale Shopping Center effectively fragments the riparian corridor at the upper reach break; SW Oleson Road parallels the creek; and SW Beaverton Hillsdale Highway crosses the creek midway.

STREAM CONNECTIVITY

Stream connectivity to downstream reaches of Fanno Creek is fair to good because of low stream gradients. Several driveways span the creek, but do not impede fish passage during most flows. An apartment complex spans the creek, and exposed sewer pipes cross the creek bed.

The Beaverton-Hillsdale Shopping Center, located at the upper extent of this reach, overlays a culvert approximately 200 meters long. This culvert significantly impairs riparian and floodplain connectivity and is considered a significant fish barrier during most times of the year.

Sylvan Creek enters Fanno Creek via a culvert connection under the shopping center. It is assumed that all or nearly all connectivity with Fanno Creek has been lost because there is a dammed wetland/pond immediately above the shopping center. Sylvan Creek is not included in this characterization report.

REFUGIA

The best refugia are found in the deeper portions of pools, and possibly at the confluence of Vermont Creek. Large wood densities are low, boulders are few, and only 6 percent undercut stream bank is present.

CHANNEL CONDITIONS AND HABITAT STRUCTURE

Silt and organics are the dominant substrate (53 percent); gravels constitute only 17 percent of the stream bottom (ODFW 2002b). Fine sediments constitute 72 percent of pool habitat and 19 percent of riffle habitat. Pools are long and deep (0.63 meter) and are the predominant habitat. Only one complex pool (pools with more than three pieces of wood) was found in the reach. This is considered undesirable for fish, since they often seek wood for refuge during high flows, to avoid predators, and for general cover. Wood abundance is low, with only 1.6 pieces of wood per 100 meter stream length. Wood volume is low (undesirable), at 0.9 m3/100 m stream length. No key pieces of wood were observed during 2001 surveys.

Channel banks are approximately one meter high, with 59 percent actively eroding and only 6 percent undercut bank.

The upper segment (approximately 25 percent, or one-third river mile) of this reach is piped under the Beaverton-Hillsdale Shopping Center. In addition to this major creek impediment, four roads cross the creek for a total of 305 meters of piped creek bed (18 percent of the total reach length).

CWS reports that glides are the predominant habitat type, with pools and riffles at 5 percent and 10 percent, respectively (CWS 2001). Conversely, ODFW reports that scour pools are the dominant habitat form (86 percent), with riffles at only 10 percent. These evaluations may differ for several reasons. First, the agencies may have surveyed different 100 m-long reaches. Second, ODFW evaluates pools based on their depth (over 0.3 meter) and bed form characteristics (evidence of scour); CWS and ODFW therefore may have used different methodologies to discriminate between glides and pools.

This stream segment is less than desirable for salmonid spawning and rearing because of lack of instream structure (wood, boulders, and undercut banks); poor riffle habitat (quantity) and low riffle gravel substrates (31percent); long, deep pools; and evidence of erosive banks. In addition, stream banks are eroded and the channel is relatively disconnected from its floodplain. Opportunities to improve habitat condition in this reach include protecting the riparian zone; stabilizing banks; and both protecting existing refugia and creating new refugia (boulders and wood).

Fanno 2 - 59th Avenue

FLOODPLAIN CONDITION

The channel is constrained by terraces within a broad floodplain (VWI = 20.0). Floodplain interactions are presumed low, but habitat surveys suggest that flows overtop the active channel and flow into the floodprone area (entrenchment ratio = 1.6). However, data also suggest that this floodprone area is constrained by terraces on both sides, yielding a narrow floodway corridor. A significant portion of the floodplain has been paved and is characterized as medium to high density residential and industrial. Stream gradient is low (0.5 percent).

RIPARIAN CONDITION

Riparian integrity is low (BES and Brown and Caldwell 1998), except at the confluence of Columbia Creek. Throughout most of the reach, vegetative canopy consists of mixed conifer and deciduous trees (ranging from 15-50 cm dbh). Canopy cover is moderate within the first 10 meters from the stream bank: 45 percent (ODFW 2002b) to 55 percent (BES 2002). The area beyond the first 10 meters then becomes generally void of riparian vegetation and effective canopy cover; landscaped plants and shrubs become dominant. SW Beaverton-Hillsdale Highway runs along the stream bank.

STREAM CONNECTIVITY

No roads cross the creek within this reach, and stream connectivity is expected to be good. A long cascade formed by boulders exists about mid-reach and may naturally impact stream connectivity. The expansive culvert running under the Beaverton-Hillsdale Shopping Center disconnects the lower portion of the reach from Fanno Creek. The upper extent of the reach is bound by SW 59th Avenue. Stream connectivity to upstream and downstream mainstem reaches is probably poor under most hydrologic regimes, however, some opportunities may exist at SW 59th Avenue during high flows.

REFUGIA

Refugia probably exist at the Columbia Creek confluence. The confluence is well vegetated and spring fed Columbia Creek provides perennial flow. Fish may use this area for off-channel refugia during high flows and for cool water refugia in the summer. In addition, microhabitat associated with large wood and pools is present (BES 2002) and undercut banks constitute 21 percent of the stream bank (ODFW 2002b).

CHANNEL CONDITIONS AND HABITAT STRUCTURE

The channel substrate is composed of gravel, silt/organic, and sand (in approximately equal proportions). The dominant habitat forms are scour pools (53 percent) and riffles (37 percent). Relative to other mainstem reaches, riffle area is moderately high throughout Fanno 2 (three times what was identified in downstream and upstream reaches). This reach may likely provide important summer rearing and spawning habitat to native fish. Average residual pool depth is 0.5 meters which is considered desirable for fish. However, only one deep pool (greater than 1.0 meter deep) was observed. Gravels constitute 36 percent of riffle habitat (desirable) and fines constitute 12 percent (marginal).

Large wood is relatively absent from this stream reach. Number of pieces is low (3.4/100 meters); wood volume is low (0.9 m3/100 meters); and no key pieces were found. The wood that is present is located in pools. Three complex pools were found in the reach, which probably provide critical habitat for residing fish.

Banks are actively eroding resulting in a stream substrate composed of 55 percent sand, silt, and other organics.

Fanno 3 – Shattuck Road

FLOODPLAIN CONDITION

In 2001, CWS classified this reach as a U-shaped valley. ODFW data suggest that the channel is constrained by terraces within a broad valley floor (VWI = 20.0). Flood flows are assumed to interact with the 50 year floodplain (entrenchment ratio = 1.6), but are not expected to overtop the first terrace height (9.0 meters). The historic floodplain is significantly overlayed with impervious area. Primary land uses include medium to high density residential, and industrial. Stream gradient is low, averaging 0.6 percent (ODFW 2001).

RIPARIAN CONDITION

Riparian integrity is poor (BES and Brown and Caldwell 1998). The riparian corridor is narrow and steep stream banks preclude riparian/stream functions. Mixed conifer and deciduous trees (ranging from 15-50 cm dbh) dominate the landscape. Canopy cover averages 45 percent over the stream channel and adjacent riparian zone (0-10 meters), but diminishes to nearly nonexistent from 10-30 meters. Beyond the immediate 10 meter corridor, high-density residential development severely impacts the riparian area. The entire channel width was inundated or wet when surveyed and showed no apparent marginal/fringe habitat characteristic of riparian function.

STREAM CONNECTIVITY

Stream connectivity is generally good within this reach. However, Shattuck Road (located at the upstream extent of this reach) impairs connectivity with upstream reaches. This culvert has not been rated. A low stream gradient and perennial flow probably keep the culvert from completely blocking fish passage. No other structures that might impede fish passage were identified

REFUGIA

Steep banks indicate physical refugia are few or are associated with undercut banks (21 percent bank form). Large wood is sparse and has been documented in only three pools (BES and Brown and Caldwell 1998). Boulders were found in riffles and cascades, and probably provide critical refuge (slack water habitat) during high flows, and from predators.

CHANNEL CONDITIONS AND HABITAT STRUCTURE

The dominant habitat forms are scour pools (53 percent), and riffles (37 percent) (ODFW 2001). Riffle bottom substrate is constituted by at least 35 percent gravel and 12 percent fines. This percentage of fines may impair riffle quality. Boulders are present and make up 12 percent of riffle substratum, creating pocket pool habitat. Pools are relatively deep (averaging 0.50 meter), with some complexity (3.8 complex pools per 1,000 meter stream length: desirable).

Stream bottom substrate is loaded with equal proportions of silt/organics (25 percent), sand (20 percent), gravel (27 percent) and cobble (20 percent) (ODFW 2001). However, BES data show long reaches of silt and fine sediment with only short reaches of gravel. Some boulders are present in fast-water habitats (riffles and cascades) and probably provide critical cover.

Bank condition is considered poor, with 55 percent of bank material actively eroding. However, 21 percent of the stream bank retains undercut banks.

Fanno 4 - 45th Avenue

FLOODPLAIN CONDITION

The creek channel is constrained by terraces lying within a broad valley floor (VWI = 20.0). Floodplain condition and connectivity vary throughout the reach. In the upper and lower reaches, the stream is relatively connected to its floodplain. The middle reach has a narrow floodplain. Both the north and south stream banks are bound by low to medium density residential and some industrial uses. These properties and associated land uses are relatively removed from the immediate stream channel (generally at least 10 meters), allowing for some connectivity with floodplain functions. The average stream gradient is 0.68 percent in the middle reach, and is lower in the upper and lower extent of this reach (ODFW 2001).

RIPARIAN CONDITION

High terraces and transportation corridors are the predominant landforms in the riparian corridor. They are relatively set back from the immediate stream bank (more than 30 meters), allowing for a functioning riparian corridor. Tree canopy cover averages 69 percent in zone 1 (0-10 meters from the stream bank), 39 percent in zone 2 (10-20 meters from the stream bank), and 23 percent in zone 3 (20-30 meters from the stream bank). Deciduous trees (15-30 cm dbh) and shrubs and vines dominate the landscape (ODFW 2001). Riparian condition is considered moderate (Harza 1997), but is a marked improvement from the immediate downstream reach (Fanno 3).

STREAM CONNECTIVITY

Stream connectivity is good throughout the reach and moderate between upstream and downstream reaches. Culverts bracket the upper and lower reach (at SW 45th Avenue and at SW Shattuck Road); neither culvert has been rated for fish passage. Connectivity with upstream and downstream reaches is critical, since this reach contains high quality stream and riparian habitat.

In addition to these more substantive barriers, several steps formed by boulders, cobbles, logs, and a beaver dam span the creek and may impeded fish movement during lower flows.

Refugia

Important cover during high flows is provided by several pools with large wood, undercut banks (25 percent bank form), a beaver pond, and several large meanders. Cool-water refugia may be found in localized areas under root wads, undercut banks, and overhanging vegetation.

The beaver pond may provide important overwintering habitat, however, it may also be a significant heat source during the summer.

CHANNEL CONDITIONS AND HABITAT STRUCTURE

This reach is characterized as a meandering glide (or scour pools), broken by steps formed from boulders, cobbles, and logs**.** Scour pools and a beaver dam constitute 86 percent of the habitat. The beaver dam/pond makes up 23 percent of the wetted area in this reach.

Pools are relatively deep, averaging 0.61meters. Four pools are deeper than 1.0 meter and provide complex habitat. Complex pools provide fish critical rearing habitat throughout the winter and summer. Riffles constitute only 11 percent of the wetted area. The riffles present are considered good quality, with low fines and other organic matter, high gravel composition, and presence of boulders.

Stream substrate is composed of a mixture of cobbles (18 percent), gravel (24 percent), sands (25 percent), and silts (34 percent). Large boulders are noticeably present in scour pools, riffles, and steps. They probably provide critical cover and refuge, particularly in the pools and riffles. Stream surveys conducted in 1998 (BES and Brown and Caldwell) and 2001 (CWS) and modeling by the City of Portland have resulted in different characterizations. For example, the CWS survey shows that no gravels exist throughout the reach, while the BES mapping indicates that more gravel than organic material exists.

Banks are actively eroding (61 percent bank form), as evidenced by the high proportion (59 percent) of sand, silt, and organic matter overlying the stream bottom.

Wood abundance and wood volume are low. Key pieces were rarely found. Those present were found mid-reach in deep pools.

This reach probably provides critical rearing and refuge habitat for fish during winter and summer periods. Deep, complex pools (along with undercut banks and boulders) are particularly important for salmonids in the winter. These habitat features provide cool-water refugia and cover from predators during summer periods and provide rearing and refuge habitat during peak flows. The dammed beaver pond probably provides critical overwintering habitat to fish.

Fanno 5 - 39th Drive

FLOODPLAIN CONDITION

The channel is constrained by terraces within a broad valley. The valley is generally classified as a mixed U and V configuration. The VWI averages 19.5, with a range of 18.0-20.0. Urban and rural residential are the predominant land uses. The lower reach is relatively developed, and floodplain connectivity is low. The upper floodplain portions are relatively undeveloped, and floodplain connectivity is believed to be moderate to good. The floodprone width is twice the active channel width and beyond the terrace expanse, signifying increased floodplain interactions during periods of high flood flows. Stream gradient averages 1.1 percent.

RIPARIAN CONDITION

The riparian zone is heavily impacted, but riparian integrity is considered fair to good throughout. Riparian width varies from being greater than 100 feet in some areas to having apartments abut the stream bank in others. Large established trees are present within the riparian corridor and effectively provide continuous shade from 0-30 meters from the stream bank.

The lower stream segment exhibits reduced riparian integrity, with a preponderance of blackberries. ODFW surveys show that invasive plants dominate riparian vegetation. However, English Ivy was cleared recently and willows were planted.

Tree size and the potential for large wood recruitment is fair throughout the reach, with the average diameter of deciduous species ranging from 30-50 cm. Tree canopy is relatively uniform throughout the entire riparian corridor, averaging 35 percent in zone 1, 43 percent in zone 2, and 40 percent in zone 3.

STREAM CONNECTIVITY

Stream connectivity is significantly impacted to downstream reaches at SW 45th Avenue and upstream reaches at SW 39th Drive. As noted previously, 45th Drive (downstream reach break) disconnects good quality stream (and riparian) habitat found in Fanno 4. The SW 39th Drive culvert has a 1.0 to 1.5 foot drop during low-flow conditions, and is believed to block fish passage to the immediate upstream reach (Fanno 6). Only one road (SW 43rd Avenue) crosses the creek within the reach. This culvert had a 1.6 meter drop at the time of the survey and probably impacts resident fish movement. However, none of these culverts have been critically evaluated or rated for fish passage.

REFUGIA

Refugia in this reach are primarily associated with undercut banks, tree roots, and stream meanders. One pond exists near the stream, but does not appear to be hydrologically connected to the mainstem, except during flood flows. Kelly Creek probably provides off-channel refugia throughout the year.

CHANNEL CONDITIONS AND HABITAT STRUCTURE

Stream channel conditions are more natural in this reach than in many other reaches, as indicated by areas of dry channel bed and exposed gravel substrates. ODFW (2002b) surveys show that substrate is composed of 11 percent cobble, 37 percent gravel, 30 percent silt, and 21 percent sand. Large boulders are relatively absent. Nearly all were located in one plunge pool, constituting 10 percent of the stream substrate in this one unit.

ODFW stream surveys indicate that scour pools compose 74 percent of the habitat. However, CWS surveys show that stream habitat is composed of approximately 10 percent riffles and 10 percent pools, with the remaining 80 percent glides. The discrepancy between these two surveys may be in each agency's definition of pool. CWS and ODFW have different minimum depth criteria, with CWS's classifications erring on the side of glides and ODFW's surveys erring on the side of pools, if scour is present. Personal communications with Gerrit Rosenthal show that pools are generally shallow and stream gradient is low. This characterization has used ODFW data in order to maintain continuity among reaches.

Pools are abundant (74 percent) and moderately deep, with residual pool depths averaging 0.44 meters. No deep pools (deeper than 1.0 meter) were observed. Three complex pools (with wood) are present within the reach, which is considered desirable at 4.4 complex pools per 1,000 meters of stream length. These pools probably provide important winter and summer refuge. However, pools are only moderately deep, with very little channel form complexity (boulders are generally absent).

Sand, silt, and organics constitute 67 percent of pool bottom substrate, and cobbles and gravels constitute 33 percent of pool substrate. Gravel substrates are more prevalent in the upper reach than the lower, indicating hyporheic flow may be more prominent. ODFW noted beaver activity in the middle portion of this reach.

Riffle habitat is low (18 percent), but is considered desirable with 62 percent gravels, 15 percent cobbles, and only 9 percent fines. Although the riffle habitat is not abundant, it is of high quality and probably provides critical spawning habitat.

The channel is U-shaped, indicating channel erosion and bank instability (43 percent actively eroding). The dominance of silt and sand in stream substrates (51 percent) indicates continual bank failure and erosion.

Key pieces of wood were found in the upper end of the reach.

Fanno 6 - 30th Avenue

FLOODPLAIN CONDITION

The channel is most prominently constrained by urban landforms (residential land use and transportation corridors) and, to a lesser extent, terraces within a broad valley. The VWI averages 10.8, with a range of 6.0-15.0. In most parts of the reach, the SW Beaverton-Hillsdale Highway embankment impairs floodway connections to either the north or south; the highway is about 25 feet from the stream. A very small parcel of floodplain area is present just above the SW 39th Place culvert (the downstream extent of this reach). Although the highway effectively disrupts floodplain connectivity, flood flows undoubtedly top the creek channel. The floodprone width is more than three times greater than the active channel width and twice the height of the active channel height, signifying that floodplain interactions are occurring. ODFW data show that this reach exhibits the highest potential for floodplain interactions (ODFW 2002b).

Stream gradient is low (1.5 percent).

RIPARIAN CONDITION

The highway embankment and long culverts impair riparian integrity. A narrow riparian fringe of large deciduous trees (30-50 cm dbh) is present throughout much of the reach, but is broken by the SW Beaverton-Hillsdale culvert. Shrubs and vines vegetate the riparian corridor. Canopy closure is moderately good throughout the riparian corridor, averaging 54 percent in zone 1, 50 percent in zone 2, and 44 percent in zone 3. Large established trees are present within the riparian corridor and provide continuous shade from 0-30 meters from the stream bank. ODFW reported beaver activity in the lower and upper portion of this reach.

STREAM CONNECTIVITY

Stream connectivity is very poor in this reach. The stream reach is relatively disconnected from downstream reaches by SW 39th Drive and is broken from upstream reaches by SW Beaverton-Hillsdale Highway and SW 30th Avenue. The culvert under SW 30th Avenue, located at the upstream end of the reach, is steep, with a very small wetted perimeter and high velocities. The culvert under SW Beaverton Hillsdale Highway is approximately 100 feet long.

Connectivity within the reach is poor because of the number of roads crossing the creek; and the number of cascades and steps (naturally formed as well as manmade) that form parts of the creek bed.

REFUGIA

Stream refugia can be found in secondary channels, which constitute one-third of the wetted habitat. In addition, some refugia are probably associated with large boulders found in pools and riffles. Large wood is also present, providing critical cover and refuge. Undercut banks were rarely found (only 8 percent bank form).

CHANNEL CONDITIONS AND HABITAT STRUCTURE

Stream habitat is dominated by riffles (46 percent) and scour pools (42 percent). However, ODFW surveys show that much of the creek is culverted or piped, even when no road crossings are present. Approximately 21 percent of the creek bed is piped through culverts. The natural channel and portions of constructed channels (daylighted reaches) are U-shaped and are symptomatic of bank erosion (36 percent actively eroding stream bank). Steps formed by boulders, cobbles, and manmade materials are present, as are cascades. As a result, habitat in this reach provides only localized value and function.

Stream substrate is composed mostly of gravel (29 percent) and cobble (25 percent), and, to a lesser extent, organic materials and silt (16 percent). Riffles area is high (45 percent) and of high quality, with gravels and cobbles constituting 35 percent and 32 percent, respectively, of the substratum. The proportion of fines overlying riffle habitat is low (7 percent), and large boulders are present. This reach holds high-quality riffle habitat and could provide important spawning and rearing habitat if it were accessible to fish.

Scour pools are also prevalent, providing marginal fish habitat. Average pool depth is 0.44 meters. Only one deep pools (deeper than 1.0 meter) was observed, and few complex pools were noted (1.6 per 1,000 meters of stream length).

Limited instream structure exists to provide significant rearing and/or resting habitat. Wood abundance and volume are low (3.1 m3/100 meters); this is, however, higher than wood observed in any other surveyed reach. Wood volume and abundance are highest at the upstream extent of the reach. Large, well established trees along the highway embankment provide sources of large and medium sized wood to the creek.

Unlike other segments, terraces on both sides of the creek do not confine this reach. One-third of the creek channel lies in secondary channel habitat, demonstrating that the creek has opportunities to move laterally across the landscape.

Fanno 12 – Headwaters

Note: Because ODFW and CWS did not survey this reach; limited data are available to characterize the habitat elements.

FLOODPLAIN CONDITION

The stream channel is constrained by terraces. Floodplain function is expected to be minimal. Hillsides are steep and narrow, and stream gradient is moderately steep at 4.3 percent. Land use is predominantly rural and medium density residential.

RIPARIAN CONDITION

SW Beaverton-Hillsdale Highway and other roadway culverts impair riparian integrity. The riparian zone is continuous throughout most of the reach, but is fragmented by residences and culverts. Harza evaluations show that riparian habitat is generally poor throughout, although higher-quality habitat was noted above SW Bertha Boulevard. It is likely that hyporheic and seepage areas are important in this reach and contribute to perennial surface flows.

STREAM CONNECTIVITY

Stream connectivity between upper and lower creek reaches is poor, with steep culverts at SW 30th Avenue (lower reach) and SW Bertha Boulevard (upper reach).

REFUGIA

Refugia are believed to be limited because of the steep stream gradient and narrow valley. Large wood is present, but has not been well documented.

CHANNEL CONDITIONS AND HABITAT STRUCTURE

Channel conditions downstream of SW Bertha Boulevard are considered poor for fish, but are considered more favorable in reaches upstream of Bertha Boulevard. Channel substrates have not been surveyed, but are believed to be dominated by gravels.

The channel structure is presumed to have little complexity due to channel alterations and proximity to residential stream bank development.

Tributaries of Fanno Creek

Vermont Creek, Ash Creek, North Ash Creek, and Woods Creek were assessed in similar detail as mainstem Fanno Creek. Red Rock Creek, Pendelton Creek, Patton Creek and Columbia Creek are assessed with very little detail and characterizations are general. Other tributaries to Fanno Creek that are not captured in this characterization include Ball Creek and Sylvan Creek.

South Ash Creek – Mainstem Headwater Reach

FLOODPLAIN CONDITION

The channel is constrained by alternating hillslopes and terraces within a broader valley. The VWI averages 7.4, with a range of 2.0–20.0. The floodprone width is four times the active channel width, indicating that flows top the banks occasionally and interact with the immediate floodplain. ODFW notes that the floodprone height is generally higher than terrace heights, signifying intact channel function. Channel gradient is moderately steep (4.5 percent), with steeper gradients in the headwaters. Urban forms and activities dominate the landscape. The upland area is developed with low-density residential development on relatively large lots (BOP 2001).

RIPARIAN CONDITION

Riparian vegetation is considered good throughout this reach. Mixed conifer and deciduous (second growth) trees and grasses are common. Trees generally range from 3-15 cm dbh. Crown cover is relatively full and intact throughout the immediate 30 meter riparian corridor: 64 percent from 0-10 meters, 71 percent from 10-20 meters, and 63 percent from 20-30 meters.

Hillslopes and terraces bound the riparian area. Homes often abut and cross the creek; numerous roads cross the creek; and several exposed sewer pipes span the creek channel. In addition, trails parallel the creek, and an old pump station abuts the creek in the upper headwater area. These features disrupt connectivity within the riparian corridor. CWS reports riparian buffers extending to 20 feet, with 96 percent canopy cover.

STREAM CONNECTIVITY

Seven roadways crossing Ash Creek and homes abutting the creek bank impair stream connectivity. The hydraulic impact of these barriers is generally unknown. However, SW 62nd Avenue is believed to completely block fish passage. This culvert is approximately 100 meters long and runs under a housing complex. In addition, SW Lauradel and SW 55th Avenue are believed to impede fish migrations. These passage impediments are found in the upper 300 meters of the headwater reach. Exposed sewer pipes span Ash Creek approximately 270 meters downstream from SW 62nd Avenue. In addition to these manmade barriers, cascades and steps may limit stream connectivity and resident fish movement throughout most of the year. No barriers presently exist at the confluence of Fanno and Ash Creek.

REFUGIA

Instream refugia is probably found near wood clusters and boulders. Undercut banks are present, but not prevalent; they constitute 8 percent of total stream bank. Deeper pools may provide protective cover, relative to the prevailing channel depth.

CHANNEL CONDITION AND HABITAT STRUCTURE

Ash Creek is relatively unstable, with 31 percent actively eroding bank. Riffles, cascades, and scour pools are dominant habitat types, constituting 51 percent, 21 percent, and 16 percent of wetted area, respectively. Steps formed by boulders, cobbles, and logs are also common and may impede resident fish movement. In addition to these more natural habitat forms, seven roadways cross the creek, piping Ash Creek into culverts that vary in length. They cumulatively constitute 15 percent of total channel length and 6 percent of wetted area.

Riffle area is high, and riffle quality is good. Gravel, cobble, and sand compose riffle substrate in equal proportion (21-30 percent), with only 9 percent sediments overlying riffle habitat. This headwater reach may provide important spawning grounds to resident fish.

Cascades are common throughout the reach, particularly in the uppermost headwater segment. Most are formed by boulders and cobbles.

Although pools generally constitute a low proportion of wetted area (16 percent), they are moderately good quality, based on substrate composition (equal proportions of sands and gravel), average residual pool depth (0.36 meter), relative pool depth (140 percent of the prevailing channel depth), and number of complex pools (with wood and boulders). Pools are few, but depth refugia and instream structure probably provide important cover to resident fish. Although wood is present in pools and provides important channel roughness, it is severely lacking in other parts of Ash Creek. Overall, wood abundance is low, volume is low, and key pieces are rare. Mid-sized trees (15-30 cm dbh) will be an important source of large woody debris in the future.

CWS survey data show that channel substrates are dominated by gravel and cobbles, and that riffles (80-90 percent) are the primary habitat type (CWS 2000).

EVALUATION OF ASH CREEK

- Upper Ash Creek probably provides important flow maintenance for lower potions of Ash Creek, particularly during the summer.
- Homes that abut the creek side, trails that parallel the creek channel, and sewer pipes that span the creek impair riparian integrity. However, tree canopy cover is relatively high within the adjacent riparian corridor (30 meters), and trees are mid-sized (second growth).
- Instream refugia is found near wood, boulders, and deep areas in pools.
- Riffle area and quality are good and probably provide critical spawning grounds for resident fish.
- Pool area is relatively low, but pool quality is high. Pools probably provide important rearing habitat in summer and winter (if fish can access these areas).
- Several large open spaces exist above SW 55th Avenue and could be potential restoration (or protection) sites.

Note: Because this characterization assessed only the headwater reach, it is difficult to evaluate the importance of this reach to fish populations that inhabit the Ash Creek subbasin, as well as the Fanno Creek subbasin. The characterization is very reach specific and does not include stream conditions and stream connectivity of areas downstream of this headwater reach.

North Ash Creek – Headwater Reach

FLOODPLAIN CONDITION

Stream gradient is moderately steep at 6.3 percent, and the drainage is constrained by alternating terraces and hillslopes within a broad valley floor. The VWI averages 7.1 and ranges from 2.5 - 16.0. The floodway is relatively narrow, averaging 9.7 meters, and the floodprone width is 3.5 times the active channel width, indicating floodplain interactions within the immediate floodway. North Ash Creek originates in a developed residential neighborhood (near SW 50th Avenue and SW Brugger), and flows through a wooded ravine surrounded by low-density residential development (BOP 2001). Homes are close to the creek, and urban landscaping has reduced floodplain connections.

RIPARIAN CONDITION

ODFW notes that the riparian zone has a fairly wide, consistent buffer despite new development. CWS 2000 survey data note tree canopy cover ranging from 75-95 percent. ODFW survey data show that tree canopy cover within the immediate 30 meter riparian corridor averages 58 percent within 0-10 meters, 37 percent within 10-20 meters, and 22 percent within 20-30 meters. ODFW data show that the effective riparian corridor does not extend beyond the immediate 10-20 meters from the stream bank. A wooded residential neighborhood (with large Douglas fir trees) provides a relatively extensive forest canopy between SW 52nd Avenue and SW 57th Avenue (BOP 2001). Dominant species composition includes second growth mixed conifer and deciduous trees, ranging from 15-30 cm dbh. Shrubs are also prevalent.

The riparian corridor is fragmented most noticeably at SW Dolph Drive, SW Orchid Drive, SW Lancelot Drive, and SW 55th Avenue. Terraces and hillslopes are dominant landforms in the riparian corridor.

STREAM CONNECTIVITY

Four roadways east of the Multnomah County boundary fragment North Ash Creek: SW Dolph Drive, SW Orchid Drive, SW Lancelot Lane, and SW 55th Avenue. The degree of hydraulic discontinuity at these crossings is not fully documented. West (or downstream) of the Multnomah County line, additional roads cross the creek, impeding fish movement. In addition, a step/log spans the creek just below Moonshadow Park (downstream reach break). The log is approximately 0.5 meter high and is considered (was built to be) a barrier to resident fish. In addition to these barriers, several bedrock and boulder cascades and steps (formed by bedrock, boulders, and logs) exist in the upper half of the reach and may impede resident fish movement, particularly during lower flows.

A concrete structure located approximately 100 meters upstream of the confluence with Ash Creek is expected to completely block fish migrations into North Ash Creek. This structure creates a large dammed pool of 470 square meters. Resident populations are therefore discretely disconnected from populations in Ash Creek, as well as Fanno Creek.

REFUGIA

Root wads provide minimal instream refugia in select areas (ODFW 2001). Boulders, wood, and undercut banks are rare.

Some off-channel refugia may be found at the confluence of two tributaries that enter North Ash Creek immediately below SW Dolph Drive and above SW Orchid Drive.

CHANNEL CONDITION AND HABITAT STRUCTURE

Banks are slightly unstable, with 26 percent actively eroding. However, undercut banks are rare, signifying intense mid-channel flows. Riffles predominate (37 percent), followed by cascades (24 percent) and scour pools (14 percent). Bedrock and boulders form cascades. In addition, three segments of North Ash Creek are piped under roadways, resulting in nearly one-fourth (24 percent, or 173 meters) of the creek bed running through piped channels. ODFW (2001) notes several sewer manholes in the creek bed and exposed sewer pipes spanning the creek.

Riffles constitute 37 percent of wetted habitat and are of good quality, with 50 percent gravel, 9 percent cobble, and only 17 percent fine sediment. Pools constitute only 14 percent of wetted habitat, and glides constitute 10 percent of wetted habitat. Pools are significantly aggrading, with 66 percent fines, and only 19 percent gravel and 9 percent sand. These conditions are characteristic of significant sediment deposition (probably during storm flows) that results in the conversion of pools to glides. Glides are generally more shallow and do not provide the important depth refugia and spawning gravels (at pool tail-outs) that are characteristic of pools. A preponderance of glides is indicative of impaired habitat condition and processes.

Average residual pool depth is 0.28 meters, and average prevailing channel depth is 0.10 meters; although they are shallow, pools probably provide important protective cover relative to other habitats. Large wood is lacking throughout this reach; abundance and volume are low, and no pieces greater than 10.0 by 0.6 meters were observed. Pools are severely lacking instream structure and complexity. Only one pool within the reach contains three or more pieces of wood, and all pools are severely lacking large boulders and cobbles. Large root wads were observed lying within the active channel, but above the wetted channel; they probably provide important channel roughness (and potentially instream cover to resident fish) during flood flows. Future sources of large wood (and leaf litter) will come from second-growth deciduous trees.

EVALUATION OF NORTH ASH CREEK

- Nearly a quarter of North Ash Creek is piped through roadway culverts.

- Riffles are abundant (37 percent of wetted habitat) and are of good quality.

- Pools constitute only 14 percent of habitat, while glides constitute 10 percent. Conversion of pool to glide habitat indicates declining habitat condition. A preponderance of glides versus pools decreases depth refugia and spawning gravels.

- Resident fish populations are discretely disconnected from populations in Ash Creek, and Fanno Creek. Within North Ash Creek, stream connectivity is impaired by culverts and naturally impacted by cascades and steps. The extent of impairment is not completely known. North Ash Creek is disconnected from Ash Creek and Fanno Creek by a structure (and dammed pool) located near the confluence of North Ash and Ash Creek.

- Dominant riparian species composition include second-growth deciduous trees and shrubs.

Note: Because this characterization assessed only the headwater reach, it is difficult to evaluate the importance of this reach to fish populations that inhabit the Ash Creek subbasin, as well as the Fanno Creek subbasin. The characterization is very reach specific and does not assess stream conditions or stream connectivity of areas downstream of this headwater reach.

Woods W1 and W2 – Lower and Middle Woods Creek

FLOODPLAIN CONDITION

The lower portion this stream reach is characterized as a single unconstrained channel running through a broad valley. The VWI averages 18.5, with a range of 2.0 – 20.0. Floodplain conditions have not been well defined, but stream gradients are low (approximately 0.8 percent), and it is likely there was historic floodplain connectivity and function. The floodprone width is significantly larger than the active channel width, indicating that flood flows top the stream banks and floodplain interactions could occur regularly; the entrenchment ratio is 13.9. Aerial photographs show that the historical floodplain is hydrologically disconnected from Woods Creek. Channel straightening (Oleson Road to SW 65th Avenue), urban development (particularly near the confluence with Fanno Creek), and forest clearing (from Oleson Road downstream) are primary contributors. Floodplains are partially intact and appear to be functioning from SW 61st Avenue upstream to Multnomah Boulevard. Predominant land uses within middle Woods Creek include wetlands and residences.

RIPARIAN CONDITION

Riparian condition varies along lower and middle Woods Creek. Homes abut the stream bank, riparian width is narrow, and stream banks have been cleared in the lower portion of middle Woods Creek (Hideway Park). The combination of these impacts yields a relatively narrow, fragmented riparian corridor. However, ODFW notes that the creek exhibits “decent” riparian conditions, and numerous springs, seeps, and wetland habitat exist near Oregon Episcopal School. Hillslopes and terraces are common landforms throughout the riparian corridor.

CWS reported tree canopy (crown cover) of 60-100 percent. BES and Brown and Caldwell (1998) surveys report slightly lower crown cover at approximately 50 percent (above SW 60th Avenue). ODFW surveys show tree canopy cover averaging 70 percent in zone 1, 48 percent in zone 2, and 53 percent in zone 3 within the immediate riparian corridor. Large, well-established mixed conifers and hardwoods (and grasses) are common; these include Douglas fir, cedar, alder, and willow.

Riparian and wildlife habitat is considered high within the reach, and fish habitat is considered marginal (BES and Brown and Caldwell 1998).

STREAM CONNECTIVITY

Fish passage is completely blocked at the downstream side of a dammed pool at the Portland Golf Club. This dammed pool is near the confluence with Fanno Creek and prevents fish movement into and out of Woods Creek. Within Woods Creek, stream connectivity is generally fair to good. SW 60th Avenue, SW Oleson Road, and other roadways probably impair stream connectivity, but are not believed to completely block fish passage. Additionally, a fish ladder exists about a quarter miles downstream from SW Oleson Road.

REFUGIA

Instream refugia are not abundant because of the absence of large wood, boulders, undercut banks, deep pools, secondary channels, and tributaries. Beaver dams and associated pools probably provide primary refugia.

CHANNEL CONDITION AND HABITAT STRUCTURE

Stream banks, are stable with only 18 percent actively eroding banks. Width–to-depth ratio is moderately low (7.4), indicating properly functioning conditions.

Steam habitat surveys report mixed results for instream structure and habitat type in this reach. ODFW notes a predominance of dammed and backwater pools (84 percent), and CWS surveys report glides (with few pools) as the common habitat type. Scour pools and riffle constitute only

9 percent and 3 percent of the wetted area, respectively. Riffle area is severely lacking. In addition, riffle quality is moderately low; gravel and cobble collectively compose 40 percent of the substrate, while fines and organics compose 50 percent of riffle habitat. Lack of riffle habitat and low riffle quality probably impair the carrying capacity and biological productivity of this system.

Pool area is extremely high (93 percent) in this reach. The dammed pool within the Portland Golf Club constitutes a significant proportion of this pooled habitat. Alcoves, backwater pools, and beaver dams also create pooled habitats. Lateral scour pools constitute only 9 percent of pool habitat, and are probably the most hospitable pool habitat for resident fish. The large dammed pools may be a significant heat source to Woods Creek, as well as to Fanno Creek. Channel substrate in dammed pools is dominated by fines and organics (80-100 percent) and, to a lesser extent, sand (0-20 percent). Lateral scour pools are also dominated by silts (78 percent) and secondarily by sand (14 percent) and cobble (6 percent). Pool complexity is low, with very little wood, few boulders, and minimal depth refugia; the average residual pool depth is 0.38 meters and average channel depth is 0.26 meters.

Wood is lacking throughout all of lower and middle Woods Creek. Wood abundance and volume are low, and large pieces are rare.

EVALUATION OF LOWER AND MIDDLE WOODS CREEK

- Large dammed (and backwater) pools may be a significant heat source to Woods Creek and Fanno Creek.

- Riffle area is low (7 percent), while pool area is high (93 percent). Lateral scour pools constitute only 9 percent of total pool area. These characteristics, along with high silt loads overlying the stream bottom, severely impair riffle quality, pool quality, and subsequent epifaunal and macroinvertebrate production.

- Woods Creek is a large tributary to Fanno Creek and could provide important fish habitat. However, its potential has been reduced or eliminated by urban development, culverts, a dam at the confluence of Woods Creek and Fanno Creek, and stream channelization and straightening. Historic floodplains are hydrologically disconnected, and the riparian corridor is narrow and fragmented. However, large conifers and deciduous trees are present and provide relatively good crown cover and sources of woody debris.

- Only a small portion of the reach is in public ownership, so restoration opportunities on public lands are limited.

Woods W3 – Upper Woods Creek (Headwaters)

FLOODPLAIN CONDITION

Floodplain connectivity in upper Woods Creek is limited; the stream channel is narrow and incised, and the floodplain is generally narrow (less than 100 feet). The channel is generally constrained by terraces and hillslopes within a broad valley. The VWI averages 7.3, with a range of 2.5-17.0. The floodprone width is only twice the active channel width (entrenchment ratio 2.3); channel width-to-depth ratio is relatively small (6.5), signifying that flood flows are relatively confined within terraced creek banks. Stream gradient is moderately high (4.2 percent).

ODFW notes that wider, intact floodplains exist at tributary confluences and in the lower portion of Upper Woods Creek (between Multnomah Boulevard and Garden Home Road).

Land use is residential and green space. Homes are set back outside the immediate stream corridor. Upper Woods Creek is believed to be well connected with its floodplain, and aquatic land interactions are believed to be intact.

RIPARIAN CONDITION

Riparian condition and wildlife habitat are considered very good throughout upper Woods Creek (ODFW 2001; BES and Brown and Caldwell 1998). Of all the tributaries of Fanno Creek (within the City of Portland), Woods Creek has the most extensive riparian vegetation (BOP 2001). Much of the stream corridor lies within mature (second-growth) mixed conifer forest, and the upper reach is descriptive of a forested ravine dominated by large conifers. Predominant tree species include Douglas fir, western red cedar, western hemlock, big leaf maple, and alder. Riparian width spans to 200 feet within the park area. Within the immediate 30-meter riparian corridor, canopy cover averages 74 percent within 0-10 meters, 82 percent within 10-20-meters, and 58 percent within 20-30 –meters. Throughout the entire upper watershed, canopy cover averages 95 percent or more (CWS 2000). Tree age and size are diverse, with diameters ranging from 3.0–100.0 cm. Grasses and forbes are also common.

The riparian corridor is longitudinally broken at SW Multnomah Boulevard, SW Garden Home Road, and SW 45th Avenue. Trails and human activity also impact the riparian corridor. Hillslopes and terraces are predominant landforms in the riparian corridor.

Seeps and hyporheic flows (present in upper Woods Creek) are critical for augmenting summer flows. These habitats appear to be intact and protected, except at road embankments and in the uppermost mainstem area (near SW Taylors Ferry Road).

STREAM CONNECTIVITY

Stream connectivity is impaired at SW Multnomah Boulevard, SW Garden Home Road, and SW 45th Avenue. Information was not available to characterize culvert crossings at SW Multnomah Boulevard and SW Garden Home Road. SW 45th Avenue completely blocks resident fish movement into Woods Memorial Park. The culvert is long, has a 2- to 3-foot hydraulic drop at the downstream end, and was constructed to attenuate peak flows; it is therefore very inhospitable to fish movement. SW Taylors Ferry Road also impairs stream connectivity; however, resident fish are not believed to occupy habitats above this reach. In addition to these major roadways, many other roads cross the creek and probably impair fish movement within upper Woods Creek.

REFUGIA

Tributary confluence areas, along with large wood and boulders, provide the best refugia in upper Woods Creek (ODFW 2001).

CHANNEL CONDITION AND HABITAT STRUCTURE

Stream banks are considered stable, with 18 percent actively eroding banks. However, undercut banks are rare, constituting only 3 percent of the bank form. Width-to-depth ratio is 6.5, signifying entrenchment.

The dominant habitat forms are riffles (42 percent), cascades (23 percent), and scour pools (18 percent). Although steps do not constitute a significant proportion (area) of habitat, they occur often and possibly create migration barriers to resident fish. If fish are present, the prevalence of cascades probably limits their home range. CWS surveys show 45 to 100 percent riffles and up to 25 percent pools (CWS 2000).

Riffles are high quality, with 46 percent gravel, 14 percent sand, and only 11 percent sediment and organics. Scour pools are relatively low in proportion to other habitat types (e.g., approximately two-thirds of total pool area and only 18 percent of total habitat). Scour pools have a high proportion of fines (49 percent), signifying deposition during storm flows, and a low proportion of gravel (20 percent) and sand (25 percent). However, the pools probably provide important cover to fish (depth refugia); average residual pool depth is 0.36 meter, significantly deeper than the prevailing stream depth (0.15 meter). Other forms of cover are rare. Wood is lacking in pools, and boulders and other larger substrates are absent. The lack of pool area (and impaired pool quality, except for depth refugia) would probably limit fish presence and productivity, particularly during high storm flows and summer low flows.

Although sources of large wood and coarse particulate organic matter are present within upper Woods Creek, wood pieces are rare. Large pieces are associated with pools; however, habitat surveys show very low wood count, low volume, and few large (key) pieces. Large wood appears to be very transient within the system and provides very little structural complexity.

EVALUATION OF UPPER WOODS CREEK

- Upper Woods Creek probably does not support year-round fish use. Cascades and steps are common, effectively limiting home ranges and restricting fish movement. However, this area contains excellent riffle habitat—if resident fish access this area, they would probably find optimal spawning grounds. Additionally, riffle habitat probably supports epifaunal production and subsequent macroinvertebrate production. When flows become high, young fish probably move into downstream reaches that are more hospitable for rearing. This area may provide important allochthonous inputs into downstream reaches in the form of small woody debris, nutrients, and macroinvertebrates.

- Pool area is relatively low, and pool quality is generally poor, with 49 percent fine sediment overlying pool substrate and very little instream cover. Depth refugia probably provide the best protective cover to resident fish.

- Upper Woods Creek is not accessible to fish from lower reaches because of the number and severity of connectivity breaks. SW 45th Avenue completely blocks fish movement into Woods Memorial Park. Even if this reach were available to fish, however, they probably would not reside throughout the summer, when flows are low (less than 0.01 cfs). This reach provides good habitat for amphibians and other water-dependent species.

Vermont V1 – Lower Vermont Creek

FLOODPLAIN CONDITION

The channel is bound by multiple terraces within a broad valley floor. The VWI averages 13.0, ranging from 4.0-20.0. Floodprone width is generally wide compared to the active channel width (entrenchment ratio = 5.7), signifying unconstrained channel functions. Stream gradient is low, averaging 0.9 percent.

Vermont Creek flows through a variety of different land uses; rural residential and wetlands are the predominant land uses. A wetland area (beaver pond) spans more than 1,000 feet in width and occupies an area immediately above Shattuck Road. In addition to this site, a small tributary-associated floodplain area exists just below SW 49th Avenue. Aerial photographs show that, except for these isolated areas, residential development and landscaping are common along most of the stream bank and floodplain functions are impaired throughout a significant portion of the reach. Consequently, areas of the creek running through residential areas are slightly to moderately entrenched and have low sinuosity.

RIPARIAN CONDITION

Riparian condition varies throughout the reach as a result of fragmented habitats caused by housing developments, road crossings, cleared stream banks, and associated landscaping (ODFW 2001). However, ODFW noted “many” beaver dams in riparian areas upstream of Shattuck Road. BES and Brown and Caldwell (1998) considers riparian habitat quality to be good along this 1,200-foot stream reach, which constitutes approximately 50 percent of the primary channel length in lower Vermont Creek. Riparian integrity is variable upstream of Vermont Street, ranging from good to poor, depending upon local stream conditions.

Canopy cover is relatively good, with crown cover of 50 percent near the confluence of Vermont Creek and Fanno Creek and 90-100 percent at the confluence in Bauman Park (CWS 1997). Although tree cover is variable, it is highest adjacent to the creek: 32 percent in zone 1, 24 percent in zone 2, and 19 percent in zone 3. Large (30-50 cm dbh), well-established conifers (western red cedar) and deciduous trees (big leaf maple and alder), along with shrubs and vines, characterize riparian vegetation. Young conifer and hardwood saplings are also present throughout the riparian corridor. In addition to forest-type habitats, grassy openings, wetlands, wet meadows and willow thickets have been documented in lower Vermont Creek (BOP 2001).

There is no documentation of springs and seeps.

STREAM CONNECTIVITY

Stream connectivity is disrupted at SW Oleson Road (RM 0.14) and Shattuck Road (RM 0.42).

The impacts on resident fish movement are unknown, but probably impair resident fish movement seasonally, particularly during low summer flows. In addition, stream connectivity is broken at SW Vermont Street and 52nd Avenue (near river mile 1.0). The reach break is long and complex; the creek is culverted for approximately 175 feet at the Vermont Street crossing, then piped into a 200-foot storm pipe that runs under Vermont Street. The severity of this hydraulic break has not been documented, but even under optimal conditions, the combined effect of the two piped creek segments probably completely blocks fish from swimming upstream. BES's 1997 Resource Management Plan identified this stream reach as undersized (for stormwater capacity), with areas of excess velocity (BES and Brown & Caldwell).

REFUGIA

Instream refugia are predominantly associated with the deep (over 1.0 meter) beaver pond above Shattuck Road and a tributary confluence below SW 49th Avenue. Undercut banks are rare (8 percent for both stream banks), boulders are rare, and wood volume is low.

CHANNEL CONDITION AND HABITAT STRUCTURE

During 2001, ODFW observed that over 70 percent of stream banks were actively eroding. Results from stream surveys conducted in 1997, however, show that most of the reach has low potential for bank erosion (BES and Brown and Caldwell 1998).

ODFW personnel observed in 2001 that much of the reach had been rechanneled during sewer work over the past 30 years.

Terraces, steps, and beaver dams characterize instream structure. Predominant habitat types include lateral scour pools (53 percent) and dammed (beaver pond) pools (33 percent). A large beaver pond complex is present immediately above Shattuck Road. Riffles constitute only 6.5 percent of habitat in the reach, which may limit the carrying capacity (or potential fish productivity) within the subbasin.

Stream bottom substrates are composed of cobbles, gravels, sand, and silt. The relative proportion of each varies throughout the reach and stream morphology. Silt and organic material compose the majority (86 percent) of stream substrate in beaver ponds. Scour pools contain high proportions of silt and organics (58 percent) and sand (20 percent), and riffles are comprised of sand (19 percent), gravel (27 percent) and cobble, indicating good-quality spawning and rearing habitat. Notably, riffles have moderately high proportions (29 percent) of fine silts covering the stream bottom, which may significantly impair riffle quality. The high proportion of fines and organics in both the beaver ponds and scour pools also indicates high deposition during storm flows.

Pools are of relatively good quality. Average residual pool depth (for scour pools) is 0.41meter, generally considered marginally desirable for small tributary streams. However, the average channel depth is 0.29 –meter, yielding a relative pool depth of 41 percent and indicating that pools functionally provide limited protective cover or refugia. However, the beaver pond averages 1.0 meter (and greater in some areas) and probably provides important cover and overwinter rearing areas to resident fish during storm flows. In addition to depth refugia, the beaver pond provides important wood complexity relative to the rest of lower Vermont Creek. Wood is severely lacking throughout lower Vermont Creek—abundance and volume are low, and key pieces are rare. Most wood is located in the beaver pond complex and other deep pools.

Fish habitat conditions are generally considered marginal throughout most of the reach. However, an area of higher-quality fish habitat is noted below the Shattuck Road crossing. The upper 400 feet are believed to provide very little fish habitat.

HYDROLOGY

Flows are characteristic of perennial channel flow, although summer flow volumes are estimated to be less than 0.01 cfs (personal observation, Gerrit Rosenthal, September 2002). Peak flows have not been estimated, but are likely to be 20-50 –cfs, based on basin size. Flow in this reach is affected by the straight channel, low stream gradient, and channel morphology (which exhibits a terrace-drop pattern).

EVALUATION OF LOWER VERMONT CREEK

- Culverts and roadways severely truncate lower Vermont Creek. SW Oleson Road adversely affects connectivity with mainstem Fanno Creek, and probably limits upstream movement during most of the year. Fish probably move between Oleson Road and Shattuck Road but probably do not move upstream of Shattuck Road; this limits residence to 0.40 –river mile. In addition, fish probably do not pass above SW Vermont Street (and SW 52nd Avenue), again providing only 0.50-river mile for resident fish.

- Resident fish probably rear (and seek refuge) in the beaver pond. During storm flows, this may be one of the few areas that provide high-water refugia to fish. Undercut banks are rare, boulders are few, wood is lacking, and deep pools located in mainstem flow probably do not provide adequate flow refugia. Resident fish that do not have access to this area are therefore probably swept downstream during high to moderate flows.

- Riffle area is extremely low (7.5 percent) and of questionable quality. Cobble, gravel, and sand compose riffle substrate, indicating good quality. However, the high proportion of fine sediment and organics overlying these substrates may significantly impair spawning and rearing grounds.

- Both the beaver pond and in-channel pools function as depositional zones for fine sediment during storm flows. Expected stream armoring may not occur regularly enough to maintain healthy stream function (sediment removal, substrate distribution, etc.), and the stream bottom may be aggrading with fine sediment.

- Lower Vermont Creek is characterized by highly mixed habitat conditions. ODFW observed sculpin in this reach, but did not observe any salmonids.

- A large number of beaver complexes are present.

Vermont V2 – Upper Vermont Creek (Gabriel Park)

FLOODPLAIN CONDITION

Stream gradient averages 3.1 percent. The channel is constrained by alternating terraces within a broader valley floor. The VWI averages 10.8, with a range of 7.0-15.0. Floodplain connections appear to be intact in the lower portion of the reach (above 49th Avenue) and in portions of Gabriel Park near the confluence with North Fork Vermont Creek. Floodprone width is twice the active channel width, indicating that flood flows periodically top the banks and interact with the floodplain. Green space (parks) and residential homes are common features and uses on the landscape.

RIPARIAN CONDITION

A significant portion of the reach runs through Gabriel Park; the stream corridor is relatively intact, in a semi-natural state. Predominant landforms include hillslopes, high terraces, and roadways.

Although localized restoration work has occurred along the mainstem and riparian condition is considered good, interpretation of aerial photographs shows that the riparian corridor is generally less than 50 feet wide (overall) below 45th Avenue. The riparian corridor along north fork Vermont Creek is narrow. The widest continuous corridor is found inside the park, along the south fork and mainstem Vermont Creek; canopy cover is 90 percent and 97 percent, respectively. Tree canopy cover elsewhere averages 78 percent in zone 1 (0-10 meters), 83 percent in zone 2 (10-20 meters), and 71 percent in zone 3 20-30 meters within the immediate riparian corridor. Large, well-established (30-50 cm dbh) conifers and hardwoods, along with young saplings (3-15 cm dbh) were encountered most frequently. Large trees (up to 100 cm dbh) are abundant along south fork Vermont Creek. Predominant species include cedar, Douglas fir, maple, and alder.

The riparian canopy is fragmented most dramatically at 45th Avenue, which crosses over mainstem Vermont Creek and south fork Vermont Creek. The south fork has an additional riparian break at Multnomah Boulevard; it disappears under an apartment complex/parking lot. In addition, foot trails impact riparian condition in the park. Consequently, riparian habitat condition is considered low throughout much of this reach, especially; within the middle portion of the park and along north fork Vermont Creek (BES and Brown and Caldwell 1998).

Hyporheic areas and functions have not been documented; however, hyporheic flow is known to exist within the park (along mainstem and south fork Vermont Creek). These areas are protected by fences or are relatively unaffected because of lack of human access.

STREAM CONNECTIVITY

Culverts and storm drains associated with 45th Avenue impact stream connectivity in mainstem and south fork Vermont Creek. The 45th Avenue culvert (on mainstem Vermont Creek) is approximately 75 feet long; the hydraulic conditions associated with this culvert have not been documented. Connectivity with headwater springs and seeps above Gabriel Park have not been documented, but flows are very low above the park and stream-related habitat is limited.

Caldew Street and Multnomah Boulevard (and an apartment complex) impair fish passage on south fork Vermont Creek; headwater reaches are probably inaccessible to fish.

REFUGIA

Within the upper Vermont Creek subbasin, undercut banks are rare, pools are shallow and boulders are scarce (constituting only 1 percent of pool substrate). Instream refugia are probably associated with complex pools (with wood) and tributary confluence regions (if they are accessed).

CHANNEL CONDITION AND HABITAT STRUCTURE

ODFW surveys show that nearly all (94%) stream banks habitat is actively eroding. Surveys conducted in 1997, however, note low to moderate erosion potential throughout the mainstem and north fork (Harza 1997). The north fork consists of a rock substrate and is seasonally dry. South fork substrates include a mixture of gravels, cobbles, and bedrock.

The predominant habitat types in upper Vermont Creek are riffles (43 percent), cascades (32 percent), and lateral scour pools (17 percent). Riffles are also the dominant habitat type in the south fork (personal communications, Gerrit Rosenthal, September 2002). Substrate composition in riffles is gravel (20 percent) and cobble (19 percent), generally considered desirable for fish-bearing streams. However, substrate is covered with 42 percent fines and organics, which can significantly impair riffle quality for spawning and rearing. Additionally, the high proportion of fines overlying riffle habitat probably impairs macroinvertebrate production, an important food source for salmonids.

Pool area is low and pools are shallow, averaging 0.22 meter. Relative pool depth averages 0.10 meter. Although the pools are shallow, they may provide critical cover and refuge to resident fish, particularly during summer low flows. Substrate composition in pools is dominated by silt (79 percent). Gravel and sand constitute only 6 percent and 13 percent of substrate, respectively. The lack of coarse substrate and high amount of silt signify that pools are highly depositional in upper Vermont Creek, which is somewhat uncharacteristic of typical headwater (perennial) streams. Although pools are shallow and probably do not provide depth refugia, some have wood, which probably provides important cover during high flows and for predator avoidance.

Large woody debris is found in-channel, and abundance is considered moderately good at 16.3 pieces per 100 meters of stream length. However, wood volume is low and key pieces are rare, indicating that pieces are small and not clustered. Large trees are present in the park, providing important sources of woody debris to the stream. A significant number of large and medium (greater that 15 cm dbh) trees and downed wood are present along the south fork; however, large woody debris complexes have not been noted instream.

EVALUATION OF UPPER VERMONT CREEK

- Instream habitat is less than desirable for small headwater streams. Significant amounts of silt overlie riffle and pool habitat; pools are shallow; banks are actively eroding; wood is scarce; and channel complexity (boulders, undercut banks, wood, coarse substrate) is low.

- Upper Vermont Creek experiences intermittent flow in the north fork and low perennial flows in the south fork and mainstem. Fish probably do not inhabit this reach in summer low flows, but may use the upper reach (if accessible) during higher flows (fall, winter, and spring).

- Most of this reach lies within Gabriel Park and is protected green space; however, it is probably above the zone of viable fish populations.
- Riparian habitat has been well protected, but is still impacted by residential development above the park and by park use and trails.
- 45th Avenue effectively disconnects upper mainstem and south fork Vermont Creek from lower Vermont Creek.

Red Rock Creek – Headwater Reach

FLOODPLAIN CONDITION

The headwater reach of Red Rock Creek is highly constrained and steep (greater than 8 percent slope). Floodplain interactions are limited; however, some have been noted immediately above 68th Avenue (the downstream reach break).

RIPARIAN CONDITION

Aerial photographs and personal observations indicate that the riparian zone is intact, although narrow. CWS survey site data indicate a buffer width of approximately 3 meters.

STREAM CONNECTIVITY

Two breaks in stream connectivity exist at SW 68th Avenue and Interstate 5. Neither has been evaluated for fish passage, but both are expected to completely impede fish movement. In particular, the I-5 culvert is over 122 meter long. Red Rock Creek flows into Fanno Creek below the Beaverton-Hillsdale Shopping Center; Red Rock Creek is therefore inaccessible to fish in Fanno Creek under most (if not all) hydrologic conditions.

CHANNEL CONDITION AND HABITAT STRUCTURE

Observations near SW 68th Avenue indicate that stream bottom substrate is dominated by gravel and silt (personal observations, Gerrit Rosenthal). CWS survey data show that bedrock is predominant and forms cascades throughout the reach. A small wetland pool exists at the downstream extent of the reach.

Pendleton Creek – Headwater Reach

Note: Habitat characteristics in Pendleton Creek have not been well documented; neither the ODFW 2001 nor the CWS 2000 surveys included this reach.

FLOODPLAIN CONDITION

Floodplain condition has not been documented. However, Pendleton Creek is believed to run through a remnant floodplain that is not currently hydrologically connected to the creek channel.

Downstream of SW Shattuck Road, floodplain conditions are relatively intact, and an undeveloped patch of forest exists near SW 61st Avenue (BOP 2001). Very little riparian vegetation exists upstream of Shattuck Road. Homes, lawns, and streets abut the creek, and the channel is straightened. Anecdotal information (interpretation of aerial photographs) suggests that a pond/wetland exists immediately upstream of the Fanno Creek/Pendleton Creek confluence; the presence of this pond has not been confirmed.

Stream gradient is low (1.9percent).

RIPARIAN CONDITION

Riparian integrity, and associated wildlife habitat and tree canopy condition, is considered fair to good downstream of SW Shattuck Road. Upstream of Shattuck Road, riparian integrity is impaired and is considered low (BES and Brown and Caldwell 1998). Aerial photographs show a very narrow (and landscaped) corridor that is fragmented by numerous roadways: SW Shattuck Road, SW 59th Avenue, SW 54th Avenue, SW 53rd Avenue, SW 52nd Avenue, and SW Fairdale Court.

STREAM CONNECTIVITY

The roadways and associated culverts disrupt stream connectivity and probably isolate resident fish. Stream connectivity is believed to be relatively intact from the confluence of Pendleton Creek and Fanno Creek upstream to Shattuck Road. Basinwide, Pendleton Creek is hydraulically disconnected from Fanno Creek. The confluence region lies under the Beaverton-Hillsdale Shopping Center and is completely impassable under most hydrologic regimes.

REFUGIA/CHANNEL CONDITION AND HABITAT STRUCTURE

Channel conditions and habitat structure (including instream refugia) have not been well documented. Observations at SW Shattuck Road indicate that substrates are a mixture of sediment, fill, rock, and coarse debris (personal communication, Gerrit Rosenthal). Additional observations of channel conditions upstream of SW Shattuck Road depict habitat as a sequence of narrow runs (channelized ditch), with culverts occurring every 60-120 meters along the stream.

EVALUATION OF PENDLETON CREEK

- An undeveloped patch of forest exists near SW 61st Avenue.

Columbia Creek - Lower Columbia Creek

Columbia Creek is a northern tributary to Fanno Creek and drains the Sylvan Hills (west of SW Scholls Ferry Road). Columbia Creek flows into Fanno Creek near SW 59th Avenue (Fanno 2). It is over 1.2 miles long and has a gradient of 2-3 percent.

Columbia Creek has not been extensively surveyed to assess habitat conditions. ODFW walked the creek during 2001 and noted the following:

- The floodway is bounded by alternating terraces and hillslopes.

- Extensive stream bank erosion is evident. Banks are incised and the channel is constrained (U-shaped).

- Average pool depth is 0.1 –meter, and average riffle depth is 0.01 meter.

- Average wetted width (near the confluence of Fanno Creek) is 0.45 meter.

- The riparian corridor is considered "decent" in most areas.

- Dominant tree species in the immediate riparian corridor and floodplain are deciduous-dominated; however, mixed conifers and hardwoods are evident in the upper hillslopes of the Sylvan Hills.

- The predominant land use is suburban residential.

- Landowners near SW 58th Avenue are interested in designating riparian property as green space.

Columbia Creek is spring-fed and flows year-round. Aerial photographs indicate that an intact riparian corridor runs the length of the creek. Stream connectivity is generally good, with one exception: SW Patton Road. This crossing has a 0.65-meter drop at the culvert outlet. SW Hamilton Street also crosses the Columbia Creek, but does not appear to be a passage barrier.

Because Columbia Creek offers spring-fed (perennial) flows and is accessible from the mouth upstream to SW Patton Creek, it probably provides important off-channel refugia to fish occupying Fanno Creek (Fanno 2 and Fanno 3), particularly during high storm flows, as well as low summer flows. Columbia Creek probably augments Fanno Creek surface flows and provides important cool-water refugia.

Ivey Creek

Ivey Creek flows into Fanno Creek just upstream of SW 45th Avenue and drains the Council Crest/Bridlemile area. Ivey Creek has not been extensively surveyed to assess habitat conditions. ODFW walked the creek during 2001 and noted the following:

- Ivey Creek is constrained by terraces and hillslopes of the Sylvan Hills; however, the lower portion flows through the remnant floodplain of Fanno Creek.
- Suburban land use is predominant.
- Lower Ivey Creek is constrained. The riparian corridor is narrow and fragmented by apartment complexes that abut the creek. The riparian corridor widens in the upstream extent (with larger lots) toward Sylvan Hills. Trees there are larger, with dominant species including conifers and hardwoods.

- The confluence of Ivey Creek and Fanno Creek is piped through a culvert approximately 1.7 meters long, with a 0.2-meter drop. Sewer pipes span the creek, and manmade barriers exist near SW Hamilton and SW Dosch Road.

- Bank erosion is evident, and the channel is incised.

- Ivey Creek is spring-fed, with intermittent flow in the headwaters and perennial flows in the downstream extent.

Patton Creek

Patton Creek is similar to Columbia Creek in length, flow, and riparian habitat condition. Patton Creek drains the central portion of the Southwest Hills and Bridlemile neighborhoods. The stream is approximately 1.25 miles long, and the confluence with Fanno Creek is immediately above SW Shattuck Road. Flow is believed to be less than that of Columbia Creek—approximately 0.05 cfs (personal communication, Gerrit Rosenthal)). Riparian conditions appear to be fair to good along much of the creek's length. SW Hamilton Street is the only known road that fragments the riparian corridor and disrupts stream connectivity. Patton Creek augments Fanno Creek flows (particularly in the summer), provides important off-channel refugia, and may provide important spawning and rearing habitat for resident fish in Fanno Creek (Fanno 2 and Fanno 3).

HABITAT CHARACTERIZATION SUMMARY

Because important watershed features such as land use, effective impervious area, geology, soils, and hydrology are characterized in other parts of this report, they are not comprehensively considered in this section. The results of those characterizations should be considered to truly evaluate watershed features and processes that directly and indirectly affect ecological functions and biological communities in the Fanno Creek Watershed. For example, impervious area affects stormwater runoff timing, duration, and intensity, which subsequently impacts erodible banks, riparian vegetation, pool–riffle formation, substrate recruitment and retainment, large woody debris recruitment and retainment, and macroinvertebrate production.

Based on existing documented data, neither salmonids nor resident trout currently occupy tributaries to Fanno Creek. However, this section evaluates tributary habitat assuming that salmonids and trout may access these tributaries for spawning and rearing sometime in the future. The discussion below describes current floodplain condition, riparian condition, stream connectivity, refugia, channel condition and habitat structure in mainstem Fanno Creek and its tributaries.

Floodplain Condition

Mainstem Fanno Creek

The Fanno Creek floodplain area has been hardened, filled, and topped with impervious surfaces, effectively reducing potential floodplain interactions. Historically, mainstem Fanno Creek flowed through multiple terraces lying within the Tualatin Valley hillside. Now upper Fanno Creek is constrained by hillslopes, high terraces, roadways, and urban development and does not significantly interact with its historic floodplain. ODFW data indicate that with the exception of Fanno 5, terrace height and width are greater than floodprone height and width, indicating that the creek is bounded by constraining terraces on both sides (Table 8-1). Data also suggest, however, that channel entrenchment is low and stream gradient is low, signifying that flood flows top the banks and stream flows interact with the immediate floodway (at least within the 50-year floodplain). These interactions are perceived to occur the most in the headwater reach (entrenchment ratios are highest), and diminish in the downstream extent.

Table 8-1
Floodplain Attributes in Mainstem Fanno Creek

Basin	Reach	VWI [1]	Entrenchment Ratio [2]	Stream Gradient [3] (%)
Fanno Creek	Fanno 1	20.0	1.8	0.5
	Fanno 2	20.0	1.6	< 0.5
	Fanno 3	20.0	1.6	< 0.6
	Fanno 4	20.0	1.9	< 0.7
	Fanno 5	19.5	2.0	1.1
	Fanno 1	10.8	3.4	1.5

[1] Valley Width Index (VWI): Broad valley floor > 2.5; narrow valley floor <2.5

[2] Entrenchment Ratio (floodprone width divided by the active channel width): Values > 1.0 signify increasing floodplain interactions
[3] Stream Gradient: Low < 2%; moderate 2%-8%; steep > 8.0%

Throughout Upper Fanno Creek subbasin floodplain functions are generally impaired and are properly functioning; hydrologic connections are limited between the creek and its floodplain, adjacent wetlands, and the riparian area. The middle section of Upper Fanno subbasin likely provides the greatest opportunities, specifically, throughout Fanno 4 and Fanno 5. In Fanno 4, floodplain functions greatest in the lower and upper reach, where stream gradient is lower and channel incision is less. Floodplain interactions area greatest in the upper portion of Fanno 5, where the floodprone width is greater than the active channel width and flood flows are believed to overtop the confined channel and interact with the immediate riparian and broader floodplain area, at least within a 50-year flood events.

Tributaries to Fanno Creek

Tributaries to Fanno Creek exhibit similar floodplain condition to mainstem Fanno Creek; they are bound by alternating terraces and hillslopes, and they historically flowed through a broader floodplain valley. Stream gradients are low to moderately steep. Based on the average entrenchment ratio, the floodprone width is wider than the active channel width, signifying that floodplain interactions occur within the immediate (50-year) floodway and adjacent riparian corridor. However, terrace height is nearly always greater than the floodprone height, indicating that flows seldom access the broader floodplain.

South Ash Creek, North Ash Creek, and upper Woods Creek are constrained by alternating hillslopes and terraces, are moderately steep, and are surrounded by low-density residential development (Table 8-2). The floodway is constrained (two to four times the active channel width) relative to the historical floodplain and valley form. Lower and middle Woods Creek and Vermont Creek historically flowed through the broad Fanno Creek floodplain, meandering across expansive areas, bound by terraces and hillslopes. Although historical floodplains are evident, they currently are hydrologically disconnected from their creek channels, and floodplain interactions are impaired. Red Rock Creek, Pendleton Creek, Columbia Creek, and Patton Creek exhibit impaired floodplain condition and hydrologic discontinuity.

Table 8-2
Floodplain Attributes in Tributaries to Fanno Creek

Basin	Reach	VWI[1]	Entrenchment Ratio [2]	Stream Gradient [3] (%)
South Ash Creek	Ash 1G	7.4 (2.0 - 20.0)	3.9	4.5
North Ash Creek	Ash 1E	7.1 (2.5 - 16.0)	3.6	6.3
Woods Creek	Woods W1 & W2	18.5 (2.0 - 20.0)	13.9	0.8
	Woods W3	7.3 (2.5 - 17.0)	2.3	4.2

Vermont Creek	Vermont 1A	13.0 (4.0 - 20.0)	5.7	0.9
	Vermont 2A	10.8 (7.0 - 15.0)	2.1	3.1

[1] Valley Width Index (VWI): Broad valley floor > 2.5; narrow valley floor <2.5
[2] Entrenchment Ratio (floodprone width divided by the active channel width): Values > 1.0 signify increasing floodplain interactions
[3] Stream Gradient: Low < 2%; moderate 2%-8%; steep > 8.0%

Relative to the tributaries feeding into it, Fanno Creek is more confined and probably interacts less with its floodplain. Floodplain functions are believed to be relatively intact and functioning in South Ash Creek (the mainstem headwater reach of Ash Creek subbasin) and Lower and Middle Woods Creek. South Ash Creek's floodprone width is nearly four times the active channel width, and lower and middle Woods Creek's floodprone width is 14 times the active channel width. Stream gradients are moderately high in South Ash Creek and VWI is relatively narrow, characteristic of headwater tributary systems; floodplain interactions are therefore probably of short duration. In Woods Creek, however, the remnant floodplain is broad and stream gradient is low, yielding more prolonged aquatic land interactions during flood flows. Numerous springs, seeps, and wetland habitat have been noted in lower Woods Creek, near the confluence with Fanno Creek (notably near Oregon Episcopal School).

Riparian Condition

Tree Canopy Cover, Riparian Corridor Width, and Vegetation Composition

FANNO CREEK MAINSTEM

Riparian condition varies from poor to sub-optimal throughout different areas of Upper Fanno Subbasin. Common trees species include Douglas fir, western red cedar, western hemlock, big leaf maple, alder, and willow. In addition to these larger trees, shrubs and vines constitute a significant portion of riparian vegetation toward the headwater reach.

As shown in Table 8-3, small, second growth deciduous trees and small mixed conifer/deciduous trees dominate riparian vegetation from Fanno 1 upstream to Fanno 4. These trees provide canopy cover over the stream channel and immediate stream bank (0-10 meters), but do not adequately shade the remaining riparian corridor (from 10-30 meters beyond the creek bank). In addition, this vegetative community does not adequately provide source woody material to Fanno Creek. Based upon these characteristics, lower and middle reaches of upper mainstem Fanno Creek yield a narrow riparian area and marginal riparian condition.

Riparian condition improves moving in to the headwater reaches of Fanno 5 through Fanno 6. Both reaches have large (over 30-cm dbh), well-established deciduous trees that provide moderate canopy cover throughout the riparian area: 54 percent in zone 1 (0-10 meters), 50 percent in zone 2 (10-20 meters), and 44 percent in zone 3 (20-30 meters). However, mature conifers are notably lacking and canopy cover remains low, providing less than 60% shade cover.

Table 8-3
Riparian Attributes in Mainstem Fanno Creek

Basin	Reach	Riparian Vegetation [1]	Canopy Cover (% Shade) [2]		
			Zone 1	*Zone 2*	*Zone 3*
Fanno Creek	Fanno 1	D15, S	41	19	18
	Fanno 2	M3, M1	45	0	0
	Fanno 3	M3, M1	45	0	0
	Fanno 4	D15, S	69	39	23
	Fanno 5	D30, S	35	43	40
	Fanno 6	D30, S	54	50	44

[1] Riparian vegetation classifications include:

D15: Deciduous dominated (15-30-cm dbh, second-growth trees)
D30: Deciduous dominated (30-50-cm dbh, large established trees)
S: Shrubs and vines
G: Grasses
M1: Mixed conifer/deciduous (1-3-cm dbh, seedlings and new plantings)
M3: Mixed conifer/deciduous (3-15-cm dbh, young trees or saplings)
M15: Mixed conifer/deciduous (15-30-cm dbh, second growth)
M30: Mixed conifer/deciduous (30-50-cm dbh, large established trees)
M50: Mixed conifer/deciduous (50-100-cm dbh, large established trees)

[2] Zone 1: 0-10 m; Zone 2: 10-20 m; Zone 3: 20-30 m

TRIBUTARIES TO FANNO CREEK

Nearly all tributaries provide more tree canopy cover, a wider riparian corridor, more representative native species composition (mixed conifer/deciduous), and larger established trees than upper mainstem Fanno Creek. Briefly, Woods Creek and Vermont Creek have larger, well-established conifers and hardwoods trees, and Ash Creek resembles mainstem Fanno Creek, with medium-sized conifers and hardwoods.

Woods Creek provides the best riparian condition ranging from optimal conditions in the upper, headwaters to suboptimal (yet still functioning) in the middle reaches. In upper Woods Creek, riparian species are comprised of large (50-100-cm dbh), mature conifers and hardwoods and canopy cover is high throughout the 30-m riparian corridor. Moving downstream, riparian condition diminishes; however, large (30-50-cm dbh) established conifers and hardwoods remain dominant overstorey species throughout the continuous riparian corridor. However, tree canopy cover is lower, yielding less protective shade cover.

Upper Vermont Creek similarly shows good riparian condition, with large and small conifers and hardwoods, a riparian corridor that extends to 30 meters or more, and tree canopy cover greater than 70 percent throughout the entire 30 meter riparian corridor. As with Woods Creek, riparian condition diminishes moving downstream into lower Vermont Creek. Here, large conifers and hardwoods predominate adjacent to the stream bank, however, canopy cover remains low throughout the entire riparian corridor, indicating loss of functioning conditions.

South Ash Creek provides marginal riparian function, based on the presence of medium sized conifers and hardwoods throughout the riparian corridor, and the substantive shade cover these trees provide. If this area remains protected, riparian functions will only increase with time.

Unlike South Ash Creek, North Ash Creek is dominated by second growth deciduous trees, that yield some protective cover along the streambank, but provides very little shade cover 10-m beyond the stream bank. As a result, North Ash Creek is believed to provide only moderate riparian function.

Notably, Red Rock Creek and Pendleton Creek have narrow riparian corridors. Riparian condition is considered decent in Columbia Creek, fair to good in Patton Creek and narrow and fragmented in Ivey Creek (ODFW 2001).

Table 8-4
Riparian Attributes in Tributaries of Fanno Creek

Basin	**Reach**	**Riparian Vegetation** [1]	**Canopy Cover (% Shade)** [2]		
			Zone 1	***Zone 2***	***Zone 3***
South Ash Creek	Ash 1G	M15, G	64	71	63
North Ash Creek	Ash 1E	D15, S	58	37	22
Woods Creek	Woods W1 & W2	M30, G	70	48	53
	Woods W3	M50, G	74	82	58
Vermont Creek	Vermont V1	M30, S	32	24	19
	Vermont V2	M30, M1	78	83	71

[1] Riparian vegetation classifications include:

D15: Deciduous dominated (15-30-cm dbh, second-growth trees)
D30: Deciduous dominated (30-50-cm dbh, large established trees)
S: Shrubs and vines
G: Grasses
M1: Mixed conifer/deciduous (1-3-cm dbh, seedlings and new plantings)
M3: Mixed conifer/deciduous (3-15-cm dbh, young trees or saplings)
M15: Mixed conifer/deciduous (15-30-cm dbh, second growth)
M30: Mixed conifer/deciduous (30-50-cm dbh, large established trees)
M50: Mixed conifer/deciduous (50-100-cm dbh, large established trees)

[2] Zone 1: 0-10 m; Zone 2: 10-20 m; Zone 3: 20-30 m

Riparian Fragmentation

Roadways, homes, trails, and exposed sewer pipes fragment the riparian corridor in all mainstem reaches and tributary reaches. The severity and impact of these impediments vary. The Stream Connectivity section below provides details about stream connectivity by reach.

Hyporheic Condition

Only anecdotal information is available to evaluate hyporheic conditions in upper Fanno Creek subbasin. The following is a brief, and not comprehensive, summary of known hyporheic flows and seeps.

- Numerous springs, seeps, and wetlands have been noted in lower Woods Creek (near Oregon Episcopal School), and numerous seeps and springs have been documented in upper Woods Creek in Woods Memorial Park.
- Springs and seeps also exist in Gabriel Park in both the mainstem and south fork Vermont Creek (headwaters).
- A small wetland area exists in Red Rock Creek, and a wetland/pond area is believed to be present near the confluence of Fanno Creek and Pendleton Creek.
- Seeps and springs probably exist in the headwaters of mainstem Fanno Creek (upstream of Fanno 4), although they have not been documented or mapped to-date.

Based on an assessment of vegetative species composition, forest age, riparian width, canopy cover, riparian fragmentation and presence of wetland and hyporheic areas, the riparian reserve is not properly functioning. Notably, the riparian area in upper Fanno Creek subbasin is fragmented and poorly connected to the channel to the extent that it does not substantively protect aquatic habitats and / or provide shade cover, protective cover, or refugia. In addition, although some areas with more mature trees exist, conifer species are notably lacking; where present, they are young and do not presently provide substantive ecological benefit. Finally, the riparian reserve does not adequately provide source large woody material.

Basinwide, urban development within the riparian area has resulted in the conversion of mixed conifer and deciduous trees to landscapes dominated by second-growth deciduous trees, shrubs, and grasses. Parking lots, streets, lawns, homes, and buildings are prominent land features. Loss of mature forests and the conversion of forest floor to impervious surfaces have resulted in dramatic changes in Fanno Creek's hydrograph and subsequent changes to floodplain, riparian, and stream condition. Increased (and flashy) stream flow caused by elevated surface runoff and degradation of riparian and streambank vegetation has caused streams to adjust by channel incision. Consequently, stream banks are steep, unstable, actively eroding, and hydrologically disconnected from adjacent riparian and floodplain habitats.

Stream Connectivity

Mainstem Fanno Creek

Table 8-5 lists key barriers to fish passage in upper mainstem Fanno Creek. Upper Fanno Creek is highly disconnected from lower and middle Fanno Creek and the Tualatin River Basin. The SW Beaverton-Hillsdale Highway/Scholls Ferry Road interchange (Beaverton Hillsdale Shopping Center at RM 12.1) effectively impedes fish passage into upper Fanno subbasin. Here, the creek is piped for approximately 800 feet. Fish may pass above this point during high flow, but it is unlikely. If local fish populations exist upstream of this area, they are probably independent from populations residing in this (and other downstream) reaches or are seeded during high-flow events. Other key roadways that significantly impact fish migrations include SW Shattuck Road (Fanno 3), SW 39th Avenue (Fanno 5), and SW 30th Avenue (Fanno 6).

Although these culverts have not been examined specifically for fish passage, resident fish probably cannot navigate the culverts except under very unique hydrologic conditions. Flow would need to be deep enough to provide a through-waterway, but not swift enough to function as a velocity barrier.

Conversely, key areas with no barriers include Fanno 2 (0.32-river mile), Fanno 3 (0.42-river mile), and Fanno 4 (0.51-river mile). Although fish movement between these reaches is impaired (due to roadways identified in Table 8-5), movement within them is good. Numerous roads and culverts impair fish passage within Fanno 5, Fanno 6 and Fanno 12.

Table 8-5
Fish Passage Barriers in Mainstem Fanno Creek

Reach	Barrier # and Type	Impact of Hydraulic Break - Fish Passage	Location
Fanno 1	**Beaverton-Hillsdale Hwy**	Completely impassable	Fanno 1/Fanno 2
Fanno 2	SW 59th Ave.	Passable	Fanno 2/Fanno 3
Fanno 3	SW Shattuck Rd.	Unknown impact	Fanno 3/Fanno 4
Fanno 4	SW 45th Ave.	Unknown impact	Fanno 4/Fanno 5
Fanno 5	SW 43rd Dr.	Unknown impact	Mid-reach
	SW 39th Dr.	Completely impassable	Fanno 5/Fanno 6
Fanno 6	**Beaverton-Hillsdale Hwy**	Completely impassable	Mid-reach
	SW 30th Ave.	Completely impassable	Fanno 6/Fanno 7
Fanno 7	SW Bertha	Unknown impact	Mid-reach

Numerous roadways impede fish passage throughout the year in mainstem Fanno Creek. As a result resident fish have a limited range for spawning and rearing. A culverted reach running under Beaverton-Hillsdale Shopping Center separates the lower and middle subbasin from the upper subbasin. As a result, resident fish are sequestered to the upper basin, and anadromous fish cannot access historic spawning and rearing habitats. In addition to Beaverton Hillsdale Shopping Center, key culverts limiting fish passage throughout upper Fanno subbasin include: SW Shattuck Road, SW 45th Avenue, and SW 43rd Avenue. If these culverts were passable year-round, 1.5 rivermiles of stream habitat would be available (from Fanno 2 to Fanno 5).

Tributaries to Fanno Creek

Table 8-6 lists key barriers to fish migrations in tributaries to Fanno Creek. Trout have not been documented in tributaries to Fanno Creek (except at the mouth of South Ash Creek); however, Columbia Creek, Vermont Creek, South Ash Creek and Patton Creek are open channel and are hydrologically connected to mainstem habitats. All other tributaries (in upper Fanno subbasin) have culverts at (or very near) their confluence with Fanno Creek.

Table 8-6
Fish Passage Barriers in Tributaries to Fanno Creek

Reach	Barrier # and Type	Impact of Hydraulic Break – Fish Passage	Location
South Ash Creek (headwater reach)	SW Lauradel	Completely impassable (~ 32m long)	Upper 300- m of reach
	SW 62nd Ave./Subdivision	Completely impassable (~ 100 m long)	Upper 300 m of reach
	SW 55th Ave.	Unknown impact	Upper 300 m of reach

	4 additional roadway culverts	Unknown impact	Within reach
North Ash Creek (headwater reach)	Concrete dam	Completely impassable	**100 m upstream of confluence with South Ash Creek.**
	SW Dolph Dr.	Unknown impact (1.0-m culvert)	East of Multnomah County line
	SW Orchid Dr.	Unknown impact (1.2-m culvert)	East of Multnomah County line
	SW Lancelot Ln	Unknown impact (0.7-m culvert)	East of Multnomah County line
	SW 55th Ave.	Unknown impact (0.8-m culvert)	East of Multnomah County line
Lower and Middle Woods Creek	Portland Golf Club	Completely impassable	**Confluence of Fanno Creek**
	SW Oleson Rd.	Unknown impact	East of Multnomah City line
	SW 60th Ave	Unknown impact	East of Multnomah City line
Upper Woods Creek	SW Multnomah Blvd	Unknown impact	Within reach
	SW Garden Home Rd	Unknown impact	Within reach
	SW 45th Ave	Completely impassable	Downstream of Woods Memorial Park
	SW Taylors Ferry Rd.	Completely impassable	Upper headwaters
Lower Vermont Creek	SW Oleson Rd.	Seasonally passable?	Within reach
	SW Shattuck Rd.	Seasonally passable?	Within reach
	SW Vermont St /52nd Ave	Completely impassable (2 piped segments = ~ 375 m total)	Within reach
Upper Creek Vermont	SW 45th Ave.	Completely impassable (~ 23 m long)	Within reach
	SW Multnomah Blvd. /Apts	Completely impassable	Within reach
	SW Caldew St	Unknown impact	Within reach
Red Rock Creek	Beaverton Hillsdale shopping Center	Completely impassable	**Confluence with Fanno Creek**
	SW 68th Ave.	Completely impassable	
	Interstate 5	Completely impassable (> 120 m)	
Pendelton Creek	Beaverton Hillsdale Shopping Center	Completely impassable	**Confluence with Fanno Creek**
	SW Shattuck Rd.	Seasonally passable?	Within reach
	SW 59th Ave.	Unknown impact	Within reach
	SW 54th Ave.	Unknown impact	Within reach
	SW 53rd Ave.	Unknown impact	Within reach
	SW 52nd Ave.	Unknown impact	Within reach
	SW Fairdale Ct.	Unknown impact	Within reach
Columbia Creek	SW Patton Rd	Seasonally passable?	Within reach
	SW Hamilton Rd.	Unknown impact	Within reach
Patton Creek	SW Hamilton Rd.	Unknown impact	
Ivey Creek	Culvert	Completely impassable	**Confluence with Fanno Creek**
	Concrete barriers	Unknown impact	SW Hamilton and SW Dosch

Vermont Creek, South Ash Creek, Columbia Creek, and **Patton Creek** are accessible from mainstem Fanno Creek and probably provide important off-channel refugia during high flows and cool-water refugia during periods of low stream flow and elevated stream temperatures. In addition, these creeks probably augment Fanno Creek summer base flows.

Woods Creek, **North Ash Creek**, **Red Rock Creek**, **Pendelton Creek** and **Ivey Creek** have fish passage barriers at or near the confluence of Fanno Creek. Currently, fish populations do not populate these subbasins. Resident fish populations (that previously occupied these habitats) have probably been flushed out of the system throughout the years. Without the ability of fish to move back into these creeks and re-seed habitats, the creeks will probably remain devoid of fish communities.

Refugia

Stream refugia are relatively absent in most of upper Fanno Creek and its tributaries; large wood and/or larger natural rock are both lacking. Tributary confluences, undercut banks, boulders, deep pools, and small amounts of large wood (predominantly found in pools) provide primary refugia.

- Undercut banks probably provide important refugia throughout most of Fanno Creek, particularly in Fanno 4. Undercut banks are rare in all tributaries.
- Deepest pools per stream length are found in Fanno 4; however, deep pool habitat (based on relative pool depth) is also evident in Fanno 2 and Fanno 6. In addition, deep pool areas are found in North and South Ash Creek and upper Woods Creek. Beaver dams provide the best refugia habitat in South Vermont Creek, particularly just upstream from Alpenrose Dairy.
- Wood clusters are generally associated with pools and are found from Fanno 2 through Fanno 5. Complex pools (with wood) are also present in Vermont Creek.
- Although large boulders are not prevalent, they probably provide localized in-channel refugia.

In the absence of in-stream refugia, off-channel habitats may provide critical refuge to resident fish during different times of the year, specifically during high storm flows and low summer flows. In upper Fanno subbasin, most off-channel refugia habitat is found in secondary channels (that often function as overflow channels during high flows) and tributary confluence areas.

- Secondary channels are present in isolated areas of upper Fanno subbasin, most notably in Fanno F11: secondary channels comprise one-third of wetted habitat in this upper headwater reach. Notably, secondary channels are rare in other reaches of mainstem Fanno Creek.
- Vermont Creek, South Ash Creek, Columbia Creek, and Patton Creek are accessible to resident fish from Fanno Creek, and probably provide important off-channel refugia during high flows and cool-water refugia during warm periods.

Channel Condition and Habitat Structure

Mainstem Fanno Creek

CHANNEL FORM

As depicted in Table 8-7, width to depth ratios indicate that channel form is optimal with both pool and riffle habitat present. However, the channel dimension is predominately rectangular suggesting sub-optimal channel condition.

Table 8-7
Channel Form in Upper Fanno Creek

Reach	Width to Depth Ratio	Channel Shape	Pool to Riffle Ratio
Fanno 1	6.0	u-rectangular	2.06
Fanno 2	5.9	u-rectangular	1.07
Fanno 3	5.9	u-rectangular	1.07
Fanno 4	5.7	u-rectangular	3.28
Fanno 5	5.5	u-rectangular	1.69
Fanno 6	5.5	u-rectangular	0.81

STREAM BANK CONDITION

The physiographic characteristics of the watershed and its soil types have had severe impacts on the stream system in terms of channel incision, undercutting of stream banks, and landslides (BES 1999). Urbanization undoubtedly exacerbates these conditions, yielding proportionally higher erosion than would be expected under historic (or non-urban) conditions. Oversteepened bank angles (averaging 60 percent), poor bank vegetation, incised channel and moderate root densities currently characterize most mainstem reaches.

A high proportion of stream banks (36 to 61 percent) are actively eroding with raw, unprotected areas, indicating bank instability and high potential for erosion during storm flows (Table 8-7). As with fine silt deposition, bank erosion (quantified as percentage actively eroding bank) becomes more severe in the downstream extent. Also, demonstrated by the increasing proportion of silt and sand covering the creek bottom in the downstream direction (Table 8-7). In addition, stream banks are only marginally protected with shrub and grass cover. All reaches except Fanno 4, which has notably good bank vegetation with 58% shrub cover and 39% grass and forb cover, have low vegetative cover along the stream bank. Although not ideal, more than 50 percent plant biomass remains throughout all the mainstem habitats, suggesting that although disruptive pressures are evident, they are not substantively disrupting community vigor. Notably, banks are least eroded in the headwater reaches (Fanno 5 and Fanno 6), although vegetative cover is relatively low at 75 percent and 73 percent in Fanno 5 and Fanno 6 respectively.

Although banks are actively eroding, undercut banks remain intact in mainstem Fanno Creek and probably provide important cover and refuge for fish, particularly during high storm flows. The proportion of undercut banks is high throughout the mid to upper subbasin.

Table 8-8
Channel Form in Upper Fanno Creek

Reach	% Actively Eroding	% Undercut Bank	% Shrub Cover	% Grass and Forb Cover	Combined Vegetative Cover
Fanno 1	59	6	43	21	69
Fanno 2	55	21	20	35	55
Fanno 3	55	21	20	35	55
Fanno 4	61	25	58	39	97
Fanno 5	43	17	60	15	75
Fanno 6	36	8	48	25	73

HABITAT DIVERSITY

With the exception of wood that is found almost entirely in pools, wood abundance and volume are critically low (ODFW 2002b), and very few key pieces longer than 3 meters are present. As described in Riparian Condition, small, second growth deciduous trees and small mixed conifer/deciduous trees dominate riparian vegetation from Fanno 1 upstream through Fanno 4. These trees will probably not provide a great source of large woody debris in the immediate future. However, Fanno 5 and Fanno 6 have large (>30 cm), well-established deciduous trees that, if remain, will continue to provide current and future wood sources. However, native conifers, which have slower decay time when submerged in water, will continue to be absent. Based on low wood, volume and densities of wood in-stream and lack of adequate (large-sized conifers and deciduous trees) woody debris recruitment from adjacent riparian areas, the system is considered not properly functioning.

Table 8-9
Large Wood in Fanno Creek

Reach	Number of Pieces	Volume of Wood	Number of Key Pieces
Fanno 1	1.6	0.9	0.0
Fanno 2	3.4	0.9	0.0
Fanno 3 and 4	4.6	1.9	0.1
Fanno 5	5.5	3.6	0.2
Fanno 6	7.6	3.1	0.0

SUBSTRATE

Channel conditions within the upper Fanno Creek subbasin are variable (Table 8-8). Dominant streambed materials are equally distributed between silts and organics (29 percent), sand (28 percent), gravel (27 percent). Larger sized cobbles (18 percent) and boulders (6 percent) comprise are present in relatively low proportions.

Table 8-10
Substrate Composition in Fanno Creek

Reach	% Fines	% Gravel	% Cobble
Fanno 1	53	17	14
Fanno 2	25	27	20
Fanno 3 and 4	34	24	8
Fanno 5	30	37	11
Fanno 6	16	29	25

Substrate composition indicates that upper Fanno subbasin is <u>not functioning properly</u>, except in the upper headwater reach (Fanno 6). Here, gravels and cobbles are the dominant substrate and fines are relatively low. Downstream from this reach, fines dominate and embeddedness is relatively high (> 25%). Notably, good spawning gravels and cobbles exist through Fanno 2 and Fanno 3; however, embeddedness likely limits the functional capacity of this area to provide good spawning and rearing grounds. Substrate composition indicates that poorest conditions exist in Fanno 1.

KEY HABITAT

Scour pools are the dominant habitat type, constituting 68 percent of the wetted area; riffles constitute only 20 percent of the wetted area.

Riffle Area and Quality

Although pool area is present, corresponding riffle habitat is lacking; Fanno 1, Fanno 4, and Fanno 5 have only 10 percent, 11 percent, and 18 percent riffle habitat, respectively. This low proportion and area of riffle habitat may significantly limit the carrying capacity of the system by limiting the amount of spawning and rearing habitat.

Table 8-11
Riffle Area and Substrate Composition

Reach	Total Riffle Area (m2)	% Riffle Area	% Gravel	% Cobble	% Fines	% Silt, Sand and Organics
Fanno 1	585	10	31% (M)	30	19 (M)	32
Fanno 2	341	37	36% (D)	26	12 (M)	28
Fanno 3 and 4	282	11	43% (D)	18	9 (D)	30
Fanno 5	205	18	63% (D)	15	9 (D)	23
Fanno 6	1,123	46	35% (D)	32	7 (D)	20

Of those riffle areas present, they have adequate gravel and cobble composition, with relatively low fine sediment accumulation, signifying low embeddedness and desirable fish bearing habitat. The best riffle habitat in terms of riffle area, high proportion of gravels and cobbles, and low fines is found in Fanno 6. However, riffles contain a relatively high proportion of sand, silt and organic matter yielding marginal habitat function in the headwater reaches and undesirable habitat function in the rest of the upper Fanno subbasin.

Pool Area and Quality

Long, deep, meandering pools constitute a significant proportion of stream habitat in Upper Fanno Subbasin (Table 8-9). These habitats likely function as depositional areas for fine sediment as evidenced by the high proportion (34 to 72 percent) of sediment loading throughout the upper subbasin. Low stream gradients, along with chronic low summer base flows, probably result in accumulated suspended (or resuspended) solids settling-out in the downstream direction. While the proportion of fines increases, the proportion of sand and gravel (generally) decreases downstream. High deposited fines (20 to 50 percent silt, sand and organics) documented in upper Fanno Creek are symptomatic of an unstable and eroding stream channel.

Table 8-12
Pool Area and Substrate Composition

Reach	Pool Frequency	% Pool Area	% Sand	% Fines
Fanno 1	1.1	86 (D)	10	72
Fanno 2	11.3	53 (D)	23	40
Fanno 3 and 4	9.0	86 (D)	30	47
Fanno 5	7.9	76 (D)	25	42
Fanno 6	18.5	42 (D)	27	34

The greatest number of deep pools and the greatest residual pool depth is found in the lower (Fanno 1) and middle reaches (Fanno 4) (Table 8-10). Pools are only moderately deep in the headwaters (Fanno 6), but exhibit the greatest relative channel depth, indicating that channel form diversity (between pools, riffles and glides) and instream cover is highest in this reach. As a result, this area likely provides the best overall habitat in all of upper mainstem Fanno Creek.

Table 8-13
Pool Depth

Reach	Deep Pools (> 1.0-m)		Average Residual Pool Depth (m)	Average Channel Depth (m)	Relative Pool Depth (%)
	# Deep Pools	# Deep Pools/ 1000 m			
Fanno 1	6.0	3.4	0.63	0.49	29
Fanno 2	1.0	1.3	0.50	0.32	56
Fanno 3 and 4	4.0	4.3	0.61	0.45	36
Fanno 5	0.0	0.0	0.44	0.30	33
Fanno 6	1.0	0.5	0.44	0.20	120

Based on the low number of deep pools and low relative pool depth (except in Fanno 6) and the high proportion of fine sand, silt and organics deposited reach-wide, the system is at risk; fine sediments likely reduce pool volume yielding a reduction in flood storage capacity.

Complex pools with wood and boulders provide important structure and roughness in Fanno Creek. These habitat attributes help the creek withstand erosive flows and provide cover to resident fish. In upper Fanno Creek, complex pools (defined as pools with greater than 3-km wood complexity per 1,000 –meters of stream length) are present, but boulders are notably lacking (Table 8-11). Boulders are scarce, and those that were probably present in the past have either been removed or have moved downstream during high flows.

Table 8-14
Complex Pools in Fanno Creek

Reach	Complex Pools		Substrate % Boulders
	# Complex Pools	# Complex Pools / 1000 m	
Fanno 1	1.0	0.6	4
Fanno 2	3.0	3.8	3
Fanno 3 and 4	4.0	4.3	4
Fanno 5	3.0	4.4	0
Fanno 6	3.0	1.6	4

Tributaries to Fanno Creek

The following evaluation of habitat condition assumes that fish will access and use these habitats sometime in the future. Detailed habitat surveys have not been conducted in Red Rock Creek, Pendleton Creek, Columbia Creek, Patton Creek, and Ivey Creek. Some anecdotal information is available and is noted where appropriate.

Table 8-15
Channel Form in Upper Fanno Tributaries

Reach	Width to Depth Ratio	Channel Shape	Pool to Riffle Ratio
South Ash Creek	9.7	NA	0.67
North Ash Creek	5.4	NA	1.30
Lower and Middle Woods Creek	7.4	NA	1.42
Upper Woods Creek	6.5	NA	0.80
Lower Vermont Creek	5.3	NA	1.51
Upper Vermont Creek	7.6	NA	0.79

NA = Not Available

STREAM BANK CONDITION

As shown in Table 8-16, stream banks are at risk in Woods Creek, and are not properly functioning in both Ash and Vermont Creek.

Ash Creek

Stream banks along Ash Creek are moderately eroded at 26 and 31 percent in South and North Ash Creek respectively and banks are vegetated at approximately 80 and 84 percent. Existence of shrubs, grasses and forbs along the stream bank suggest that disruptive pressures, such as high stream flows) are not effecting community vigor; however, based on evidence of bank erosion, stream bank protection is not functioning properly in Ash Creek.

Woods Creek

Of these three tributary systems, Woods Creek has the most stable creek habitat, based upon evidence of stream bank erosion and vegetative composition. Banks have comparatively low bank erosion (18 to 20 percent) and high vegetative cover (96 and 86 percent) indicating that disruptive pressures do not preclude colonization of vegetative species. Although vegetative banks exist, bank erosion remains moderately high suggesting that stream bank protection is at-risk.

Vermont Creek

Banks are 72 percent and 92 percent actively eroding in lower and upper Vermont Creek, respectively, and undercut banks are rare throughout. As noted previously, stream gradient is high in upper Vermont Creek, which probably exacerbates erosion during high storm flows. In addition, vegetative cover is marginally low. Absence of grasses and forbs suggest that erosive pressures preclude stream bank vegetation from establishing and that stream banks are not properly protected.

Table 8-16
Bank Condition in Upper Fanno Tributaries

Reach	% Actively Eroding	% Undercut Bank	% Shrub Cover	% Grass and Forb Cover	% Combined Vegetative Cover
South Ash Creek	31	8	37	47	84
North Ash Creek	26	1	36	44	80
Lower and Middle Woods Creek	18	3	37	59	96
Upper Woods Creek	20	1	23	63	86
Lower Vermont Creek	72	8	34	34	68
Upper Vermont Creek	94	2	41	19	60

1/ Zone 1: 0-10-m

SUBSTRATE

Substrate composition and embeddedness vary throughout the different tributary reaches. The following are key summations, as shown in Table 8-17:

Ash Creek

- The best substrate composition exists in South Ash Creek. Here gravels and cobbles dominate and embeddedness is relatively low (at 13%). The result is that this area of creek likely provides some of the best habitat relative to other upper Fanno subbasin tributary reaches.
- North Ash Creek likewise has good gravel and cobble composition, yet embeddedness is high at 36% yielding habitat that is not properly functioning. Based on the presence of gravels and cobbles and there dominance (e.g., 50% combined), it appears that alluvial processes are occurring such that larger sized substratum is moving into the system; however, sediment inputs are high, limiting the functional capacity of these substrates.

Woods Creek

- Lower and Middle Woods Creek are severely impaired with fine sediment and organic loading at 68%. In addition, recruitment of gravels and cobbles are low.
- Substrate composition is notably better in Upper Woods Creek. For example, gravels and cobbles exist (at 49% total stream bed composition) yielding "at risk" condition, but notably better than Lower and Middle Woods Creek. Sediment composition is marginally high (at 24%) in this reach.
- As described above, banks are relatively well protected, albeit at-risk, suggesting that sediments may be coming in from point source locations, rather than from erodible stream banks.

Vermont Creek

- Substrate composition in Vermont Creek is very poor. Fine sediment and organics dominate, followed by sand; and gravels and cobbles make-up less than 20 percent of the substratum in both Lower and Upper Vermont Creek.
- System-wide, gravels and cobbles are lacking, however, Upper Vermont Creek has high riffle area. Gravels are present in these habitats, although at marginal levels, and high proportions of fine silt, sand and organics overlay the riffle habitats, suggesting that gravels are embedded.
- Source sediment loading is likely coming from unstable, erosive banks. As described above in Channel Form; stream banks in Lower and Upper Vermont Creek are unstable, are highly eroded and lack stream bank vegetation.
- Based upon the low proportions of key riffle-type substrates and preponderance of fine silt, sand and organics (68 to 73 percent in Lower and Upper Vermont respectively), recruitment of bed load materials and balance of sediment input and transport are not properly functioning.

Table 8-17
Substrate Composition in Upper Fanno Tributaries

Reach	% Fines	% Sand	% Gravel	% Cobble	% Boulder	% Bedrock
South Ash Creek	13	13	25	25	18	0
North Ash Creek	36	9	35	15	4	0
Lower and Middle Woods Creek	68	15	10	5	1	0
Upper Woods Creek	24	18	32	17	8	1
Lower Vermont Creek	50	18	18	12	2	0
Upper Vermont Creek	56	17	14	11	2	0

HABITAT DIVERSITY

Wood is severely lacking in all tributary reaches with the exception of upper Vermont Creek, which has moderate wood counts (Table 8-18). Although source woody material will likely exist in the future in both Woods and Vermont Creek, the absence of wood in stream today severely impairs habitat diversity and habitat function in these creeks. As noted above, in Refugia, other types of in stream cover and structure are lacking in all upper subbasin tributaries. A more immediate source of wood is needed in the short and mid-term in order to provide functional habitat structure and protective cover to resident fish.

Ash Creek

- Both South Ash Creek and North Ash Creek lack large wood pieces and substantive wood volume.
- Riparian tree species in Ash creek are predominately second growth mixed conifer and deciduous species that will continue to grow and provide source woody material in the long-term future.

Woods Creek

- Upper Woods Creek, which is located in Woods Memorial Park, has some in stream, however wood volume is low and large, key pieces are rare.
- Based on riparian condition, specifically the dominance of conifers and deciduous trees (within the immediate 10-m) and size of riparian trees (> 30-cm dbh), adequate sources of future woody material exists, particularly in upper Woods Creek, where trees average 50 to 100-cm dbh.

Vermont Creek

- Some wood exists in upper Vermont Creek, however, wood volume is low and large key pieces are lacking.
- As with Upper Woods Creek, the presence of larger sized (30-50-cm dbh) conifers and deciduous trees along the stream corridor suggest that source woody material exists for future recruitment.

Table 8-18
Large Wood in Upper Fanno Tributaries

Reach	# Pieces Per 100 m	Volume (m3) Per 100 m	# Key Pieces Per 100 m^3
South Ash Creek	2.8	2.1	0.0
North Ash Creek	3.2	2.3	0.0
Lower and Middle Woods Creek	3.3	1.7	0.0
Upper Woods Creek	4.3	4.7	0.1
Lower Vermont Creek	4.7	1.9	0.0
Upper Vermont Creek	16.3	7.0	0.0

KEY HABITAT

For the purpose of this evaluation riffle habitat and pool habitat was assessed. Other key habitats, such as off-channel pools, secondary channels and seasonal (or floodplain) wetlands were previously evaluated in Refugia. Generally, fish bearing habitats (e.g., pools and riffles) are adequately represented throughout all upper Fanno subbasin tributaries (Table 8-15). Each tributary has both pool and riffle habitat present that are consistent with healthy stream functions (e.g., width to depth ratios range from sub-optimal to optimal in tributary reaches surveyed). Notably, North Ash Creek, Upper Woods Creek and Lower Vermont Creek comparatively have the best functioning creek habitat, respective of pool and riffle habitats.

Riffle Area and Quality

As shown in Table 8-19, riffle area is relatively high in South Ash Creek, North Ash Creek, Upper Woods Creek, and Upper Vermont Creek, but severely lacking in lower and middle Woods Creek and lower Vermont Creek with 3% and 7% riffle area respectively. In addition, riffle area that exists has low gravel composition and is embedded with fines; hence, if fish could access these two areas, the lack of riffle habitat and poor riffle quality would probably limit potential fish productivity.

Ash Creek, Upper Woods and Upper Vermont Creek have adequate riffle area. The following are key notables:

South Ash Creek

Riffle area is high (51 percent), gravels and cobbles (51 percent) predominate and embeddedness is low (9 percent). System-wide sediments are likewise low (averaging 12 percent); hence, it appears that most are settling-out into pool environs, such that they do not functionally limit habitat function in this reach. Notably, South Ash Creek provides some of the best riffle habitat of all surveyed upper Fanno subbasin tributary reaches.

Upper Woods Creek

Riffle area is high and gravels predominate, while percent fine sediment is low, yielding good quality riffle habitat. Like South Ash Creek, Upper Woods Creek provides some of the best riffle habitat of other surveyed tributaries.

North Ash Creek

Riffle area is present at 37 percent, and gravels and cobbles predominate (59 percent combined). However, riffle quality is compromised with relatively high proportions of fines (17 percent) overlaying riffle habitat. As described previously in the Substrate section, it appears that alluvial processes are occurring, such that gravels and cobbles are coming into the creek, however, fine sediment inputs exceed sediment transport and levels leaving the system, hence, riffle quality is impaired.

Upper Vermont Creek

Riffle area is high (43 percent), gravels and cobbles are represented, but percent fines overlaying riffle habitat is very high at 42 percent. These high silt loads are seen throughout Upper Vermont Creek and significantly limits potential fish productivity in this upper headwater reach.

Table 8-19
Riffle Area and Substrate Composition

Reach	% Riffle Area	% Gravel	% Cobble	% Fines
South Ash Creek	51	30	21	9
North Ash Creek	37	50	9	17
Lower and Middle Woods Creek	3	20	20	50
Upper Woods Creek	42	46	14	11
Lower Vermont Creek	7	27	20	29
Upper Vermont Creek	43	20	19	42

Pool Area and Quality

The amount of pool habitat (pool area) varies significantly from subbasin to subbasin. As shown in Table 8-20, pool area is highest near confluence reaches (with Fanno Creek). In addition, all pools show signs of deposition beyond what is considered natural stream functioning; 20 - 50 percent deposited fines signify deposition (Barbour 1999). Amassed sediments likely reduce pool volume and minimize potential pool depth. As shown in Table 8-21, pools are only moderately deep, and average channel depth is relatively shallow. Complex pools with wood are found in all tributary reaches, particularly in South Ash Creek and Vermont Creek (Table 8-22).

Ash Creek

Pool area is low in both South Ash Creek and North Ash Creek, with 16 percent and 14 percent respectively, only half what is considered desirable for fish bearing habitat. Pools are heavily silted-in, in North Ash Creek with 66 percent fines, and only 19 percent and 9 percent gravel and sand, respectively.

South Ash Creek and North Ash Creek probably provide the best depth refugia of other surveyed tributaries, with pool depths more than twice the prevailing channel depth. South Ash Creek likewise has complex pools (with large wood) and is the only reach surveyed with substantive boulder cover.

Woods Creek

Lower and Middle Woods Creek has a very high proportion of pool habitat (93 percent), however 84% of this pool habitat is found in a dammed pool and a backwater pool at Portland Golf Club. These pools are depositional areas for sediment and organics, which comprise 80 to 100 percent of the creek bottom. Amassed sediments reduce the pool volume, and potential pool depth, yielding pools that are only marginally deeper (about one-half) than the prevailing channel depth. Pools are notably lacking wood and boulder cover. The result is that pool habitats are not properly functioning.

Upper Woods Creek also has a beaver pond, which makes-up about a third of the total pool habitat in the upper headwater reach. Remaining pool habitat provides important depth refugia, with pool depths more than twice the prevailing channel depth. However, large wood pieces are lacking, yielding poor quality pool habitat.

Vermont Creek

Lower Vermont Creek has a relatively high proportion of pool habitat (87 percent), although 33% of this habitat is in a dammed beaver pond, leaving approximately 54% pool area. Substrate composition in this remaining pool habitat is predominately filled with fine sediment, which comprises approximately 60 percent pool bottom substrate. This high proportion of silt, significantly reduces pool volume and subsequent pool depth in this reach. The result is that pool habitat is not functioning properly. Notably, of all upper Fanno subbasin tributary reaches surveyed, Lower Vermont Creek provides the deepest pools; however, relative to the prevailing creek depth (0.26 meters), these environs do not likely provide more substantive cover than is found in other habitats. Although wood is notably lacking system-wide throughout other habitats, large key pieces exist in pools, providing important cover and channel complexity.

Pool area in Upper Vermont Creek is notably low (17 percent wetted area) and is heavily filled-in, with 79 percent silt atop the creek bottom. The relative pool depth in Upper Vermont Creek is substantively higher than the prevailing channel depth, indicating that pools likely provide depth refugia. In addition to depth refugia, large wood pieces are present providing important cover and channel stability.

Table 8-20
Pool Area and Substrate Composition in Upper Fanno Tributaries

Reach	% Pool Area	% Gravel	% Sand	% Fines
South Ash Creek	16	23	21	29
North Ash Creek	14 [6]	19	9	66
Lower and Middle Woods Creek	93 [3]	0	0 -20 [4]	80 - 100 [4]
Upper Woods Creek	26 [7]	20	25 [5]	49 [5]
Lower Vermont Creek	87 [1]	15 [2]	20 [2]	58 [2]
Upper Vermont Creek	17	6	13	79

[1] 33% of 87% pool area includes a beaver pond/pool complex

[2] Substrate does not include beaver ponds, which are dominated by silt and organics (86%)

[3] 84% of 93% pool area includes a dammed and backwater pool habitat at Portland Golf Club

[4] Substrate proportions vary with dammed pool type; ranges are given

[5] Substrate represents lateral scour pools (~ 15% of 26% total pool area)

[6] Glides constitute 10% of wetted area; substrate composition averages 36% gravel, 14% sand, and 45% silt and organics

[7] 8% of 26% pool area includes dammed beaver pond

Table 8-21
Pool Depth in Upper Fanno Tributaries

Reach	Average Residual Pool Depth (m)	Average Channel Depth (m)	Relative Pool Depth (%)
South Ash Creek	0.36	0.15	140
North Ash Creek	0.28	0.10	180
Lower and Middle Woods Creek	0.38	0.26	46
Upper Woods Creek	0.36	0.15	140
Lower Vermont Creek	0.41	0.29	41
Upper Vermont Creek	0.22	0.10	120

Table 8-22
Pool Complexity in Upper Fanno Tributaries

Reach	Complex Pools [1]		Substrate
	# Complex Pools	# Complex Pools/1000 m	% Boulders
South Ash Creek	4.0	2.2	9
North Ash Creek	1.0	1.4	1

Lower and Middle Woods Creek	5.0	1.6	1
Upper Woods Creek	3.0	1.5	1 [1]
Lower Vermont Creek	9.0	3.4	1
Upper Vermont Creek	5.0	4.4	0

[1] **10**% boulder composition was noted in one plunge pool in upper Woods Creek

VEGETATION AND WILDLIFE

BES and Brown and Caldwell (1998, p. 25) describes plant and wildlife communities as follows:

> In the remaining forested areas of the Fanno Creek watershed, the most common native conifer species are western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and Douglas fir (*Pseudotsuga menziesii*). Red alder (*Alnus rubra*), bigleaf maple (*Acer macrophyllum*), and Oregon ash (*Fraxinus latifolia*) are the most common deciduous trees. Native shrubs include vine maple (*Acer circinatum*), Indian plum (*Oemleria cerasiformes*), and salmonberry (*Rubus spectabilis*). Sword fern (*Polystichum munitum*) and lady fern (*Athyrium filix-femina*) are common along each of the streams. In addition to these native species, numerous ornamental trees, shrubs, and groundcovers have been introduced to the watershed. Some of these, such as Himalayan blackberry (*Rubus discolor*) and English ivy (*Helix hedera*), are invasive and have crowded out native plants in many areas.
>
> The wildlife species most commonly observed in the Fanno Creek watershed are those that can tolerate a wide variety of habitats and the disturbance usually associated with residential and commercial development. Based on the geographic location of the watershed, amphibians that may be present include the northwestern salamander (*Ambystoma gracile*), long-toed salamander (*A. macrodactylum*), ensatina (*Ensatina eschscholtzii*), Pacific chorus frog (*Hyla regilla*), and others. Garter snakes (*Thamnophis* species) are common. At least 100 bird species are thought to use the Fanno Creek watershed. Black-capped chickadees (*Parus atricapillus*), American robins (*Turdus migratorius*), song sparrows (*Melospiza melodia*), Steller's jays (*Cyanocitta stelleri*), American crows (*Corvus brachyrhynchos*), and northern flickers (*Colaptes auratus*) are commonly seen. Great blue herons (*Ardea herodias*) and mallards (*Anas platyrhynchos*) are observed occasionally. Mammals typical of the Fanno Creek watershed include raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), skunks (*Mephitis mephitis*), muskrats (*Ondatra zibethicus*), and fox squirrels (*Sciurus niger*). Several species of mice, shrews, moles, and voles are also likely to occur.
>
> Palustrine forests and scrub-shrub wetlands are thought to provide breeding and/or foraging habitat for over 200 wildlife species (Brown et al., 1975). Herbaceous wetlands are expected to provide breeding habitat for approximately 70 species and foraging for 178 wildlife species.

Other wildlife observed in tributaries to Fanno Creek include peregrine falcon, beaver, nutria, and wood ducks (Vermont Creek); pileated woodpeckers (Ash Creek and Woods Creek); and red tail hawk (Ash Creek) (ODFW 2001; BOP 2001). Coyotes have been reported in Gabriel Park (Upper Vermont Creek), and deer have been sighted in Woods Creek (BOP 2001).

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CHAPTER 9

Biological Communities: Fanno Creek Watershed

This chapter characterizes habitat and biological communities in the Fanno Creek Watershed. It includes:

- Biological Communities by Reach (Target Species)
- Biological Communities Summary

FOCAL SPECIES AND POPULATION DESCRIPTION

Salmon are a useful indicator of environmental condition for three reasons: first, legal and social requirements for salmon recovery in the lower Willamette and lower Columbia rivers result in obligations for the city; second, although uncertainties exist, scientific knowledge of the environmental requirements for salmon far exceeds that of most other aquatic species (for example, many federal and state water and environmental quality guidelines are based on the biological requirements of salmon and trout); third, current scientific literature suggests that environmental conditions that support native fish also provide a favorable environment for other native aquatic and terrestrial wildlife and for improved water quality. In addition, salmon have complex life histories that involve resident and anadromous traits. Populations respond to changes in watershed condition, for example, hydrology, habitat, water quality and other biological communities. ***For these reasons, we use cutthroat trout as a focal species, or biological indicator of watershed health in Upper Fanno Creek.*** Cutthroat trout have complex life histories that involve residency and migratory behavior, and their development and maturation is dependent upon the freshwater habitats in which they live.

ANALYTICAL APPROACH

Ecosystem Diagnosis and Treatment (EDT) was used to relate environmental conditions in Fanno Creek to cutthroat performance. EDT is a computer model that evaluates fish population performance (reference and current) based on principle watershed processes: hydrology, habitat and water quality. It is unique in that it links fish productivity to on-the-ground watershed characteristics. For example, the model integrates water quality data, ODFW Aquatic Inventory data, and hydrologic data and equates that information to specific life stage development, and can assess what factors are most limiting to growth and survival. EDT has been used extensively throughout the Willamette and Columbia River regions to assess habitat and its affect on salmon productivity (McConnaha 2003), and thus provides a common tool from which to evaluate fish productivity in different geographic regions.

As with living fish, EDT incorporates life history diversity (via life history hypothesis) of cutthroat to effectively evaluate potential population productivity respective to habitat condition. The life history hypothesis describes multiple age classes and includes the potential for both the resident and migrant life histories to occur in Fanno Creek. Refer to Appendix I for additional details regarding the life history hypothesis for Fanno Creek cutthroat.

Four population parameters were evaluated to fully assess biological performance for cutthroat trout: 1) Biological capacity (quantity of habitat); 2) Biological productivity (quality of habitat); 3) Equilibrium abundance (quantity and quality of habitat); and 4) Life history diversity (breadth of suitable habitat). Capacity and productivity are parameters of a Beverton-Holt production function; and abundance is calculated from this relationship. Life history diversity is represented as a Diversity Index that is the percentage of viable life history trajectories or strategies: spawning, rearing and migration. These population parameters were evaluated to assess (a) species population potential, (b) limiting factors, and (c) protection and restoration value.

> **(A) Population Potential** describes habitat potential respective to steelhead and coho (refer to Section 4.0).
>
> **(b) Limiting Factors** describe the effect that individual environmental attributes have on potential fish population abundance, productivity and diversity. The results are summarized in "dot diagrams" in which the size of a dot is proportional to the change in productivity because of setting the EDT attribute to its restored value (Refer to Section 5.0).
>
> **(c) Protection and Restoration Value and Priorities**. Spatial differences between geographic areas within Tryon Creek were summarized as the Protection and Restoration value of each geographic area for steelhead and coho. Protection priority is defined as the percent change in an environmental attribute when the current values for all attributes in a geographic area are set to a highly degraded condition. Restoration priority is the percent change in an environmental attribute when the current values for all attributes in a geographic area are set to a restored condition (refer to Section 6.0).

Reach structure and geographic areas

Upper Fanno Creek describes the upper 4.1 miles of mainstem habitat, and seven prominent tributaries: Woods, Vermont, Sylvan, Pendleton, Columbia, Hamilton, and Ivy creeks. Collectively these areas comprise Upper Fanno Creek. Mainstem reaches were further broken into seven mainstem reaches. Stream reaches are the same as those previously identified by the Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventory Project. Stream reaches are defined by functional characteristics of the creek channel, such as tributary confluences, changes in valley form and channel form, major changes in vegetation and / or changes in land-use ownership (Moore et.al 1997). In addition to these landscape attributes, unique channel forms such as culverts and fish barriers were identified in order to rate each respective to its impact on fish productivity. The analysis also included three additional (unnamed) headwater tributaries. Following is a brief summary of each respective stream reach.

(a) Upper Fanno Creek (mainstem)

FANNO 1: OLESON ROAD (RM 10.7 – RM 12.14)

This reach begins at the confluence of Vermont Creek and extends upstream to the Beaverton-Hillsdale Shopping Center. The reach parallels SW Oleson Road for much of its length and is the lowest reach evaluated by ODFW (lower half of ODFW Reach 1). A substantial portion of the stream corridor is in commercial use. Two tributaries enter this reach: Pendleton Creek and Sylvan Creek. Pendleton Creek enters near the radio tower/sewage treatment plant site. Sylvan Creek enters at the upper end through a buried culvert near the junction of SW Beaverton-Hillsdale Highway and Scholls Ferry Road. This piped stretch comprises approximately 800 feet of creek channel.

FANNO 2: 59TH AVENUE (RM 12.14 – RM 12.46)

This reach begins at the SW Beaverton-Hillsdale/Scholls Ferry Road interchange and ends at the confluence of Columbia Creek (below SW 59th Avenue). The reach is approximately 0.3 miles long and drains portions of Multnomah County and Portland in the Green Hills area. This reach is prominently culverted under the Beaverton-Hillsdale Shopping Center.

FANNO 3: SHATTUCK ROAD (RM 12.46 – RM 12.88)

This reach begins at the confluence of Columbia Creek and extends upstream to Patton Creek, which enters Fanno Creek just above SW Shattuck Road. This reach is approximately 0.42 miles in length. Land use is medium to high density residential and commercial. Patton Creek drains the portions of the Southwest Hills and Bridlemile area in Portland and Multnomah County.

FANNO 4: 45TH AVENUE (RM 12.89 – RM 13.39)

This reach begins at the confluence of Patton Creek and ends at Ivey Creek, just upstream of SW 45th Avenue. This reach is approximately 0.55 mile in length. Land use is mixed residential, utilities, and commercial; several privately owned undeveloped lots bound the creek.

FANNO 5: 39TH DRIVE (RM 13.39 - RM 13.71)

This reach begins at the confluence of Ivey Creek and ends immediately above Kelly Creek, at SW 39th Drive. Reach length is short: 0.32 mile. Land use is predominantly low- and medium-density residential. There are several large undeveloped parcels and two undeveloped street rights-of-way (SW 43rd Avenue and SW 42nd Avenue). Kelly Creek drains the Kelly Park area. A flow gage is located at SW 56th Avenue.

FANNO 6: 30TH AVENUE (RM 13.71 – RM 14.39)

This reach begins at SW 39th Drive and ends at SW 30th Avenue. The reach is approximately 0.68 miles in length. High-density residential development (apartments), roads, and SW Beaverton-Hillsdale Highway dominate the landscape. However, the majority of parcels that constitute the riparian zone are undeveloped and in private ownership.

FANNO 7: HEADWATERS (RM 14.39 – RM 14.66)

This reach begins at SW 30th Avenue and extends upstream through the Beaverton-Hillsdale Shopping Center. Headwater creeks enter Fanno Creek mainstem near the downstream portion of this reach. ODFW and Clean Water Services (CWS) identified the southeast channel (at the upper end of this reach) as a tributary to Fanno Creek and identified the northern reach originating from Gray Middle School as mainstem Fanno

Creek. This interpretation is counter to previous surveys conducted by BES, which refer to the southeast tributary as mainstem Fanno Creek (and headwaters). The BES convention is used in this characterization to remain consistent with past survey efforts and references. Because ODFW and CWS did not survey the southeast channel as part of mainstem Fanno Creek, few data are available to characterize habitat elements in that portion of the reach. Medium-density residential use and SW Beaverton-Hillsdale Highway dominate land use in reach 12, with commercial use in the uppermost reaches at the shopping center.

(b) Upper Fanno Tributaries

WOODS CREEK

Woods Creek runs through Beaverton and Portland; approximately 60 percent of it (middle and upper Woods Creek) is within incorporated Portland. Because ODFW surveys document conditions throughout all of Woods Creek, this characterization evaluates the entire creek. Land use is generally low-density residential, with some commercial development, particularly along Multnomah Boulevard.

- Lower and Middle Woods Creek - Lower Woods Creek begins at the confluence of Woods Creek and Fanno Creek, within City of Portland jurisdiction. The city boundary, which coincides with middle Woods Creek, begins at Oleson Road and extends upstream to approximately 500 feet below SW Multnomah Boulevard. The stream segment is approximately 5,500 feet long. BES and Brown and Caldwell (1998) conducted surveys along this reach in 1997; CWS (2000) conducted surveys in 2000; and ODFW (2001) conducted surveys in 2001. A water quality monitoring station is located at Oleson Road.

- Headwaters of Woods Creek - Upper Woods Creek flows through Woods Creek Memorial Park and then through areas of residential development in its lower reaches. This reach begins approximately 500 feet below SW Multnomah Boulevard, extends upstream into Woods Creek headwaters (Woods Memorial Park), and ends at SW Taylors Ferry Road. The reach is approximately 6,350 feet long. South Fork Woods Creek runs along SW 45th Avenue near the entrance of Woods Memorial Park, and mainstem Woods Creek originates just above SW Capitol Highway, near I-5.

VERMONT CREEK

The Vermont Creek subbasin is heavily developed with low-density residential and commercial land uses. Upper Vermont Creek begins in a residential area upstream of Gabriel Park and continues through residential developments to its confluence with Fanno Creek. This characterization includes approximately 85 percent of the subbasin.

- Lower Vermont - This reach extends from the confluence of Vermont Creek and Fanno Creek (and Bauman Park) upstream to a SW 52nd.

- Upper Vermont - This reach begins at a tributary approximately 900 feet downstream of SW 52nd and extends upstream to the headwaters of Vermont

Creek that drain Gabriel Park. The mainstem is 3,620 feet long and originates upstream of Gabriel Park, along SW Caldwell Street near SW 36th Avenue. The north fork originates near SW Vermont Street and SW 37th Avenue. The south fork originates near the Garden Home/Multnomah Boulevard intersection and enters mainstem Vermont Creek approximately 100 feet below SW 45th Avenue. Few data are available to evaluate the south fork, which is the longest reach of the three-headwater creeks and is believed to provide perennial flow during the summer.

PENDLETON CREEK

Pendleton Creek passes through residential developments with some open space and then through a commercial area near its confluence with Fanno Creek. It joins Fanno Creek immediately downstream of the Multnomah County boundary (just below the Beaverton-Hillsdale Shopping Center) and extends upstream to above SW Fairvale Court, near SW 48th Avenue. The tributary is approximately one mile long. The subwatershed drains approximately 240 acres. Land use is primarily low-density residential. Data are limited for Pendleton Creek. Neither ODFW (2001) nor CWS (2000) included Pendleton Creek in their surveys. The 1997 BES and Brown and Caldwell resource inventory evaluates six short segments of the creek. Habitat assessments are therefore based largely on anecdotal field observations, aerial photographs, and topographic map evaluations.

COLUMBIA CREEK

Columbia Creek flows into mainstem Fanno Creek near SW 59th Avenue (Fanno 2). The creek is spring fed and originates in the Sylvan Hills.

IVEY CREEK

Ivey Creek flows into Fanno Creek just upstream of SW 45th Avenue (Fanno 4/Fanno 5) and drains the Bridlemile neighborhood.

Information Sources

Habitat condition is based on historic and current knowledge of hydrology, physical habitat, water quality and biological communities – this information is characterized in other chapters of the document. The content of the watershed characterization was vetted through the City of Portland’s Tryon and Fanno Creek Watershed Advisory Team, which includes members from Clean Water Services, neighborhood associations, Oregon State Parks, and other City bureaus. Environmental information was queried from numerous sources including recent habitat surveys, environmental surveys, EDT and hydrologic and hydraulic models.

Fish communities were evaluated based on the results of a fish study conducted by ODFW from 1999 through 2001 (ODFW 2001) and on past surveys and sightings. ODFW surveys included extensive (spring, summer, and fall) and intensive (summer) stream surveys. Surveys were not conducted in the winter because of high flow conditions, and consideration for the health and safety of the field sampling crew. Key data collected by ODFW included fish presence / absence, fish length, weight and condition factor. The IBI was calculated for each stream reach. A summary of these study findings is documented in Appendix J. In addition to ODFW surveys, the ODFW fish distribution maps (http://rainbow.dfw.state.or.us/nrimp/information/fishdistmaps.htm), the Harza Study (1994) and

City of Portland fish surveys were evaluated to characterize current fish communities in Upper Fanno Creek.

Scenario development

Two scenarios were evaluated to describe potential cutthroat productivity in Upper Fanno Creek: reference and current condition. The reference condition was constructed from historical maps and by reference to habitat benchmarks for western Washington/Oregon streams (Peterson et al. 1992). Cutthroat performance under the reference condition represents the intrinsic potential of the stream. The current condition is based on empirical data.

ESTIMATED CUTTHROAT POPULATION POTENTIAL

Estimating cutthroat population potential is done by comparing the estimated current abundance, productivity and life history diversity potential to similar reference potential, based upon habitat condition and function. Indices of habitat potential (and its influence on fish abundance) do not represent actual fish abundance, productivity or diversity as measured or observed in Fanno Creek. Actual abundance, productivity or diversity is not known, but presumably varies from year to year due to factors within and outside the subbasin (e.g., changing ocean conditions). These measures were compared to the estimates under the reference condition to provide an overall measure of the impact of urbanization on Fanno Creek.

The following is a brief summary of findings detailed in the Assessment of Habitat Potential in the Urban Streams and Rivers of Portland, Oregon – Analysis of Cutthroat Trout Habitat Potential and Limiting Factors for Fanno Creek. The full report can be found in the Appendix I.

The equilibrium abundance of cutthroat trout in Upper Fanno Creek under current habitat conditions was estimated to be around 390 adults (Table 3). This represents about an 85 percent reduction in cutthroat trout potential relative to the reference condition. Current productivity of cutthroat in upper Fanno was estimated to be 2.4, which is a 75 percent reduction from the historic level. The life history diversity of cutthroat is 14 percent of that estimated in the historic condition. This indicates a considerable narrowing, both spatially and temporally, of the "window of opportunity" within which suitable conditions exist in Fanno Creek for cutthroat trout. These changes reflect the effects of habitat change resulting from urbanization and land use change in the Fanno Creek Watershed.

Table 1

Estimated potential of habitat in the Upper Fanno Creek Watershed to support adult, spawning cutthroat trout.

Population	Scenario	Diversity index	Productivity	Adult Capacity	Adult Abundance
Upper Fanno Cutthroat	Current potential	14%	2.4	671	393
	Reference potential	100%	10.1	2,797	2,519

LIMITING FACTORS ANALYSIS

The following results describe the suite of environmental attributes limiting potential cutthroat population productivity in each geographic area, relative to spawning and rearing. Environmental attributes were evaluated by substituting the reference condition for the current condition one attribute at a time and examining the model response (or change in population performance).

Limiting factors in Upper Fanno Creek are presented below. Similar reach level results are provided in the Assessment of Habitat Potential in the Urban Streams and Rivers of Portland, Oregon – Analysis of Cutthroat Trout Habitat Potential and Limiting Factors for Fanno Creek (Appendix I). The geographic area scale provides a strategic examination of habitat limitations across the entire Upper Fanno Creek subbasin, while the reach scale focuses on specific locations of habitat limitations.

Habitat Constraints in Upper Fanno Creek

Major factors contributing to the decline of cutthroat production in Upper Fanno Creek include changes to hydrology (stream flows), riparian and floodplain condition, water quality (high sediment loading, stream temperature, and pollution), fish passage obstructions, low habitat complexity and lack of key habitats. These environmental attributes are further described below:

Hydrology – Stream Flow

Basinwide, hydrologic regimes do not represent historic flow cycles and volumes. Altered hydrologic regimes are prevalent throughout Upper Fanno Creek Basin. The area is about 85% built out and impervious surfaces cover over 33% of the watershed contributing to high stormwater runoff. In addition, the landscape is highly fragmented by residential and commercial land uses and transportation corridors, particularly along and south of Beaverton-Hillsdale Highway. The result is that normal hydrologic processes such as transpiration (from vegetation), evaporation and infiltration are out-of-balance, such that surface runoff is more prominent than would naturally occur with minimal impervious area, yielding high stream velocity and more frequent peak flows and low base flows in the winter, and high peak flows and low base flows in the summer.

“Flow, both summer low flow as well as stream “flashiness”, was a limiting factor especially in the tributaries. Hydrologic modeling indicated that Upper Fanno Creek peak flows have increased approximately 210 percent from predevelopment and the discharge has increased

from ~55 cubic feet per second per square mile of drainage area (cfs/mi^2*) to ~117 cfs/mi*^{2} *(MGS Engineering 2001)" (Mobrand-Jones and Stokes, 2005).*

The effects of these altered flow regimes are evident throughout the Upper Fanno Watershed; sediment deposition is high, stream banks are eroded, large wood retention is low, and the channel is incised and trapezoidal in shape. The combination of these effects have disconnected the creek from the riparian and floodplain area and resulted in a lowered groundwater table (Ponce and Lindquist, 1990).

Riparian and Floodplain Condition

Based on an assessment of vegetative species composition, forest age, riparian width, canopy cover, riparian fragmentation and presence of wetland and hyporheic areas, riparian reserves throughout Upper Fanno Creek watershed are not properly functioning. Riparian areas are fragmented and poorly connected to the channel to the extent that they do not substantively protect aquatic habitats or provide shade cover, protective cover, or refugia. In addition, although some areas with more mature trees exist, conifer species are notably lacking. Where present, they are young and do not presently provide substantive ecological benefit. Finally, the riparian reserve does not adequately provide a source of large woody material.

Nearly all tributaries provide more tree canopy cover, a wider riparian corridor, more representative native species composition (mixed conifer/deciduous), and larger established trees than Upper Fanno Creek. For example, Woods Creek and Vermont Creek have larger, well-established conifers and hardwood trees, while Ash Creek resembles mainstem Fanno Creek, with medium-sized conifers and hardwoods.

Basinwide, urban development has resulted in the conversion of mixed conifer and deciduous trees to landscapes dominated by second-growth deciduous trees, shrubs, and grasses. Parking lots, streets, lawns, homes, and buildings are prominent land features such that floodplains have been hardened and filled. In addition, high terraces, roadways, and urban development abut the creek channel.

Increased (and flashy) stream flow caused by elevated surface runoff and degradation of riparian and streambank vegetation has caused streams to adjust by channel incision. Consequently, stream banks are steep, unstable, actively eroding, and hydrologically disconnected from adjacent riparian and floodplain habitats.

Riparian and floodplain habitats that are connected to its river channel will help attenuate stream flows and decrease peak flows, store water, recharge the groundwater and subsequently maintain base flow during the summer. In addition to helping maintain normative hydrologic processes, floodplains and wetlands filter sediments, supply organic matter (including large wood) and bed-form substrates to the channel, and help moderate stream temperatures (via subsurface and hyporheic flows). The use of wetlands to mitigate downstream flooding has been recommended as a strategy for the larger Willamette Basin in An Evaluation of Flood Management Benefits through Floodplain Restoration on the Willamette River, Oregon (Williams and Associates, Lmtd, 1996). Floodplain and wetland environs also provide important habitat to aquatic and terrestrial wildlife. Floodplain wetlands (or seasonal wetlands), oxbows, and secondary channels, provide important high flow refugia and overwintering habitat to native fish communities, particularly salmonids. Native fish likewise use off-channel habitats as refuge from adverse instream conditions, such as high flow velocity, large volumes of suspended solids, or large concentrations of pollutants. The adjacent riparian area helps maintain these hydrologic connections and provides unique aquatic – terrestrial interactions. For example, riparian areas are essential for providing shade to the stream, source woody material (and leaf matter), protective cover (overhanging vegetation), stream bank stabilization, and capturing and filtering sediments. Providing opportunities for flood flows to top the bank and inundate the riparian area and broader floodplain area are necessary to maintain aquatic – land interactions.

Fine Sediment

BES watershed analysis (Grid Model) indicates that commercial, multifamily and transportation land uses are significant sources of stormwater loading into Upper Fanno Creek. Infrequent street sweeping, along with less effective facility maintenance practices allow sediments to build-up. The consequence is significant contributions of sediment loading. Higher velocity stream flows further erode unprotected streambanks, adding more settleable and suspended solids into the stream channel.

Excess (greater than 20 percent) sand and silt (less than 6.4 mm) in gravel can reduce both survival and emergence of fry. Amassed (or deposited) fine sediment and extreme silt loads (greater than 25 mg/L) (Bell 1973) can clog fish gills, affecting a fish’s ability to “breath” (or absorb oxygen). Additionally, fine sediment effectively plug the much needed interstitial spaces found in the channel substrates. These micro habitats are used by aquatic invertebrates (the primary food organisms of salmonids) and provide cover to fish through the winter. Indirect effects that fish may experience include reduced feeding, avoidance reactions and delayed (or ceased) migrations (if a silt curtain persists).

In Upper Fanno Creek settleable sediments disproportionately fill scoured pool areas, effectively covering other steam bottom substrates, lessening pool depth and reducing pool volume. The result is that habitat complexity, flood storage capacity, and key spawning and rearing habitats are impaired and are not functioning properly. Predominate sources of sediment loading into Upper Fanno Creek are a combination of both sediment loads in stormwater run-off and sediments injected into the creek during erosive flows. Watershed analysis (Grid Model) indicates that commercial, multifamily and transportation land uses are significant sources of stormwater loading into Fanno Creek. In addition, stream channel and bank erosion resulting from higher peak stream flows contribute to this problem.

Stream Temperature

High stream temperatures are presumed to be high basin wide due to lack of riparian canopy. Urban development is dense and residential landscaping is common throughout the uplands and riparian areas. Refer to the complete Fanno Creek Water Quality chapter in this report for a thorough and detailed description of stream temperature in Upper Fanno Creek.

Pollutants

Very little information was available to characterize pollutants in Upper Fanno Creek. Lacking this information, pollutant water quality was not rated for any of the reaches in Upper Fanno Creek. Pollutants did not show-up in the analysis as a limiting factor to cutthroat trout productivity, however, it would be incorrect to assume that there are no water quality issues in

Upper Fanno Creek. Transportation corridors, urban infrastructure and development, and use of pesticides and herbicides are believed to be potential sources of pollutants in Upper Fanno Creek. Although we do not currently know what these concentrations are for PAH's, metals and organic pollutants, we presume that background levels exist because of the more urbanized and built-out environment throughout the Fanno Watershed.

Culverts and Blockages to Fish Migration

The culverts in Upper Fanno Creek have not been modeled, nor have they been rated for fish passage. Culvert length, slope and drop height is available for some culverts, but was not available for all. Where information exists, each was evaluated based upon ODFW fish passage criteria, using past literature and documentation. Additional blockages such as long-term (and permanent) beaver ponds and constructed dams were likewise evaluated for permanent or temporary fish passage impediment.

Upper Fanno Creek is highly disconnected from lower and middle Fanno Creek and the Tualatin River Basin. The SW Beaverton-Hillsdale Highway/Scholls Ferry Road interchange (Beaverton Hillsdale Shopping Center at RM 12.1) effectively impedes fish passage into the Upper Fanno Subbasin. Here, the creek is piped for approximately 300 feet.

Although these culverts have not been examined specifically for fish passage, resident fish probably cannot navigate the culverts except under unique hydrologic conditions. Flow would need to be deep enough to provide a through-waterway, but not swift enough to function as a velocity barrier. As a result, resident fish have a limited range for spawning and rearing, and resident fish are sequestered to the upper basin, while anadromous fish cannot access historic spawning and rearing habitats. Refer to Table 2 for a summary of key fish passage impediments.

Vermont Creek, South Ash Creek, Columbia Creek, and Patton Creek are accessible from mainstem Fanno Creek and probably provide important off-channel refugia during high flows and cool-water refugia during periods of low stream flow and elevated stream temperatures. In addition, these creeks probably augment Fanno Creek summer base flows.

Woods Creek, North Ash Creek, Red Rock Creek, Pendleton Creek and Ivey Creek have fish passage barriers at or near the confluence of Fanno Creek. Currently, fish populations do not populate these creeks. Resident fish populations (that previously occupied these habitats) have probably been flushed out of the system throughout the years. Without the ability of fish to move back into these creeks and re-seed habitats, the creeks will probably remain devoid of fish communities.

Table 2. Summary of Fish Passage Barriers in Upper Fanno Creek basin.

Basin	Barrier	Passable?	CWS List (2005)	ODFW Priority (1999)
Fanno Creek (mainstem)	Beaverton –Hillsdale Hwy / Shopping Center	Impassable	Yes	
	SW 30th Dr.	Impassable		
	SW 39th Dr.	Impassable	Yes	
	SW Shattuck Rd	Seasonally passable	Yes	
	SW 45th Ave	Unknown		
	SW 59th	Unknown		
	SW 54th	Unknown		
	SW 53rd	Unknown		
	SW 52nd	Unknown		
	SW Fairdale Ct	Unknown		
	SW 43rd Dr.	Unknown	Yes	
Vermont Creek	SW Oleson Rd	Seasonally passable	Yes	
	SW Shattuck Rd	Seasonally passable		
	SW Vermont St. / 52nd Ave	Impassable		Medium
	SW 45th Ave / Caldew St	Impassable		Low
	Multnomah Blvd	Impassable		
Woods Creek	Portland Golf Club	Impassable		
	SW 45th Ave	Impassable		Low
	6006 Canby St	Unknown		Medium
	SW Taylors Ferry	Impassable	Yes	
	SW Oleson Rd	Unknown	Yes	
	SW 60th Ave	Unknown		
	Multnomah Blvd	Unknown		
	4850 SW Garden Home Rd	Unknown	Yes	Low
North Ash Creek	6315 SW Dolph Dr	Unknown	Yes	Low
	SW Orchid Dr	Unknown		
	SW Lancelot Ln	Unknown		
	SW 55th Ave.	Unknown		
South Ash Creek	SW 62nd Dr.	Impassable		
	SW Luradel	Impassable		
	SW 55th Ave	Unknown		

Habitat Complexity

Complex pools with wood and boulders provide important structure and roughness in Upper Fanno Creek. These habitat attributes help the creek withstand erosive flows and provide cover to resident fish. In Upper Fanno Creek, complex pools (defined as pools with greater than 3 km wood complexity per 1,000 meters of stream length) are present, but boulders are notably lacking; those that were probably present in the past either have been removed or have moved downstream during high flows. With the exception of wood that is found almost entirely in pools, wood abundance and volume are critically low (ODFW 2002b), and very few key pieces longer than 3 meters are present. Small, second growth deciduous trees and small mixed conifer/deciduous trees dominate riparian vegetation from Fanno 1 upstream to Fanno 4. These trees will probably not provide a great source of large woody debris in the immediate future. Fanno 5 and Fanno 6 have large (>30 cm), well-established deciduous trees that, if they remain, will continue to provide wood sources. However, native conifers, which have slower decay time when submerged in water, will continue to be absent. Based on low wood, volume and densities of wood in-stream and lack of adequate (large-sized conifers and deciduous trees) woody debris recruitment from adjacent riparian areas, the system is considered not properly functioning.

Overall, lack of large wood combined with the prevalence of higher, flashy storm flows (resulting in channel erosion and bank sloughing) significantly impacts stream habitat formation and maintenance of good quality spawning and rearing fish habitat, and is likely a prominent factor limiting habitat complexity and fish productivity. Riparian forests provide important sources of wood in the near term and into the future.

Key Habitats

Upper Fanno Creek is straight, incised and wide with eroded stream banks. The Creek generally flows through one primary channel; secondary channels and side channels are rare. Because of the simplified channel form, important habitats are lacking such as undercut banks, backwater pools and off-channel habitats, deep pools and high quality riffle habitats. Lack of these important spawning and rearing areas significantly reduces potential population productivity.

Over steepened bank angles (averaging 60 percent), poor bank vegetation, incised channel and moderate root densities currently characterize most mainstem reaches. A high proportion of stream banks (36 to 61 percent) are actively eroding with raw, unprotected areas, indicating bank instability and high potential for erosion during storm flows. Bank erosion is more severe in the downstream extent, and nearly all reaches surveyed show low vegetative cover along the stream banks. However, more than 50 percent plant biomass remains throughout all the mainstem habitats, suggesting that although disruptive pressures are evident, vegetative communities are re-establishing.

Undercut banks remain intact in mainstem Fanno Creek and probably provide important cover and refuge for resident fish, particularly during high storm flows. Scour pools are the dominant habitat type, constituting 68 percent of the wetted area; riffles constitute only 20 percent of the wetted area.

POOLS. Long, deep, meandering pools constitute a significant proportion of stream habitat in Upper Fanno Creek. These habitats function as depositional areas for fine sediment as evidenced by the high proportion (34 % to 72 %) of sediment loading in pools and corresponding shallow pool depth. The greatest number of deep pools and the greatest residual pool depth is found in Fanno 1 and Fanno 4. The most significant relative pool depth, compared to relative channel depth is in Fanno 6. In Fanno 6, channel form diversity (between pools, riffles and glides) and instream cover is presumed to be highest.

RIFFLES. Although pool area is present, corresponding riffle habitat is lacking, specifically in Fanno 1 (10%), Fanno 4 (11%), and Fanno 5 (18%). Low area of riffle habitat likely limits potential fish productivity in these reaches by limiting the amount of spawning and rearing habitat. However, riffle quality is relatively good in these reaches (respective of gravel and cobble composition and low fine sediment accumulation) signifying good fish bearing habitat.

Throughout the remainder of Upper Fanno Creek, riffle habitats contain a relatively high proportion of sand, silt and organic matter yielding marginal habitat function. The best riffle habitat (in terms of riffle area, high proportion of gravels and cobbles, and low fines) is found in Fanno 6.

Habitat Constraints by Geographic Area

Following is a brief summation of habitat constraints by geographic area in Upper Fanno Creek. Note – information is taken directly from the Assessment of Habitat Potential the in the Urban Streams and Rivers of Portland, Oregon – Analysis of Cutthroat Trout Habitat Potential and Limiting Factors for Fanno Creek (Mobrand-Jones and Stokes 2005). Refer to Appendix I for the detailed report.

At both geographic scales, the effects that different environmental attributes have on cutthroat trout were ranked. For convenience, the top three limiting factors for each geographic area or reach were color-coded. In the tables below, the limiting factors are ranked within a row and rates attributes *within* a geographic area. A limiting factor may be ranked first within a geographic area that has relatively limited restoration potential and hence be less important overall compared to a factor with a lower rank in a reach with high restoration potential.

Upper Fanno Creek Mainstem

The limiting factors for cutthroat trout potential in Upper Fanno Creek mainstem are displayed in Table 5 by reach. **SEDIMENT LOAD**, **HABITAT DIVERSITY**, **FLOW,** and **TEMPERATURE** are pervasive limiting factors throughout the upper watershed:

- In the Upper Middle Fanno geographic area, the priority area for restoration is Fanno16_B, the section of Fanno Creek between Woods and Vermont Creeks. In this reach, the most limiting factors in decreasing order of importance are sediment load, habitat diversity and temperature.

- In the Upper Fanno Creek mainstem, Fanno23_01 (Fanno 4 - Patton Creek to SW 45th St. culvert), Fanno21_07 (Fanno 2 - Safeway parking lot to Columbia Creek), Fanno25_01 (Fanno 5 – Ivy Creek to SW 39th Dr. culvert), and Fanno22_01 (Fanno 3 - Columbia Creek to SW Shattuck Road) have the highest restoration potential (Table 5).

Table 3. Limiting habitat attributes for cutthroat trout in Fanno Creek above its confluence with Woods Creek. Sediment load, Habitat diversity, Flow, and Temperature are pervasive limiting factors throughout the upper watershed. In the Upper Middle Fanno, the priority area for restoration is Fanno16_B. In the Upper Fanno, Fanno23_01, Fanno21_07, Fanno25_01, and Fanno22_01 have the highest restoration potential.

			Cutthroat Habitat Attributes: Upper Fanno Mainstem											
Geographic Area	Reach	Restoration Ranking	Channel Form	Pollutants	Competition (other sp)	Flow	Food	Habitat diversity	Harassment	Oxygen	Pathogens	Predation	Sediment load	Temperature
	Woods Creek													
Upper Middle Fanno	Fanno16_B	1	6	11	9	5	11	2	7	10	4	8	1	3
	Fanno21_01_A	2	6	10	7	3	10	2	9	10	5	8	1	4
	Fanno21_01_B	3	7	10	8	3	10	1	9	10	4	6	5	2
	Fanno21_01_C	3	4	9	5	2	9	1	8	9	9	6	3	7
	Safeway Parkinglot													
Upper Fanno	Fanno21_03_A	13	7	10	8	2	10	1	6	10	5	9	3	4
	Fanno21_03_B	7	6	10	7	3	10	1	9	10	5	8	2	4
	Fanno21_05	6	8	10	6	3	10	1	9	10	5	7	2	4
	Fanno21_07	2	6	10	7	3	10	2	9	10	5	8	1	4
	Fanno22_01	3	8	9	6	4	9	2	9	9	5	7	1	3
	Fanno22_03	16	8	10	6	3	10	1	9	10	5	6	2	4
	Fanno23_01	1	8	8	6	5	8	3	8	8	4	7	1	2
	Fanno23_03	9	7	10	8	2	10	1	5	10	6	9	3	4
	Fanno24_01	15	8	9	6	3	9	2	9	9	5	7	1	4
	Fanno24_03	5	8	9	6	3	9	2	9	9	5	7	1	4
	Fanno25_01	3	6	10	7	3	10	1	9	10	5	8	2	4
	Fanno25_03	8	6	10	7	3	10	1	9	10	5	8	2	4
	Fanno25_04	11	8	9	6	2	9	4	9	9	5	7	1	3
	Fanno25_06	10	7	10	6	3	10	2	9	10	5	8	1	4
	Fanno25_08	12	7	10	6	2	10	1	9	10	5	8	3	4
	Fanno25_10	17	9	10	6	3	10	1	7	10	5	8	2	4
	Fanno26_01	19	7	10	8	2	10	1	4	10	6	9	3	5
	Fanno26_03	13	6	10	7	3	10	1	8	10	5	9	2	4
	Fanno26_04	17	8	9	6	3	9	2	9	9	5	7	1	4

Woods Creek

The limiting factors for cutthroat trout potential in Woods Creek are displayed in Table 4 by reach. Sediment load and Habitat Diversity, followed by Flow and Temperature, are pervasive limiting factors.

The priority areas for restoration in Woods Creek are Woods1_18 (from the park driveway culvert to unmapped tributary (Trib(Woods1.18) at SW Canby Ave.), Woods1_00 (from Fanno Creek confluence to the golf course dam), and Woods1_25.

Sediment load is the most limiting factor to cutthroat potential in these three reaches as well as the majority of lower Woods Creek. Sediment loads have increased due to flashy flows and increased surface runoff. The lack of habitat complexity has also eliminated alternating areas of scour and deposition. Habitat diversity usually reflects the lack of large wood structure in a creek.

Flow is limiting to cutthroat due to extremely flashy fall/winter flows, and decreased summer flows. The Woods Creek watershed is flashy due to impervious substrates and channelization. The mapped impervious area (roofs and impervious substrates) of Woods Creek was estimated as 28% (BES and Brown and Caldwell 1998). Modeling indicated that Woods Creek peak flows have increased approximately 220% from predevelopment and the discharge has increased from ~65 cfs/mi2 to ~130 cfs/mi2 (MGS Engineering Consultants, Inc. 2001).

Temperatures have increased due to lack of forested cover and reduced summer flows. While pathogens are indicated as being the third most limiting factor in Woods1_25, pathogens are not actually any more limiting in this reach than anywhere else in Fanno Creek. It was assumed that *Ceratomyxa shasta*, the causative agent of ceratomyxosis, which is known to occur in the Willamette basin was also present at low levels throughout the Fanno Creek watershed. However, the incidence of this disease is known to increase with increasing water temperatures. In Table 4, pathogens are identified as a limiting factor due to increased water temperatures.

Table 4. Limiting habitat attributes for cutthroat trout in Woods Creek. Sediment load and Habitat diversity, followed by Flow and Temperature, are pervasive limiting factors throughout Woods Creek. The priority areas for restoration are Woods1_18, Woods1_00, and Woods1_25.

			Cutthroat Habitat Attributes: Woods Creek											
Geographic Area	**Reach**	***Restoration Ranking***	***Channel Form***	***Pollutants***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***
Woods Creek	Woods1_00	2	6	10	7	5	10	2	9	10	4	8	1	3
	Woods1_02	8	6	10	9	4	10	2	8	10	5	7	1	3
	Woods1_04	6	7	10	8	3	10	2	4	10	6	9	1	5
	Woods1_06	7	7	10	8	3	10	2	5	10	6	9	1	4
	Woods1_08	13	7	10	8	3	10	2	4	10	6	9	1	5
	Woods1_10	22	6	10	7	3	10	2	9	10	5	8	1	4
	Woods1_12	10	7	10	8	3	10	2	4	10	6	9	1	5
	Woods1_14	4	8	9	6	5	9	4	9	9	3	7	1	2
	Woods1_16	19	7	10	8	3	10	2	4	10	6	9	1	5
	Woods1_18	1	8	8	5	4	8	7	8	8	3	6	1	2
	Woods1_19	11	7	10	8	3	10	2	6	10	5	9	1	4
	Woods1_21	12	6	10	8	3	10	2	7	10	5	9	1	4
	Woods1_23	23	3	9	5	2	9	1	4	9	9	7	6	8
	Woods1_25	3	8	8	5	4	8	7	8	8	3	6	1	2
	Woods2_01	14	6	10	8	3	10	2	7	10	5	9	1	4
	Woods2_03	8	8	8	6	3	8	5	8	8	4	7	1	2
	Woods2_04	5	6	10	7	2	10	1	9	10	5	8	4	3
	Woods2_06	18	8	8	5	2	8	7	8	8	4	6	3	1
	Woods2_08	23	5	10	6	1	10	2	9	10	4	8	7	3
	Woods2_09	17	6	10	7	2	10	1	8	10	5	9	4	3
	Woods2_11	16	9	10	7	1	10	2	6	10	5	8	4	3
	Woods2_12	20	9	9	6	1	9	2	8	9	5	7	4	2
	Woods2_14	15	4	10	7	2	10	1	8	10	6	9	5	3
	Trib(Woods1_18)-02	21	7	10	8	3	10	2	5	10	6	9	1	4

Vermont Creek

The limiting factors for cutthroat trout potential in Vermont Creek are displayed in Table 5 by reach. Temperature, Flow, Habitat diversity, and Pathogens are pervasive limiting factors throughout Vermont Creek (Table 5). Sediment Load is limiting in a few Vermont Creek reaches while Harassment and Channel form are limiting in some of the tributaries to Vermont Creek. The priority areas for restoration in Vermont Creek are VT1_13 (from SW Vermont Ave to unmapped tributary Trib(VT1.13)), VT1_11 (from walking path near SW 55th Dr to SW Vermont Ave), and VT1_01 (from Fanno Creek confluence to SW Oleson Rd).

Flow is limiting to cutthroat due to extremely flashy fall/winter flows, and decreased summer flows. The Vermont Creek watershed is flashy due to impervious substrates and channelization. The mapped impervious area (roofs and impervious substrates) of Vermont Creek was estimated as 25.5% (BES and Brown and Caldwell 1998).

Temperatures have increased due to lack of forested cover and reduced summer flows. Sediment loads have increased due to flashy flows and increased surface runoff. The lack of habitat complexity has also eliminated alternating areas of scour and deposition. Habitat diversity usually reflects the lack of large wood structure in a creek.

While pathogens are indicated as being the second or third most limiting factor in several Vermont Creek reaches, pathogens are not actually any more limiting in these reaches than anywhere else in Fanno Creek. It was assumed that *Ceratomyxa shasta*, the causative agent of ceratomyxosis, which is known to occur in the Willamette basin, was also present at low levels throughout the Fanno Creek watershed. However, the incidence of this disease is known to increase with increasing water temperatures. In Table 5, pathogens are identified as a limiting factor due to increased water temperatures.

Table 5. Limiting habitat attributes for cutthroat trout in Vermont Creek. Temperature, Flow, Habitat diversity, and Pathogens are pervasive limiting factors throughout Vermont Creek. Sediment Load is limiting in a few Vermont Creek reaches while Harassment and Channel form are limiting in some of the tributaries to Vermont Creek. The priority areas for restoration are VT1_13, VT1_11, and VT1_01.

			Cutthroat Habitat Attributes: Vermont Creek												
Geographic Area	**Reach**	***Restoration Ranking***	***Channel Form***	***Pollutants***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***
Vermont Creek	VT1_01	3	5	11	7	4	11	1	8	10	3	9	6	2
	VT1_03	8	8	11	6	3	11	4	9	10	2	7	5	1
	VT1_05	5	5	11	8	3	11	4	7	10	2	9	6	1
	VT1_07	17	5	11	7	3	11	2	9	10	8	6	4	1
	VT1_09	16	8	11	7	2	11	5	6	10	9	4	3	1
	VT1_11	2	8	11	7	3	11	1	6	10	4	8	5	2
	VT1_13	1	9	10	6	5	10	4	10	8	2	7	3	1
	VT1_14	4	9	9	5	4	9	7	9	8	2	6	3	1
	VT2_01	13	9	11	6	4	11	3	8	10	2	7	5	1
	VT2_03	7	8	11	7	2	11	5	4	10	3	9	6	1
	VT2_04	10	9	9	6	3	9	4	9	8	2	7	5	1
	VT2_05	11	9	9	5	3	9	7	9	8	2	6	4	1
	VT2_06	5	10	10	7	2	10	3	5	9	4	8	6	1
	Trib(VT1_13)-01	18	3	8	5	2	8	1	4	8	8	7	6	8
	Trib(VT1_13)-03	15	6	10	7	2	10	1	3	10	5	9	8	4
	Trib(VT1_14)-01	9	5	10	6	2	10	1	7	10	4	9	8	3
	Trib(VT1_14)-03	12	6	10	7	2	10	1	3	10	5	8	9	4
	Trib(VT2_04)-01	14	5	10	6	2	10	1	9	10	4	8	7	3

Upper Fanno Creek Tributaries

The limiting factors for cutthroat trout potential in upper Fanno Creek tributaries are displayed in Table 6 by reach. Sediment load, Habitat diversity, and Flow are pervasive limiting factors throughout the upper Fanno Creek tributaries (Table 6). In Pendleton Creek, the priority area for restoration is reach Pendleton (Fanno21_01A)-05, the section of Pendleton Creek above SW Shattuck Rd. In this reach, the most limiting factors in decreasing order of importance are Habitat diversity, Flow, and Temperature.

In Sylvan Creek, Sylvan_04 (RM 1.0-1.5), Sylvan_02 (RM 0.3-0.7), Sylvan_03 (RM 0.7-1.0) and Sylvan_01 (RM0-0.3) have the highest restoration potential (Table 6) in decreasing order. Sediment load, Habitat diversity, Flow, and Temperature are the primary limiting factors in these four Sylvan Creek reaches, as well as the smaller tributary reaches (Table 6). Habitat diversity usually reflects the lack of large wood structure in a creek. Sediment loads have increased due to flashy flows and increased surface runoff. The lack of habitat complexity has also eliminated alternating areas of scour and deposition. Temperatures have increased due to lack of forested cover and reduced summer flows.

Fanno Creek watershed is flashy due to impervious substrates and channelization. The mapped impervious area (roofs and impervious substrates) was estimated as 29% of upper Fanno Creek and 26.5% of Pendleton Creek watershed (BES and Brown and Caldwell 1998).

Table 6. Limiting habitat attributes for cutthroat trout in Upper Fanno Creek tributaries. Sediment load, Habitat diversity, and Flow are pervasive limiting factors throughout the upper Fanno Creek tributaries. In Pendleton Creek, the priority area for restoration is Pendleton (Fanno21_01A)-05. In Sylvan Creek, the lower 1.5 miles have the highest restoration potential. Columbia and Hamilton Creeks have the highest restoration potential of the smaller tributaries.

			Cutthroat Habitat Attributes: Upper Fanno Tributaries											
Geographic Area	**Reach**	***Restoration Ranking***	***Channel Form***	***Pollutants***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***
Pendleton Creek	Pendleton(Fanno21_03)-02	3	7	10	8	2	10	1	3	10	6	9	5	4
	Pendleton(Fanno21_03)-03	2	8	10	6	3	10	1	9	10	5	7	4	2
	Pendleton(Fanno21_03)-05	1	7	10	8	2	10	1	4	10	6	9	5	3
Sylvan Creek	Sylvan01	3	9	11	7	3	11	5	6	10	4	8	1	2
	Sylvan_02	2	8	11	7	5	11	2	6	10	4	8	1	3
	Sylvan_03	3	6	11	7	3	11	2	9	10	5	8	1	4
	Sylvan_04	1	6	11	6	3	11	2	9	10	5	8	1	4
	Sylvan_05	6	8	10	6	3	10	2	10	9	5	7	1	4
	Sylvan_06	7	7	11	6	3	11	1	9	10	5	8	2	4
	Sylvan_07	5	6	11	8	2	11	1	7	10	5	9	3	4
Smaller Tributaries	Columbia(Fanno21_07)-01	1	7	10	8	2	10	1	4	10	6	9	5	3
	Hamilton(Fanno22_03)-01	2	7	10	8	3	10	1	6	10	5	9	2	4
	Ivy(Fanno23_03)-02	11	6	10	8	2	10	1	5	10	7	9	3	4
	Trib(Fanno24_03)-01	3	6	10	7	3	10	1	9	10	5	8	2	4
	Trib(Fanno24_03)-03	10	6	10	8	2	10	1	4	10	7	9	3	5
	Trib(Fanno24_03)-05	6	7	10	8	3	10	1	5	10	6	9	2	4
	Trib(Fanno25_03)-01	4	7	10	8	3	10	2	5	10	6	9	1	4
	Trib(Fanno25_10)-02	5	6	10	8	2	10	1	7	10	5	9	3	4
	Trib(Fanno25_10)-04	8	6	10	8	3	10	1	7	10	5	9	2	4
	Trib(Fanno25_10)-06	9	7	10	8	3	10	2	6	10	5	9	1	4
	Trib(Fanno25_10)-08	13	6	10	8	2	10	1	4	10	7	9	3	5
	Trib(Fanno26_03)-02	12	6	10	8	2	10	1	5	10	7	9	3	4
	Trib(Fanno26_04)-01	7	7	10	8	3	10	1	5	10	6	9	2	4

Subbasin Summary - Upper Fanno Area

Major factors contributing to changes in ecosystem functions and subsequent decline in both anadromous and resident fish populations in Upper Fanno Creek include changes to stream flows (hydrology and channel hydraulics), riparian and floodplain condition and functions, water quality (high sediment loading and stream temperatures), fish passage obstructions, and impacts to the amount and quality of aquatic habitat. These environmental attributes are further described below:

Goal Area	Watershed Health Indicator	Watershed Condition
Hydrology	Stream Flows	▪ High-density impervious surface (EIA) throughout the watershed increases peak flows and reduces base flows.
Water Quality	Total Suspended Solids (TSS)	▪ High sediment loads smother spawning habitats (riffle gravels) and fill pools. ▪ Sediment associated pollutants may persist throughout the watershed. ▪ High silt cover reduces areas for macroinvertebrate production.
	Stream Temperature	▪ Elevated summer temperatures stress fish communities resulting in lethal and sub lethal effects.
	Phosphorus	▪ Elevated phosphorus concentrations, measured in some tributaries, contribute to increased algal growth. Algal blooms in the Tualatin River can result in exceedances of state chlorophyll a, pH, and dissolved oxygen standards.
	Pollutants (PAH's, metals, and organics)	▪ Chronic and acute chemical toxicity may result in lethal and / or sub lethal effects to aquatic communities, including macroinvertebrate production.
Physical Habitat	Fish Passage Barriers	▪ Roadways significantly impact fish passage throughout Upper Fanno during times of the year. Key roadways include: Beaverton-Hillsdale Shopping Center; SW Shattuck Rd, SW 59th Ave, SW 45 Ave, SW 43 Ave, SW 39 Ave, and SW 30 Ave. ▪ The severity of passage at these specific locations will be evaluated using FishXing in the future.
	Riparian and Floodplain Condition and Connectivity	▪ Second growth, deciduous-dominated riparian and floodplain vegetative communities predominate and do not provide large wood pieces or substantive volume of woody debris into the creek. ▪ Lack of native conifers as source woody debris will limit the longevity and function of wood in the creek. ▪ Lack of overhanging vegetation along the stream banks destabilizes the creek, and minimizes potential protective cover to fish and wildlife. Lack of mature native trees and shrubs contributes to increase stream temperatures in the summer.
	Key Habitats (spawning and rearing habitats)	▪ Lack of high quality riffles, deep pools, side channels, secondary channels, off-channel, backwater and seasonal wetland habitats limits potential native fish productivity.
	Stream Channel Complexity	▪ Lacking large wood; large and medium sized

		substrate and overhanging vegetation ▪ Shorter stream length with fewer meanders and simplified channel morphology (channelization).
Biological Communities	Anadromous steelhead and cutthroat, and resident rainbow and cutthroat trout historically populated Fanno Creek. Coho have populated the Tualatin River Basin and Fanno Creek since the late 1800's; Chinook probably did not populate Fanno Creek.	▪ Reticulate sculpin, redside shiner, cutthroat trout and lamprey are the most abundant fish communities; Coho and steelhead present since late 1990's (ODFW Fish Distribution Maps, December 2003).

PROTECTION AND RESTORATION VALUE

Following is a brief summation of protection and restoration value in Upper Fanno Creek. Note – information is taken directly from the Assessment of Habitat Potential in the Urban Streams and Rivers of Portland, Oregon – Analysis of Cutthroat Trout Habitat Potential and Limiting Factors for Fanno Creek (Mobrand-Jones and Stokes 2005). Refer to Appendix I for the detailed report.

Spatial priorities[1] for habitat protection and restoration were evaluated to examine how cutthroat potential changed as current conditions in areas were degraded or restored. Here we report priorities only at the Geographic Area scale but note that reach level priorities within each area are available. Areas that, when degraded, resulted in large changes in population performance, had high protection value for the current potential of the system. In a like manner, reference conditions were substituted in each area to assess the restoration potential. Those areas that showed large increases in population performance when restored were indicated as priorities for restoration.

For Upper Fanno Creek (Woods Creek and above), the top three areas for **protection** were Vermont Creek, Woods Creek, and the mainstem section above the Safeway (Figure 2). This means that these areas had the best current conditions in the upper portion of Fanno Creek for cutthroat trout, and that further degradation of these areas would have a significant impact on the current potential of the area for cutthroat trout. The top three areas for **restoration** in upper Fanno were the mainstem above Safeway, Woods Creek and the mainstem below Safeway down to Woods Creek (Figure 2). Sylvan Creek showed significant restoration potential as well.

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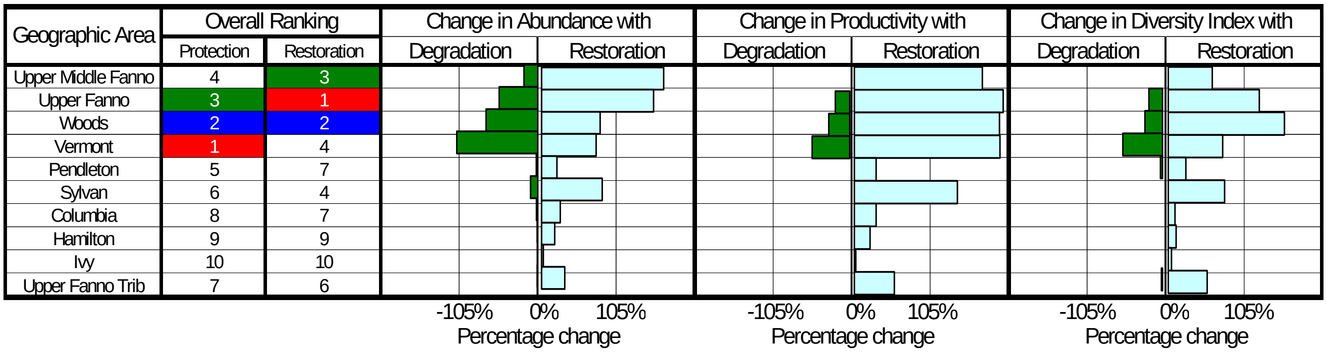
[1] Priorities only address our estimation of cutthroat habitat, do not include social, economic or other biological factors, and do not necessarily represent priorities of the City of Portland or other entities.

Upper Fanno Creek-Resident Cutthroat Trout Assessment

Relative Importance Of Geographic Areas For Protection and Restoration Measures



Geographic Area	Overall Ranking	
	Protection	Restoration
Upper Middle Fanno	4	3
Upper Fanno	3	1
Woods	2	2
Vermont	1	4
Pendleton	5	7
Sylvan	6	4
Columbia	8	7
Hamilton	9	9
Ivy	10	10
Upper Fanno Trib	7	6

Figure 1. Restoration and protection rankings for geographic areas within upper Fanno Creek

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CHAPTER 10

Habitat: Tryon Creek Watershed

This chapter characterizes habitat conditions in the Tryon Creek Watershed. It includes:

- Reach Descriptions
- Habitat Characterization by Reach
- Habitat Characterization Summary

REACH DESCRIPTIONS

Reaches are used to divide streams into segments with common hydrologic, land use, or habitat features. Reach breaks may also occur where structures such as culverts create breaks in stream connectivity and function. The following reach delineations reflect current data and habitat features.

For this report, Tryon Creek reaches were chosen that reflect land use, gradient, tributary confluences, , significant culverts and barriers, and other important habitat features.. The reach breaks coincide with the reach designations selected by the Oregon Department of Fish and Wildlife (ODFW) in 2001, during its Aquatic Inventory Project surveys. Additional reaches were delineated by City of Portland staff, notably in the headwaters of Tryon Creek subbasin. In addition, subreaches were assigned to provide detailed habitat descriptions. Approximate stream miles (from the Willamette River confluence) are described, but stream centerline (thalweg) distance has not been surveyed.

Mainstem Tryon Creek

Tryon 1: Confluence

Mouth of Tryon Creek (Willamette River) to the west side of HWY 43 t (river mile [RM] 0.0 – to 0.24; approximately 1,286 feet)

This reach includes a hydraulic jump and culvert (HWY 43 culvert, approximately 200 feet long) at the upstream end. Stream gradient is low at 2.3 percent. Critical habitat features include the confluence of Tryon Creek and the Willamette River. Land use in this area is predominantly residential; however, the Tryon Creek Water Treatment Plant is located on the south shore of this reach and directly discharges into the Willamette River.

Tryon: Lower Canyon

HWY 43 to Nettle Creek confluence (RM 0.24 –to 1.06; 4,330 feet)

Although the hillside was completely logged approximately 40-60 years ago, the area is now designated as greenspace and is largely undisturbed within the confines of Tryon Creek State Natural Area. One exception is a sewer pipe that runs along the valley bottom. Several tributaries enter the lower canyon near the upper end of the subreach. Land use in the drainage is split between park (along the riparian corridor) and low-density residential (in upland areas).

Tryon 3: Tryon Creek Park

(RM 1.06 to 2.68; approximately 8,554- feet)

TRYON 3A

NETTLE CREEK TO PARK CREEK CONFLUENCE (RM 1.06 TO 1.80; 3,960 FEET)

This subreach has a stream gradient of 0.6 percent. Vegetative canopy is nearly entire, with well-established second-growth forest. Three tributaries (Red Fox Creek, Palatine Hill Creek, and Park Creek) enter the subreach, and Park Creek marks the upper boundary of the subreach. Walking trails cross and parallel the creek through approximately one half of the subreach, and there are two footbridges. Tryon Creek State Natural Area bounds the drainage basin.

TRYON 3B

PARK CREEK CONFLUENCE TO THE CONFLUENCE OF TYRON CREEK AND ARNOLD CREEK (RM 1.80 TO 2.68; 4,640 -FEET)

This subreach has a stream gradient of 0.8 percent. Although the reach runs through a well-established forest stand, numerous trails run through the reach, and human and horse activity is high. The upper extent of the subreach ends at the confluence of Tryon Creek and Arnold Creek, immediately above SW Boones Ferry Road. The SW Boones Ferry Road culvert is approximately 150 feet long and is considered completely impassable to anadromous and resident fish. Tryon Creek State Natural Area generally bounds the drainage basin; some low-density residential areas exist in the uplands.

Tryon 4: Upper Tryon Creek

(RM 2.68 to 4.02; 7,076 feet)

This reach comprises six subreaches, based on distinct hydrologic, habitat, and land use regimes.

TRYON 4A

UPPER TRYON PARK (RM 2.62 TO 3.28; APPROXIMATELY 3,485 FEET)

This reach segment has a stream gradient of 2.3 percent. It includes SW Maplecrest Drive (100 feet long), which bounds the upper extent of the reach. Mature second0growth forests dominate the landscape. Some low-density residential use is found in the uplands.

TRYON 4B

SW MAPLECREST DRIVE TO MARSHALL CASCADE (RM 3.28 TO 3.48; APPROXIMATELY 1,056 FEET)

This reach is generally similar to Tryon 4A, except that land use is dominated by low-density residential development (with landscaped vegetation in the riparian zone and along southwest-facing slopes). Marshall Cascade (a run of rock pools and steps) bounds the upper end of this subreach.

TRYON 4C

MARSHALL CASCADE TO SW 18TH PLACE CULVERT (RM 3.48 TO 3.55; 3,696 FEET)

Four to five tributaries enter Tryon Creek in this subreach, including Burlingame Creek. The SW 18th Place culvert (approximately 70 feet long) is located at the upper end of the subreach, immediately above Marshall Cascade.

TRYON 4D

SW 18TH PLACE TO SW LANCASTER DRIVE (RM 3.55 TO 3.98; 2,270 FEET)

Quail Creek defines the upper end of this short, 850-foot subreach. The hydrology is predominantly perennial flow, but sections become perennial-surface flow (i.e., dispersed and shallow flow) in bedrock areas. Land use is a mixture of park and low-density residential.

QUAIL CREEK TO SW LANCASTER DRIVE (RM 3.92 TO 4.11; 1,050 FEET)

This subreach ends at the upstream end of the SW Lancaster Drive culvert, which is approximately 80 feet long. Land use is exclusively residential, with significant landscaping and only a partial tree canopy. Stream gradient is approximately 3.7 percent, with two short reaches of much steeper gradient.

TRYON 4E

SW LANCASTER DRIVE TO SW 26TH AVENUE/TAYLORS FERRY ROAD (FALLING CREEK)
(RM 3.98 TO 4.03; 265 FEET)

This subreach is very short (260-280 feet) with low stream gradient (2 percent). Land use is residential, and the riparian canopy is limited. The confluence with Falling Creek defines the upper extent of the subreach.

Tryon 5: Headwaters

(RM 4.03 –to > 4.85; approximately/over 3,690 feet)

The headwater section of Tryon Creek is enclosed in residential development, commercial development, and transportation uses, and is divided into five subreaches based on culvert locations.

TRYON 5A

SW TAYLORS FERRY RD. TO INTERSTATE 5/SW BARBUR CULVERT (RM 4.16 TO 4.32; 845 FEET)

This reach extends from Falling Creek to the bottom of I-5/SW Barbur Boulevard. The downstream reach is dominated by a series of five closely spaced streets and driveway culverts (near the intersection of SW 26th Ave and Taylors Ferry Road). Four closely spaced culverts (approximately 320 feet total length) bound the upper extent of the subreach. Stream gradient is moderate (2.0 percent). Residential development and landscaped lawns dominate the land use in the area and characterize the riparian and floodplain land base.

TRYON 5B

I-5/SW BARBUR BOULEVARD TO END OF OPEN REACH BELOW SW DOLPH COURT (RM 4.32 TO 4.46;740 FEET)

This reach begins with the long approximately 580 feet) I-5/Barbur Boulevard culvert. Commercial development and arterial roads dominate the landscape and land –use. As a result, stormwater runoff (from impervious surfaces) is significant throughout the subreach. The upper 150-160 feet of the subreach is an open channel, and the subreach ends just below an industrial parking lot near Dolph Court.

TRYON 5C

SW DOLPH COURT TO BOTTOM OF CULVERTS BELOW SW 30TH AVENUE (RM 4.46 TO 4.56; 530 FEET)

This short reach terminates at an apartment complex (and culverted stream segment) just below SW 30th Avenue. Wetland habitat exists immediately above SW Dolph Court.

TRYON 5D

SW 30TH AVENUE TO END OF SW CARSON STREET (RM 4.56 TO 4.85; 1,530 FEET)

This subreach is the uppermost segment on Tryon Creek. The SW 30th Avenue culvert is approximately 160 feet long and defines the downstream extent of the subreach. A series of three closely spaced culverts (approximately 260 feet in total length) bound the upper extent of the subreach. Stream corridor characteristics from above SW 30th Avenue to SW Carson Street are highly variable. Storm runoff is a dominant component of hydrology in these subreaches, and land use is primarily moderate-density residential.

TRYON 5E

HEADWATERS COMPLEX – INCLUDES ALL SMALL UPPER TRIBUTARIES ABOVE RM 4.85

The headwater complex is a series of intermittent stream segments, all flowing into mainstem Tryon Creek. Although stream flow is seasonally intermittent, peak flows probably impact water quality and hydrologic processes in downstream creek reaches.

Tributaries to Tryon Creek

Tributaries are presented in ascending geographic order in the subbasin. They include lower canyon tributaries (Nettle, Palatine Hill, Red Fox, Park and Fourth Avenue Creeks); Arnold Creek; upper tributaries (Burlingame and Quail Creeks), and Falling Creek. Arnold Creek and Falling Creek are believed to significantly impact habitat and hydrologic functions in the Tryon Creek subbasin, and are characterized in more detail than lower canyon tributaries and upper tributaries.

The estimated relative drainage size compared to the Arnold Creek catchment is shown in braces {}.

Lower Canyon Tributaries

Nettle Creek, Palatine Hill Drainage, Red Fox Creek, Park Creek, and Fourth Avenue Creek

Thorough habitat surveys have not been conducted in these lower Tryon Creek tributaries; detailed habitat descriptions are therefore not available. However, lower tributary segments flow into and are bound by Tryon Creek State Natural Area and are considered to have an intact forest canopy, high riparian integrity, and variable hydrology. The upper reaches of all these creeks are in low-density residential development.

NETTLE CREEK

Nettle Creek enters Tryon Creek at RM 1.15 (Tryon 2/Tryon 3A reach break). The mainstem reach is approximately 1.7 miles long {basin size - 0.7}. It is about 75 percent residential land use, and lies within Lake Oswego and Multnomah County.

PALATINE HILL DRAINAGE

Palatine Hill Creek is approximately 0.5 mile long {basin size - 0.2}. It is 40-50 percent residential land –use, and is largely contained in Multnomah County

RED FOX CREEK

Red Fox Creek is approximately 0.7 miles long {basin size - 0.1}. It is 50 percent residential land use and lies primarily within the City of Lake Oswego

PARK CREEK

Park Creek enters Tryon Creek at RM 2.82 (Tryon 2/Tryon 3A reach break) and is approximately 1.0 mile long {basin size - 0.3}. It is 50-60 percent residential land use and lies within Multnomah County and the City of Portland.

FOURTH AVENUE CREEK

Fourth Avenue Creek is approximately 0.7 mile long {basin size - 0.2}. About 40 percent of the subbasin lies within the property limits of Lewis & Clark College; the remainder lies within Tryon Creek State Natural Area and the City of Portland.

Arnold Creek Reach

Mouth of Arnold Creek to above SW 43rd Avenue (RM 0.0 to 1.84; approximately 9,700 feet)

Approximately 80 percent of Arnold Creek subbasin is in residential land use (within the City of Portland). Arnold Creek is divided into six subreaches; however, detailed habitat and biological community surveys have been done for only subreaches Arnold 1A and Arnold 1B. Low flows within Arnold Creek and a cascade reach just below SW 16th Place (Arnold 1B) probably isolate fish populations. At least eight tributaries enter Arnold Creek; these are not included in this characterization report.

ARNOLD 1A

MOUTH OF ARNOLD CREEK TO SW ARNOLD ROAD (RM 0.0 - 0.13; APPROXIMATELY 680 FEET)

This reach begins at the confluence of Tryon Creek and Arnold Creek. The reach is heavily wooded, with a dense canopy (except along SW Arnold Street, which runs parallel to the creek). Some of the subreach lies within Tryon Creek State Natural Area. Stream gradient is less than 1 percent. The SW Arnold Street culvert (approximately 50 feet long) defines the upper end of the subreach.

ARNOLD 1B

SW ARNOLD ROAD TO ABOVE SW 16TH PLACE (CASCADE REACH) (RM 0.13 - 0.41; 1,480 FEET)

Stream gradient averages 6 percent. This subreach is believed to be the end of anadromy, and the ODFW (2001) habitat surveys ended here. SW Arnold Street continues to parallel the stream at a distance of 50-75 feet to the north. The SW 16th Place culvert bounds the upper extent of the subreach.

ARNOLD 1C

SW 16TH PLACE TO SW LANCASTER ROAD (MIDDLE ARNOLD) (RM 0.41 - 0.78; 1,950 FEET)

Stream gradient is 1.8 percent. The predominant land use in the subreach is residential, with several driveway culverts crossing the stream channel. SW Arnold Street continues to parallel the subreach along the north slope. The SW Lancaster Road culvert (approximately 110 feet long) marks the upper extent of the subreach.

ARNOLD 1D

SW Lancaster Road to SW 31st Avenue (RM 0.78 about 1.15; 1,950 feet)

Stream gradient is approximately 3 percent; this subreach is otherwise similar to Arnold 1C. The SW 31st Avenue culvert bounds the upper extent of the subreach.

ARNOLD 1E

SW 31ST AVENUE TO SW 35TH AVENUE (ARNOLD HEADWATERS) (RM 1.15 - 1.42; 1,430 FEET)

Stream gradient is 6.3 percent. The long SW 35th Avenue culvert (approximately 100 feet) defines the upper end of this subreach.

ARNOLD 1F

ARNOLD HEADWATERS (RM 1.42 - ABOUT 1.84)

This headwaters reach is predominantly in public land ownership. It is over 2,500 feet long, with a gradient of approximately 8 percent.

Upper Tributaries

The upper tributaries include Burlingame Creek and Quail Creek. Detailed habitat descriptions (and other instream and riparian data) are not available for these two reaches. A brief description of basin size and dominant land-use by reach is provided below.

BURLINGAME CREEK

Burlingham Creek flows into Tryon Creek near RM 3.89 (Tryon 4D). The creek is approximately one mile long {basin size - 0.3}. About 90 percent of the drainage is zoned residential land use within the City of Portland.

QUAIL CREEK

Quail Creek flows into Tryon Creek near RM 3.92 (near the upper extent of Tryon 4D). The creek is approximately 0.5 mile long {basin size - 0.1}. More than 90 percent of the drainage is zoned residential land use within the City of Portland.

Falling Creek Reach

Falling Creek is approximately one mile long {basin size -0.5}. The Falling Creek drainage lies within residential urban development, roads, and parks. Limited data are available that characterizes instream channel condition and riparian and floodplain characteristics. Culverts divide Falling Creek into three subreaches: Falling 1A, Falling 1B, and Falling 1C. The SW 35th Avenue culvert is believed to define the upper limit of fish habitat in Falling Creek, but this assumption has not been confirmed.

FALLING 1A

MOUTH OF FALLING CREEK TO SW 26TH AVENUE (LOWER FALLING) (APPROXIMATELY 30 FEET)

This subreach begins at the confluence of Falling Creek and Tryon Creek (RM 4.16: Tryon 4E). Stream gradient is approximately 2.5 percent. Land use is predominantly multiple-family residential, with a large number of apartments close to the stream corridor. SW Taylors Ferry Road and SW 35th Drive parallel the stream at distances between 100 and 300 feet. The SW 35th Avenue culvert defines the upper extent of the subreach; the culvert is approximately 150 feet long and has a gradient of 6.5 percent.

FALLING 1B

SW 26TH AVENUE TO SW 35TH AVENUE (APPROXIMATELY 3,500 FEET)

FALLING 1C

SW 35TH AVENUE TO SW HUBER STREET (APPROXIMATELY 1,500 FEET)

Stream gradient is 2.2 to 2.5 percent. Land use is primarily residential, although the lower half of the subreach has few structures. The subreach ends immediately above the SW Huber Street culvert, which is approximately 60 feet long.

FALLING 1D

SW HUBER STREET TO JACKSON MIDDLE SCHOOL (UPPER FALLING) (APPROXIMATELY 200 FEET)

FALLING 1E

JACKSON MIDDLE SCHOOL (1,800 FEET)

The majority of this creek segment is buried (piped) under Jackson Middle School playfields. The lower portion of the reach lies within a residential neighborhood.

HABITAT CHARACTERIZATION BY REACH

Mainstem Tryon Creek

Tryon 1: Confluence

FLOODPLAIN CONDITION

The mouth of Tryon Creek is part of the Willamette River floodplain; portions of it are seasonally inundated. Multiple terraces currently constrain the mouth of Tryon Creek; however, the creek runs through a broader outwash, with a valley width index (VWI) of 20.0. Stream gradient is moderately steep, averaging 2.3 percent.

Although creek depth, channel flow, and floodplain inundation are influenced by perennial channel flows and Willamette River flows, floodplain interactions between Tryon Creek and its floodplain are impaired. Bank slopes are relatively severe; the channel is incised; and urban development (residential, industrial, and public utility) abuts both the north and south sides of the creek. However, the floodprone width is approximately 1.5 times greater than the active channel width, indicating that flood flows occasionally top the banks and interact with the floodplain.

RIPARIAN CONDITION

For the reasons stated above, riparian condition in lower Tryon Creek is “quite poor” (ODFW 2001). Buffers are narrow, and backyards and a sewage treatment facility are predominant land uses and features in the riparian area.

Canopy cover is approximately 50 percent within the immediate 010 meters, then drastically diminishes to 23 percent at 10-20 meters and 0 percent at 20-30 meters. Grasses and forbs are common, and overstory canopy is mostly provided by second-growth deciduous trees (15-30 – centimeters [cm] diameter breast height (dbh)). Small conifers are coming up through the understory, and cedar and arbor vita hedges are common along the landscaped portions of the creek bank. Vegetative cover is generally greater along the north bank and floodplain terrace (Figure 7 of 15, BES Vegetative Cover). Hardwoods are only moderately mature and currently do not contribute source woody material into Tryon Creek.

HWY and a railroad crossing severely disconnect Tryon 1 from Tryon 2A and impede migration of riparian-dwelling organisms.

STREAM CONNECTIVITY

Connectivity with the Willamette River is good up to HWY 43. The culvert that runs under this state highway, along with a railroad bridge, significantly reduce but do not entirely block stream connectivity with the upstream reaches of Tryon Creek. The culvert is 200-feet long, with a formidable jump and slope. Anadromous salmonids might navigate through the culvert during higher annual flow periods (winter – spring). Even then, however, passage is probably limited to periods when flows provide adequate water depth (for jump height into the culvert and passage through the baffles), yet do not pose a velocity barrier. It is unlikely that fall-run coho salmon pass above the culvert, except during very opportune periods. Flows during this period are too low in most years to allow adequate access into and through the culvert. Late-run winter steelhead may pass in late winter and early spring. Resident trout probably cannot move upstream through the culvert, but they may pass downstream during spring freshets or other high-flow periods.

REFUGIA

Undercut banks, which constitute 38 percent of bank form, probably provide most instream refugia. Additional cover may be found in deep pools, among the few pieces (and clusters) of wood and under overhanging vegetation. The beaver pond, located near the confluence of the Willamette River, may provide important high-water refugia and fringe/shoreline habitat. No off-channel habitats or secondary channels were identified during ODFW 2001 surveys, and no tributaries flow into this lower portion of Tryon Creek.

CHANNEL CONDITION AND HABITAT STRUCTURE

The confluence segment of Tryon Creek is highly eroded (69 percent actively eroding banks) and channelized, with bank slope of 25 percent (ODFW 2001).

Predominant habitat types include pools (55 percent) and riffles (20 percent) (ODFW 2001). Riffle quality is marginal to poor, with gravels and sands constituting 21 percent and 18 percent, respectively, of substrate. Fines and organics constitute 21 percent of these riffles and may significantly affect riffle quality, particularly for epifaunal and macroinvertebrate production. Cobbles constitute 27 percent of riffle substrate, and boulders constitute only 8 percent of substrate; some substratum is therefore available for epifaunal cover.

Streambed substrate in pool habitat is well mixed with cobbles, gravels, and fines (ODFW 2001). Pool quality is optimal, with 55 percent total pool area. Average residual pool depth throughout the reach is 0.64 meter, approximately 27 percent deeper than the prevailing stream depth. Although most pools are not significantly deeper than the average channel depth, four pools greater than 1.0 meter were noted within the reach and probably provide important cover and refuge throughout the year.

Complex pools with wood are rare, and boulders constitute only 9 percent of pool substrate; protective cover is therefore mostly provided in the deepest areas of the pools. Sediment deposition in pools is moderately high (31 percent), signifying erosive flows in the upper watershed and sediment fallout in this lower depositional area. Sediment concentrations greater than 25 percent of substrate coverage signify unstable conditions during storm flows. Lateral scour pools are the predominant pool type; however, one beaver pond/dam complex was noted near the confluence.

Wood count and volume are low. Wood density is 5.06-m3/100 meters; wood count is 4.55 pieces per 100 meters; and key pieces are rare (ODFW 2001).

Two stormwater outlets (one concrete and one metal) enter Tryon Creek approximately 180 meters and 190 –meters, respectively, from the confluence with the Willamette River. Their flow contribution to Tryon Creek is not known.

EVALUATION OF TRYON 1: CONFLUENCE

- Floodplain connectivity and riparian condition could probably be improved by planting native shrubs and trees in the riparian corridor and broader floodplain area. Key benefits that additional plant cover would probably provide include stabilizing creek banks and channel, providing additional canopy cover, providing instream woody structure (small wood clusters and allochthonous inputs for macroinvertebrates and fish), and attenuating creek flows.

- Lower Tryon Creek is part of the larger Willamette River floodplain and should be protected from future development or redevelopment to the maximum extent possible. In addition to providing habitat to local populations, this short reach provides critical refuge to upper Willamette Basin fish populations year-round.

- Channel condition and habitat structure could be improved by enhancing channel complexity and instream structure. Adding large wood and boulders instream would increase channel roughness and help pool and riffle forming processes. Lower Tryon Creek currently does not exhibit complex habitat types. Riffle area is low. Lateral scour pools predominate and are not significantly deeper than the prevailing channel depth; they probably do not provide significant depth refugia or protective cover.

- An evaluation of the two pipes that enter Tryon Creek is needed to determine the source (stormwater or sanitary), flow contribution, and water quality.

- Fish access into upper reaches of Tryon Creek could be improved by retrofitting or replacing the State Street culvert. This culvert is impassable nearly year-round and under most hydrologic conditions. Adult winter steelhead may be able to navigate through the culvert during very opportune periods, but other species (such as coho and coastal cutthroat) probably do not pass through the barrier.

Tryon 2: Lower Canyon

FLOODPLAIN CONDITION

The floodplain in this reach is narrow and constrained by steep valley walls. The average VWI is 4.3, and stream gradient is low at 1.3 percent (ODFW, 2001). Within the floodplain, the channel is constrained by alternating terraces. The lower canyon reach lies entirely within Tryon Creek State Natural Area and interacts with its floodplain much more than a typical urban creek (ODFW 2001). Broader floodplain areas were noted in ODFW’s 2001 stream survey. Most were associated with beaver dams and ponds, which are prevalent throughout the reach.

RIPARIAN CONDITION

Riparian condition varies from good to excellent. The corridor is wide (over 200 feet) and continuous, without breaks in longitudinal connectivity. Trails running through Tryon Creek State Natural Area do not appear to impact habitat condition and structure in Tryon Creek. However, an exposed sewer pipe (supported by concrete pillars) runs parallel to the creek for approximately 325 meters. Depending on its condition, this sewer pipe may significantly impact riparian condition and water quality.

Large deciduous trees (30-50 cm dbh) are the dominant tree class. Grasses and forbs are common. Trees probably provide important coarse organic material into the creek. Generally, canopy cover is good and continuous within the immediate 30-meter riparian zone: 56 percent in zone 1 (0-10 meters from the stream bank); 80 percent in zone 2 (10-20 meters from the stream bank); and 66 percent in zone 3 (20-30 meters from the stream bank). Vegetative cover is greater along the northerly hillslopes, particularly adjacent to the creek (Figure 7 of 15, BES Vegetative Cover).

A mid-reach landslide was noted during the ODFW 2001 stream surveys. The slide was characterized as “stable,” with no evidence of recent activity.

STREAM CONNECTIVITY

Stream connectivity is excellent. There are no culverts or other manmade structures that impair stream connectivity. However, five beaver dams are present in the mid-to-upper portion of the reach and may temporarily or seasonally impede fish movement. In addition, several steps over bedrock may impede fish movement during very low flows. These steps range from 0.4 to 0.8 meter in height. HWY 43 at the downstream extent of the reach impedes fish movement to and from Tryon 1 during certain parts (or possibly all) of the year.

REFUGIA

Undercut banks (38 percent of bank form) and wood provide primary instream refugia. Additional overwintering habitat is found in the five beaver ponds. These ponds probably provide important slack water during high storm flows.

Off-channel refugia may be found in Nettle Creek and in secondary channels (a total stream length of 36 meters). Although off-channel refugia is low, it is more than that found in most other reaches of the Tryon Creek Basin.

CHANNEL CONDITION AND HABITAT STRUCTURE

Tryon Creek is moderately unstable in this reach, with 36 percent actively eroding banks. Bank slope is also high (53 percent), indicating that erosive flows have cut and incised the main channel. Channel condition and structure vary as springs and seeps, beaver dams, and broader floodplain areas interact with the creek.

The predominant habitat forms are scour pools (51 percent), dammed pools (25 percent), and riffles (17 percent). Although the riffle area is small, 40 percent of the riffle habitat is considered optimal for fish bearing because it has more than 35 percent gravel composition. The remaining riffle habitat is considered marginal, with 15-35 percent gravel composition. More than half (65 percent) of the riffle habitat contains 12-25 percent fines and organics in the substrate (marginal fish habitat), and only 15 percent contains less than 12 percent fines (desirable). Relative to other areas in Tryon Creek, riffles in this subreach are in good condition. Only Tryon 3A and Tryon 3B exhibit more favorable riffle habitat.

Pool area is high (76 percent), the highest of any other reach surveyed in the Tryon Creek Basin. Twenty-five percent of this pool area is found in five beaver ponds and a backwater pool. Beaver ponds have characteristically high proportions of silt (45 percent) and sand (28 percent), and are probably functioning as depositional zones during erosive flows. Beaver dam heights varies from 0.3 to 0.6 –meter, and may temporarily or seasonally prevent resident fish from moving upstream (and possibly downstream).

Lateral scour pools are the predominant pool type, constituting 51 percent of the pool habitat. Riffle substrate is 17 percent gravels, 25 percent sands, and 31 percent fines. The moderately high proportion of fines indicates that lateral scour pools, like the five beaver ponds, are depositional zones during erosive flows.

Nine complex pools with wood were observed during the 2001 surveys. Boulders constitute only 2 percent of the stream bottom substrate and therefore do not provide substantive cover. However, the pools average 0.59 meter deep, approximately 25 percent deeper than the prevailing channel depth, and six pools are greater than 1.0 –meter deep. These pools probably provide important depth refugia.

Wood count through this reach is high at 42 pieces per 100–meters of stream length, but wood densities are low (1.40-m3/100 meters). The existing tree canopy comprises smaller trees (less than 30 cm dbh), with some large trees (50-90 cm dbh), indicating that potential large wood recruitment exists.

EVALUATION OF TRYON 2: LOWER CANYON

- The lower canyon reach running through Tryon Creek State Natural Area contains critical fish-bearing habitat. This area should be protected, and recreational use should be minimized in the riparian corridor and instream. Pool area and quality are optimal, and riffle habitat is good. The riparian corridor and adjacent floodplain interact with the creek. Large wood recruitment is plausible, and springs and seeps augment summer and winter base flows. The combination of these instream and terrestrial characteristics creates a favorable environ for aquatic organisms.

- Beaver activity should be encouraged and retained. Beaver ponds provide important flood storage and high-flow winter refugia to fish. In addition, they are sources of large wood clusters that provide cover to fish in both the pond and downstream creek.

- Sediments overlying stream-bottom substrates may limit fish productivity. Only 15 percent of the riffle habitat has less than 12 percent fines, which is considered desirable for salmonids. More than half (65 percent) of the riffle habitat has 12-25 percent fines and organics (marginal fish habitat). Amassed sediments may cover spawning grounds, and sediments may limit epifaunal production and subsequent macroinvertebrate production. Actions to minimize sediment load into Tryon Creek should be considered.

- Increasing the amount and density of large wood would undoubtedly improve instream refugia, add channel roughness (to armor during erosive flows), and aid channel-forming processes (habitat formation of pools and riffles) and meanders.

- The sewer pipe running along the lower quarter of the reach should be evaluated for leaks and breaks. Sewage leaking from the pipe may significantly impact riparian condition and water quality.

- Fish access into this reach of Tryon Creek could be improved by retrofitting or replacing the State Street culvert. This culvert is impassable nearly year-round and under most hydrologic conditions. Adult winter steelhead may navigate through the culvert during very opportune periods, but other species (such as coho and coastal cutthroat) probably do not pass above the barrier.

Tryon 3A: Lower Park

FLOODPLAIN CONDITION

The valley is predominantly U-shaped, with a narrow floodplain/floodway (although some wider terraces are present). The average VWI is 7.8, and stream gradient is very low (0.6 percent), suggesting that floodplain functions were historically significant in this portion of Tryon Creek. The channel is currently constrained by multiple terraces. It meanders through the valley bottom and probably interacts with adjacent riparian and floodplain habitats during some times of the year. However, channel scouring and incision probably minimize potential floodplain interactions. The floodprone width is not significantly greater than the active channel width (1.3 times greater), indicating that flood flows do not regularly extend beyond the active channel width and floodplain interactions are limited.

Floodplain expanses increase at tributary junctions, most notably at Palatine Hill drainage, Red Fox Creek, and Park Creek. The entire reach lies within Tryon Creek State Natural Area and is zoned as greenspace.

RIPARIAN CONDITION

Riparian condition is considered very good (ODFW 2001), with riparian widths greater than 250 feet and no perceived breaks in riparian connectivity. Foot trails, bridges, and a sewer line interact with the riparian corridor. A manhole was noted in the active channel (ODFW 2001).

The dominant tree class includes medium-sized (second-growth) deciduous trees (ranging from 15-30 cm dbh). Grasses and forbs are common in the understory, and climbing clematis forms part of the overstory canopy. Canopy coverage is high, ranging from 75-87 percent within the immediate 30 meters of the stream channel. High terraces and hillslopes form the riparian and floodplain area. The northern hillslopes provide greater vegetative cover than the southern hillslopes (Figure 7 of 15, BES Vegetative Cover).

Two earthen flows were noted during the 2000 ODFW stream surveys. Both slides/flows were considered inactive, but not stabilized, indicating that the slide probably occurred during winter 1999 or during recent high flows.

STREAM CONNECTIVITY

Stream connectivity is good throughout the subreach in both upstream and downstream directions. Two foot bridges (Red Fox and Iron Mountain) pass over the creek, and a sewer line parallels the creek. Neither the bridges nor the sewer line is believed to disrupt stream connectivity. Two beaver ponds were noted during the ODFW 2001 stream surveys. The dams average 0.25 meter and 0.35 meter, respectively, and may temporarily impede fish movement during low flows.

REFUGIA

Primary in-channel refugia are probably found near seeps and springs, undercut banks (30 percent of bank form), and near wood clusters. The two beaver ponds probably provide important overwinter habitat and refugia during higher storm flows.

Off-channel refugia exist in Red Fox Creek and Park Creek. The extent of their use by mainstem fish populations is not known.

The wider valley bottom may also provide opportunities for floodplain-related refugia during peak flow events.

CHANNEL CONDITIONS AND HABITAT STRUCTURE

This portion of Tryon Creek exhibits unstable banks, with 66 percent actively eroding banks. However, bank slope is relatively low (6 percent), indicating that the channel (although erosive, with exposed soils) is interacting with its floodplain to attenuate storm flows.

The dominant habitat types are scour pools (57 percent) and riffles (29 percent). Substrate is a mixture of cobbles, gravels, sand, and fines. Riffle area is moderately low, but riffle quality is relatively good; 75 percent of riffle habitat has 35 percent or more gravel substrate. Although the percent gravel composition is optimal, however, 55 of these riffles have 12-25 percent fines in the substrate (marginal conditions), and only 21 percent have less than 12 percent fines (desirable conditions). Relative to other subreaches in Tryon Creek, this subreach is in good condition, with the second-highest proportion of optimal riffle habitat basinwide.

Pool quality is very good throughout the subreach, relative to desirable fish habitat and relative to other subreaches within Tryon Creek. Pool area constitutes 65 percent of stream habitat. More than half the pools (53 percent) have depths greater than 0.5 meter, and the remainder have depths between 0.2 and 0.5 meter. In addition to deep pools, pools contain wood, yielding 13.5 complex pools per 100 meters of stream length. This is the most of all the reaches surveyed, and more than five times the amount considered desirable for fish-bearing streams.

Wood counts are relatively high throughout the subreach, with 54 pieces per 100 meters of stream length. Of all the subreaches surveyed in Tryon Creek, this reach contains the most wood per stream length, and is the only reach that contains key pieces of wood. In addition, ODFW noted two significant debris jams that were not associated with beaver activity. As noted above under Riparian Condition, tree cover is intact and will probably provide long-term sources of woody debris.

Two beaver ponds constitute 424 square meters of wetted area. Both ponds have associated beaver dams that average 0.25 meter and 0.35 meter in height, respectively, and are located approximately 250 meters downstream of the confluence with Park Creek.

EVALUATION OF TRYON 3A: LOWER PARK

- The lower reach in Tryon Creek State Natural Area contains critical fish-bearing habitat, riparian habitat, and floodplain habitat. This area should be protected, and recreational use should be minimized in the riparian corridor and instream. Specifically, pool quality (pool area, pool depths, and number of complex pools), large wood counts, and instream structure are favorable for fish productivity. Compared to other reaches in Tryon Creek, riffle habitat is good quality: 75 percent of the riffles have optimal gravel composition, and 21 percent have less than 12 percent fines (desirable condition). This reach has the best wood structure of all the reaches in the subbasin.

- Although riffle quality is relatively good in this reach, actions to minimize sediment load into Tryon Creek should be considered. Amassed sediments may cover spawning grounds, and sediments may limit epifaunal production and subsequent macroinvertebrate production.

- Increasing the amount and density of large wood would undoubtedly improve instream refugia, add channel roughness (to armor during erosive flows), and aid channel-forming processes (habitat formation of pools and riffles) and meanders.

- Floodplain connectivity with the stream channel should be enhanced. The channel appears to meander through the valley floor; however, it does not significantly interact with the floodplain. Improved connectivity with the floodplain and riparian corridor would allow the creek to adjust to differing flows, attenuate flood flows, and minimize flow-related bank erosion. Other indirect benefits of enhancing floodplain interactions include retaining woody debris and other instream structure, and stabilizing habitat-forming processes (riffle/pool formations).

- Beaver activity should be encouraged and retained. Beaver ponds provide important flood storage and high-flow winter refugia to fish. They are also sources of large wood clusters that provide cover to fish in both the pond and downstream creek.

- Connectivity to Red Fox Creek and Park Creek should be retained. Both tributaries probably provide important off-channel refugia to resident fish, and their flows augment Tryon Creek base flow year-round.

Tryon 3B: Middle Park

FLOODPLAIN CONDITION

Floodplain conditions in the middle park reach are similar to floodplain conditions in the lower park (Tryon 3A). The valley is a bit broader (with an average VWI of 10.6), generally U-shaped, and constrained by multiple terraces. Stream gradient remains low (0.5 percent). Floodprone width is greater than the active channel width, indicating that flood flows top the bank and run into the adjacent floodplain. This portion of Tryon Creek continues to be protected within the confines of Tryon Creek State Natural Area.

This reach of Tryon Creek interacts with the floodplain similarly as downstream reaches, except that the stream gradient is lower, VWI is broader, and entrenchment ratio is generally larger (i.e., flood flows span into the floodplain proportionally more than the adjacent downstream reach). The potential to reestablish or enhance floodplain interactions throughout this reach may therefore be easier (or more attainable) than in other mainstem reaches. Because Tryon Creek is relatively bound by steep valley walls, intact floodplain interactions probably played a critical role in maintaining properly functioning watershed conditions. For example, intact aquatic land interactions probably allowed the creek to adjust to higher storm flows (by meandering from hillslope to hillslope) and probably maintained summer base flows via springs, seeps, and hyporheic flows.

RIPARIAN CONDITION

Riparian condition in the middle park reach is similar to that in the lower park reach, except that more wetlands were observed in Tryon 3B during the 2000 habitat surveys. In addition, three foot trails run along and cross the creek and probably disrupt riparian functions more than in the adjacent downstream reach. The three footbridges include Obies, Beaver, and High Bridge. Other human constructs include a buried sewer line, a stormwater (or sewer) pipe entry, and a pump station (and associated screened water diversion) (ODFW 2001).

Canopy cover varies from 5 percent to greater than 95 percent, averaging 75-87 percent throughout the reach (PHS 1997; ODFW 2001). The overstory canopy is dominated by mature second-growth deciduous trees (big leaf maple, vine maple, and red alder) and conifers (Douglas fir), ranging from 15 to 30 cm dbh. High terraces and hillslopes form the riparian and floodplain area.

An inactive earthen flow was noted approximately 100 meters upstream of Beaver footbridge.

STREAM CONNECTIVITY

Stream connectivity throughout the reach is relatively good. Three artificial structures cross Tryon Creek, ranging from 0.20 to 0.35 meter high. Some or all of these barriers may impede fish movement, particularly during low summer flows. In addition, the SW Boones Ferry Road culvert bounds the upper end of this reach. The culvert is long (approximately 150 feet) and steep (2.0 percent slope), and jump height into the culvert outlet is at the maximum end of that considered navigable by fish (12 inches). A trash rack that hangs over a concrete platform is present at the culvert inlet. This structure is considered completely impassable to anadromous and resident fish moving upstream.

REFUGIA

Instream refugia are associated with a larger number (eight to 12) of small springs and seeps. Groundwater inflow varies from little or none to strong throughout isolated areas of the reach. These inflow areas may provide critical ecological functions during the summer by providing thermal refugia and maintaining summer flows.

Instream refugia associated with habitat structure are limited. Undercut banks may provide some cover. Very little woody debris or other instream structure or cover exists within the reach, and only a few large woody debris complexes have been noted.

Two tributaries enter Tryon Creek in this reach and probably provide winter and summer habitat (off-channel refugia). The tributaries are not named and are believed to be intermittent.

CHANNEL CONDITION AND HABITAT STRUCTURE

Channel banks are actively eroding (66 percent) and are unstable. ODFW noted channelized streambanks throughout the entire reach. However, bank slope is low (6 percent), indicating that although creek banks are probably exposed and erosive, the channel has not yet become incised or channelized. Unlike Tryon 3A, the channel is relatively straight and does not currently exhibit sinuosity.

Habitat consists of pools (55-60 percent) and riffles (26-28 percent). Stream-bottom substrates comprise a mixture of cobbles and gravels and are considered optimal for spawning and rearing. Riffle area is moderately low, and riffle quality is poor. Riffles are significantly covered in fine sediment and organic material; approximately 74 percent of them have greater than 25 percent fine organic matter overlying riffle substrate. These high sediment loads undoubtedly limit the potential habitat value in this reach. Riffle habitat found in the upper reach of Tryon 3B (the upper 400 meters) is in excellent quality; 100 percent of the riffle habitat has greater than 35 percent gravels, and the substrate is not embedded or covered with fines. Large sand is relatively absent, but gravel bars and sediment deposits are common.

Pool area is moderately high (57 percent), and pool quality is generally good, based on depth. Of those pools present, 72 to 81 percent are greater than 0.5 meter deep, with the highest proportion of deep pools found in the upper portion of the subreach. The remaining pools are greater than 0.2 meter, but less than 0.5 meter, deep. Pool complexity varies within the subreach, with 7.6 complex pools in the lower two-thirds of the stream reach (more than three times the number considered desirable for fish habitat). No complex pools were found in the upper third of the subreach.

Wood counts per stream length are considered fair throughout the subreach (34 pieces); however, wood volume is low and key pieces are rare. Current conditions (second-growth forest of mixed conifer and deciduous species) indicate that long-term large wood recruitment is feasible; however, channel morphology (straight) and condition (channelized stream bank) may prevent large wood from being retained.

A culvert (stormwater or sewer pipe) enters Tryon Creek approximately 120 meters downstream of SW Boones Ferry Road. A screened diversion/pump system was also noted at this location.

EVALUATION OF TRYON 3B: MIDDLE PARK

- The middle park reach contains a high proportion of pool habitat, and deep pools. These areas probably provide critical refuge to salmonids during low-flow and high-flow seasons. This area should be protected, and recreational use in the immediate riparian corridor and instream should be minimized. Substrate composition in riffle habitats in the upper 400 meters of this reach is of excellent quality; 100 percent of the riffle habitat has greater than 35 percent gravels, and the substrate is not embedded or covered with fines (More than 72 percent of the riffle habitat has less than 12 percent fines). In the lower portion of the reach, substrate composition in riffle habitats is considered very good; in 81-100 percent of the riffles, gravels constitute 35 percent or more of the habitat. However, the great spawning and rearing potential in this segment is severely impaired by the high proportion of fines present on the stream bottom; approximately 74 percent of the riffle habitats have greater than 25 percent fines covering the substrate. Amassed sediments may cover spawning grounds, and sediments may limit epifaunal production and subsequent macroinvertebrate production. Actions to minimize sediment load into Tryon Creek should be considered.

- Increasing the amount and density of large wood would undoubtedly improve instream refugia, add channel roughness (to armor during erosive flows), aid channel-forming processes (habitat formation of pools and riffles), and meanders.

- Floodplain connectivity with the stream channel should be enhanced. Improved connectivity with the floodplain and riparian corridor would allow the creek to adjust to differing flows, attenuate flood flows, and minimize flow-related bank erosion. Other indirect benefits of enhancing floodplain interactions include retaining woody debris, stabilizing stream banks, retaining instream structure, and stabilizing habitat-forming processes such as riffle/pool formations.

- Replacing or retrofitting the SW Boones Ferry Rd. culvert would provide year-round access to upper mainstem Tryon Creek (to SW Maplecrest Drive) and Arnold Creek. Habitat quantify and quality in Tryon Creek and Arnold Creek should be thoroughly evaluated to establish plausible expectations (in terms of fish productivity) if upper Tryon Creek were accessible. Specifically, if the habitat is of low quality in these reaches, providing access still may not increase fish productivity within the Tryon Creek Basin.

- The water withdrawal (pump station) approximately 120 meters downstream of SW Boones Ferry Road should be investigated. This should include quantification of water withdrawal characteristics (volume, rate, and timing) and an evaluation of the screens.

- Tributary flow contributions of the two intermittent creeks should be evaluated to determine annual flow characteristics, hydrologic connectivity with Tryon Creek, and use by resident fish.

Tryon 4A: Upper Park

FLOODPLAIN CONDITION

This segment of Tryon Creek lies within the upper portion of Tryon Creek State Natural Area. The channel is relatively confined by terraces and hillslopes (VWI of 5), and stream gradient is moderately steep (2.3 percent), indicating that floodplain functions are spatially constrained and temporally short.

RIPARIAN CONDITION

Riparian condition (and wildlife value) are good to excellent (BES and Brown and Caldwell 1997; ODFW 2001). Riparian corridors are intact, wide (over 250 feet), and not fragmented. Forest canopy is dominated by large deciduous trees (30-50 cm dbh), grasses, and forbs. Maples and cedars predominate. Tree canopy cover is moderate, increasing from 33 to 51 percent from the stream bank out to the edge of the riparian corridor (0-30 meters). Few areas with less than 25 percent vegetative cover exist (Figure 7 of 15, BES Vegetative Cover). High and low terraces and hillslopes characterize riparian land forms.

STREAM CONNECTIVITY

The SW Boones Ferry Road culvert isolates this segment of Tryon Creek from downstream habitats and fish populations. The culvert is long (approximately 150 feet), steep (2.0 percent slope), and jump height to the culvert outlet is at the maximum end extent of that considered navigable by fish (12 inches). The upper end of the reach is bound by the SW Maplecrest Drive culvert, which is long (80 feet), steep (over 2.0 percent slope), and perched (12 inches). The culvert is considered impassable to resident fish.

Within this portion of Tryon Creek, stream connectivity is fragmented by numerous steps. During the ODFW 2001 surveys, steps were characterized as concrete weirs, concrete steps, step logs, and step cascades. These structures vary in height, ranging from a 0.15-meter drop to 0.8-meter drop. These natural and manmade instream barriers probably impact resident fish movement, specifically during low flow periods.

REFUGIA

Instream refugia are limited throughout the reach; few or no backwater pools and side channels are present, and undercut banks are few. Large wood probably provides the best instream structure. Springs and seeps (noted on the south bank) probably provide important hyporheic flows during the summer. Tributaries and intermittent creeks probably provide important off-channel refugia during winter and cool stream temperatures in the summer.

Arnold Creek provides important off-channel tributary habitat.

CHANNEL CONDITION AND HABITAT STRUCTURE

Channel conditions are generally fair to good throughout the subreach, but are considered sub-optimal in the lower segment, immediately above the SW Boones Ferry Road culvert. Surveys conducted in 1997 showed excessive sediment immediately upstream of SW Boones Ferry Road

(BES and Brown and Caldwell 1997). Banks are unstable (58 percent actively eroding) and are channelized throughout the upper 150 meters.

Channel complexity and diversity is generally low. Habitat is characterized as riffle/step forms in the lower reach; rapids at mid-reach; and pool/step forms in the upper reach. Steps formed by concrete, logs, and cobbles are common throughout this reach. Pool area is comparatively lower than in downstream reaches. This upper park reach has only 34 percent pool area (moderate), and only 35 percent of the pool habitat is greater than 0.5 meter deep (considered desirable for fish-bearing streams). Remaining pools range from 0.2 to 0.5 meter deep, and are considered moderate fish habitat. This subreach marks the upstream extent where complex pools are present; it has 2.1 complex pools per 100 meters stream length.

Wood density is low (3.82-m3/100 meters); it is considered undesirable for fish habitat, but is relatively good compared to other subreaches within Tryon Creek. This subreach marks the upstream extent of where wood counts are greater than 10 pieces per 100 meters of stream length (marginal habitat condition); habitat quality associated with wood counts and densities is considered undesirable upstream of this subreach.

Stream-bottom substrates are mixed, comprising fines, gravels, and coarse cobbles. Riffle habitat is generally considered desirable; 71 percent has more than 35 percent gravel composition. However, riffle quality is impaired by amassed sediments and fines overlying the riffle habitat; 81 percent of the riffle area has between 12 and 25 percent fines, and 15 percent has more than 25 percent fines. These amassed sediments probably impair habitat quality and fish productivity.

Bedrock is common mid-reach, where stream channelization was also noted (ODFW 2001). This reach lies immediately downstream of a culvert outlet approximately 25 meters downstream of SW Maplecrest Drive.

EVALUATION OF TRYON 4A: UPPER PARK

- This subreach marks the upstream extent of where wood counts are greater than 10 pieces per 100 meters of stream length, and pool quality is marginal. Instream structure associated with large woody debris and depth refugia are severely lacking upstream of Tryon Creek State Natural Area. Increasing the amount and density of large wood would undoubtedly improve instream refugia, add channel roughness (to armor during erosive flows), and aid channel-forming processes (habitat formation of pools and riffles) and meanders.

- This subreach marks the upstream extent of where desirable pool conditions are present. Although riffle habitats have adequate gravel composition, they are largely covered in fine sediments, severely limiting the potential of these habitats to support salmonid rearing. Actions to minimize sediment load into Tryon Creek should be considered.

- Floodplain connectivity with the stream channel should be enhanced. Improved connectivity with the floodplain and riparian corridor would allow the creek to adjust to differing flows, attenuate flood flows, and minimize flow-related bank erosion. Other indirect benefits of enhancing floodplain interactions include retaining woody debris, stabilizing stream banks, retaining instream structure, and stabilizing habitat-forming processes such as riffle/pool formations.

- Replacing or retrofitting SW Boones Ferry Road culvert would provide year-round access to this reach and Arnold Creek. Habitat quantity and quality in this portion of Tryon Creek and Arnold Creek should be thoroughly evaluated to establish plausible expectations (in terms of fish productivity) if this portion of Tryon Creek were accessible. Specifically, if the habitat is of low quality in these reaches, providing access still may not increase fish productivity within the Tryon Creek Basin.

- Replacing or retrofitting SW Maplecrest Drive would provide year-round access to an additional segment of Tryon Creek (Tryon 4B). Habitat quantity and quality in this portion of Tryon Creek should be thoroughly evaluated to establish plausible expectations (in terms of fish productivity) if this portion of Tryon Creek were accessible. Specifically, if the habitat is of low quality in these reaches, providing access still may not increase fish productivity within the Tryon Creek Basin.

- The stormwater and/or sewer pipe outlet approximately 25 meters downstream of SW Maplecrest Drive should be investigated to determine its water source, flow contribution (volume, rate, and timing) and water quality. ODFW notes that Tryon Creek is channelized where the culvert enters the creek and immediately downstream (13+ meters) of the outlet.

- Connectivity to Arnold Creek should be retained, and tributary flow should be evaluated. Arnold Creek provides important base flows to Tryon Creek and probably provides important off-channel refugia to resident fish.

Tryon 4B: SW Maplecrest Drive to Marshall Cascade

FLOODPLAIN CONDITION

The floodplain (and valley bottom) is broad (VWI = 10.5), and the channel gradient is moderately steep (3.1 percent). There is therefore great potential for aquatic/land interactions between Tryon Creek and its floodplain, especially during higher flows. However, residential development impacts the floodplain, particularly along the northeast side of the creek, which consequently receives the highest solar input. Vegetation is partially landscaped, and areas of open pasture and cleared land exist. Part of this subreach is within Marshall State Park.

RIPARIAN CONDITION

Riparian integrity is fair to poor (ODFW 2001). Tree canopy cover is relatively low (0-20 percent) near the stream bank (0-20 meters). Common tree species include maple and alder. Shrubs and grasses provide the greatest amount of shade (or cover) throughout the entire riparian area. The understory is sparse because of footpaths and other recreational uses. Hiking trails transect steep banks (and cliffs) and are often on top of the stream bank in Maplecrest Park. Hyporheic conditions have not been documented.

The SW Maplecrest Drive culvert and residential landscaping fragment the riparian corridor. The southwest side of the stream corridor maintains higher canopy cover within Marshall State Park. However, much of the riparian area has been cleared of mature trees. Lawns, pastures, and other human use are common, and wetland habitat is rare.

STREAM CONNECTIVITY

The SW Maplecrest Drive culvert (which bounds the downstream reach break) is considered completely impassable because of its length, slope, and outlet drop. Stream connectivity to the upstream reach is impaired at Marshall Cascades, a natural fish barrier.

Marshall Cascades is long (60 meters, or approximately 200 feet) and impairs fish passage during most periods of the year. Some opportunities for passage may exist during high storm flows, when creek depth is high enough to allow movement beyond the cascade, boulder, and bedrock rapid reach. This cascade reach probably marked the end of anadromy for winter steelhead. It is (and was) undoubtedly a barrier to resident populations during most of the year.

REFUGIA

Instream refugia are limited within the reach because of the absence of large wood or rocks, bank erosion, fragmented riparian areas, and an absence of channel diversity. The primary refugia are found in deep pools and among small wood clusters.

Two tributaries enter Tryon Creek near river mile 3.3 and probably provide some off-channel refugia. These tributaries have fish passage barriers approximately 0.2 mile from their confluence with Tryon Creek, but probably provide important winter refugia to Tryon Creek populations during high flows.

CHANNEL CONDITION AND HABITAT STRUCTURE

Fish habitat is considered sub-optimal (BES and Brown and Caldwell 1997). Stream banks are partially eroded (58 percent), but some areas are stable. ODFW 2001 survey notes show that Tryon Creek is channelized throughout most of the reach. Stream bank development, manmade bank structures, and the SW Maplecrest Drive culvert significantly impact natural habitat-forming processes. In addition, the absence of large boulders and large wood (wood density = 0.39-m3/100 meters and wood count = 3 pieces/100 meters), coupled with lack of streamside and instream vegetation, reduces the amount and quality of instream structure and fish habitat.

Stream-bottom substrate composition is fair, with a mix of substrate types. ODFW data indicate that gravel composition in riffles is desirable; for all surveyed riffles, gravels constituted greater than 35 percent of the stream-bottom substrate. Similar to downstream reaches (Tryon 4A and most of Tryon 3B), however, sediments and fines impair riffle habitat quality. Fines constitute between 12 and 25 percent of the substrates in all riffle habitat, yielding marginal riffle quality. Rapids formed by boulders are common.

Pool area is extremely low (7-9 percent), and no complex pools with wood are present. Approximately one-half of the pools are greater than 0.51 meter deep, providing some depth refugia.

A culverted pipe enters Tryon Creek approximately 25 meters upstream of SW Maplecrest Drive.

EVALUATION OF TRYON 4B

- Riparian widths and riparian continuity are significantly reduced within private (residential) parcels of land. Instream structure is lacking within the stream reach. Floodplain connectivity, riparian condition, and habitat structure and condition could probably be improved by planting native shrubs and trees in the riparian corridor and broader floodplain area. Key benefits that additional plant cover would probably provide include stabilizing creek banks and channel, providing additional canopy cover, providing instream woody structure (small wood clusters and allochthonous inputs for macroinvertebrates and fish), and attenuating creek flows.

- The absence of large wood and boulders limits habitat structure and compromises the area's benefit as potential fish habitat. Lack of pool area and complex pools limits potential salmonid rearing. Increasing the amount and density of large wood would undoubtedly improve instream refugia, add channel roughness (to armor during erosive flows), and aid channel-forming processes (habitat formation of pools and riffles) and meanders.

- Excellent riffle substrate exists; however, amassed sediments probably impair potential habitat quality. One hundred percent of the riffle habitats are considered marginal, with more than 12 percent fines covering stream bottom substrates. Actions to minimize sediment load into Tryon Creek should be considered.

- Replacing or retrofitting SW Maplecrest Drive would provide year-round access to an additional segment of Tryon Creek (Tryon 4B). Habitat quantity and quality in this portion of Tryon Creek should be thoroughly evaluated to establish plausible expectations (in terms of fish productivity) if this portion of Tryon Creek were accessible. Specifically, if the habitat is of low quality in these reaches, providing access still may not increase fish productivity within the Tryon Creek Basin.

- Marshall Cascades is a natural cascade that probably impairs fish passage during most periods of the year. Some opportunities for passage may exist during winter flows, when creek depth is high enough to allow movement beyond the cascade, boulder, and bedrock rapid reach. In addition to impeding resident fish movement, the cascade was probably the end of anadromy for most salmonid populations.

- The stormwater and/or sewer pipe outlet approximately 25 meters upstream of SW Maplecrest Drive should be evaluated to determine its water source, flow contribution (volume, rate, and timing), and water.

- Tributary flow contributions of the two intermittent creeks should be evaluated in terms of annual flow characteristics, hydrologic connectivity with Tryon Creek, and use by resident fish.

Tryon 4C: Marshall Cascade (upstream to 18th Pl.)

FLOODPLAIN CONDITION

Stream gradient is moderately steep (2.7 percent). The floodplain and floodway are narrower than Tryon 4A and Tryon 4B, with a VWI of 8.0. The floodplain is generally considered disconnected from the stream channel.

RIPARIAN CONDITION

Riparian condition varies throughout the stream reach, ranging from low to high in alternating segments (BES and Brown and Caldwell 1997). The riparian corridor is formed by high and low terraces and hillslopes. The vegetated corridor is generally greater than 100 feet in width and is minimally fragmented. SW 18th Place bounds the upper end of the reach. Tree canopy is intact and continuous, and is characterized by mixed conifer/deciduous second-growth forest. Common tree species include big leaf maple and Douglas fir.

STREAM CONNECTIVITY

Marshall Cascades characterizes this entire reach and impedes fish movement throughout. Marshall Cascades is long (60 meters, or approximately 200 feet) and impairs fish passage during most periods of the year. Some opportunities for passage may exist during high storm flows, when creek depth is high enough to allow movement beyond the cascade, boulder, and bedrock rapid reach. This cascade reach probably marked the end of anadromy for winter steelhead. It is (and was) undoubtedly a barrier to resident populations during most of the year.

SW 18th Place also impairs stream connectivity to upstream reaches. This barrier bounds the upstream extent of the reach and is considered completely impassable, based on length (70 feet) and slope (velocity barrier).

REFUGIA

Pools probably provide the best instream refugia. An intermittent tributary probably provides some off-channel refugia, particularly during high flows.

CHANNEL CONDITION AND HABITAT STRUCTURE

Channel conditions are fair to good, but are considered sub-optimal for fish rearing throughout much of the reach (BES and Brown and Caldwell 1997). Primary habitat includes rapids, cascades, and steps formed by both bedrock and boulders. Pocket pools within these fast water habitats are present, but do not provide substantive pool area or depth.

The following observations were made during one field visit (100 feet below SW 18th Place) in May 2003 (personal communication, Chad Smith and Cindy Studebaker):

- Storm flows have eroded the stream banks and downcut the stream channel to bedrock substrate in the upper portion of the reach.

- Water currently fills greater than 25 percent of the creek channel, and channel substrates are mostly exposed in non-pool habitats.

- The only area where the creek appears to be confined is at SW 18th Place. The remaining portion of the reach is relatively unconstrained, although downcut to bedrock hardpan.

- Stream banks are relatively stable and show little evidence (approximately 5 percent) of erosion or bank failure.

- Scour pools and rapids dominate the lower subreach; cascades, rapids, and bedrock pools dominate the upper reach (approximately 100 feet below SW 18th Place.). Approximately 70 percent sediment deposition overlying bedrock substrate just below SW 18th Place.

- Large wood count (six pieces per 100 meters of stream length) and density (3.5-m3 per 100 meters of stream length) are low (undesirable).

EVALUATION OF Tryon 4C: MARSHALL CASCADE

- Marshall Cascades is a natural cascade that probably impairs fish passage during most periods of the year. Some opportunities for passage may exist during winter flows, when creek depth is high enough to allow movement beyond the cascade, boulder, and bedrock rapid reach. In addition to impeding resident fish movement, the cascade was probably the end of anadromy for most salmonid populations.

- Replacing or retrofitting the SW 18th Place culvert may not provide additional access to Tryon Creek. This culvert lies immediately above Marshall Cascade, which is considered a natural barrier to resident fish. Fish populations that persist above the cascade reach have probably been isolated from downstream populations for many years. Some fish may have historically passed above Marshall Cascades in the past, but it was probably during very discrete periods.

- Based on habitat form, it is unlikely that fish reside in this reach for prolonged periods of time. The reach is steep, provides very little cover, lacks substantive pool area, and lacks typical rearing habitat (riffle type habitat) that is characteristic of fish-bearing streams. In addition, absence of instream refugia, preponderance of bedrock substratum, and lack of substantive pool habitat may send fish downstream during peak flows. Increasing the amount and density of large wood would undoubtedly improve instream refugia, add channel roughness (to armor during erosive flows), and aid channel-forming processes (habitat formation of pools and riffles) and meanders.

Tryon 4D: SW 18th Place to Quail Creek

FLOODPLAIN CONDITION

Floodplain condition is similar to downstream reaches, except that homes are a more prominent land use and feature in the floodplain.

RIPARIAN CONDITION

Riparian integrity is considered fair to poor, and wildlife habitat value is considered low (BES and Brown and Caldwell 1997). Riparian areas are fragmented by homes, landscaped yards, and a relatively narrow riparian corridor (less than 100 feet in width). Common tree species include cedar, alder, hemlock, and maple. Tree canopy coverage varies from 10 to 100 percent within the riparian area (Figure 7 of 15, BES Vegetative Cover). In areas with sparse overstory canopy, grasses and forbs dominate. Residential development entirely surrounds the riparian corridor (and surrounding floodplain) in the upper portion of the reach. Much of the subreach has been channelized, or the banks have been modified to protect residences.

A bridge (driveway) crosses Tryon Creek approximately 150 meters downstream from SW Lancaster Drive. This driveway spans the creek; although it does not impair stream connectivity, it undoubtedly impacts riparian connectivity.

STREAM CONNECTIVITY

The culvert that runs under SW 18th Place completely blocks stream connectivity to downstream reaches. The culvert is relatively long (70 feet) and steep (over 2.0 percent) and is considered a velocity barrier. SW Lancaster Road completely blocks fish movement into upstream reaches. The culvert running under SW Lancaster Street is also steep (> 2.0 percent) and moderately long (50 feet).

Connectivity within the upper 200 meters is poor, with numerous steps formed by bedrock, boulders, and artificial structures (e.g., dams, weirs). These steps range from 0.1-1.6 meters in height.

REFUGIA

The confluence of Tryon Creek and Quail Creek and the confluence of Tryon Creek and Burlingham Creek provide moderate habitat value (BES 1997) and, presumably, off-channel refugia. Boulders are prevalent from the mid- to upper reach and may provide high-water refugia in cascades and rapids.

CHANNEL CONDITION AND HABITAT STRUCTURE

A 1993 study found marginal fish habitat in this reach of Tryon Creek. The reach is bound by culverts on the upstream and downstream extent and is significantly fragmented in the upper portion. In addition, stream banks are landscaped and lined with rock walls (BES and Brown and Caldwell 1997). Private homes are abundant and are very close to (and encroach into) the immediate riparian corridor.

Rapids, cascades, and steps formed by bedrock and boulders are common in the lower 140 meters, then transition to sequences of shallow pools for approximately 300 meters. Rapids and steps dominate the upper 370 meters. Channels are scoured in isolated areas, but scouring is not prevalent throughout the entire reach (ODFW 2001). Gravels are common in the lower reach; boulders are common from mid-reach through the upper reach; and bedrock is common throughout. Woody debris is severely lacking throughout the reach; abundance and volume are low, and no key pieces were noted (ODFW 2001).

EVALUATION OF TRYON 4D:

- Rapids and cascades dominate instream habitat in the lower and upper reach. Pools found mid-reach might provide some rearing habitat. Instream structure is noticeably lacking. Resident fish may use this reach for temporary rearing or for transport, but probably do not rear year-round. Lack of riffle and substantive pool habitat, along with a preponderance of cascades, rapids, and shallow pools, probably limit year-round rearing. This area may provide important transitory habitat.

- Stream banks are heavily impacted by residential development and associated landscaping and rock embankments. Riparian widths and riparian continuity are significantly reduced within private (residential) parcels of land. Floodplain connectivity, riparian condition, and habitat structure and condition could probably be improved by planting native shrubs and trees in the riparian corridor and broader floodplain area. Runoff of chemicals and other contaminants from residential areas and streets (e.g., sediments, pesticides, oils, metals, fecal wastes) may be a significant contaminant source.

- Additional plant cover would probably provide key benefits, including stabilizing creek banks and channel, providing additional canopy cover, providing instream woody structure (small wood clusters and allochthonous inputs for macroinvertebrates and fish), and attenuating creek flows. Increasing the amount and density of large wood into Tryon Creek would undoubtedly improve instream refugia, add channel roughness (to armor during erosive flows), and aid channel- forming processes (habitat formation of pools and riffles).

- Because Tryon 4D does not provide substantive fish-bearing habitat, removing or retrofitting the SW 18th Place culvert and Lancaster Road culvert may not substantially improve resident fish productivity. Fish could access Quail Creek and Burlingham Creek; fish presence/absence and productivity in these two tributaries is not currently known. Habitat quality and quantity in upstream reaches should be evaluated before considering removal (or retrofit) of the Lancaster Road culvert.

- Connectivity to Quail Creek and Burlingham Creek should be retained. The flow contributions from these tributaries should be evaluated in terms of hydrologic connectivity and annual flow characteristics. Both tributaries probably provide critical flows during low-flow periods and are important for peak flow attenuation. Tributary flow may also impact downstream water quality (temperature, sediments, and toxics).

Tryon 4E: Falling Creek

Conditions on this short subreach are similar to Tryon 4D; however, stream banks are heavily landscaped and homes abut the creek bank. Falling Creek enters Tryon Creek at the upper end of the subreach. The confluence of these two systems may provide critical refugia for residing fish and other aquatic species. The upper extent of this reach (Tryon 4E/Tryon 5) is bound by Taylors Ferry Road, which is considered passable.

The following observations were made just below SW Taylors Ferry Road in May 2003 (personal communications, Chad Smith and Cindy Studebaker):

- The effective riparian corridor is very narrow and does not extend above the terraced bank. Landscaped yards probably provide important vegetative cover and canopy; however, natural vegetative structure is lacking, and lawns create unnatural riparian habitat.

- Vegetative canopy cover generally ranges from 25–50 percent, with some areas greater than 75 percent. The more vegetated areas generally abut the creek bank.

- The creek is relatively channelized. SW Taylors Ferry Road effectively constrains a segment of the reach, and lawns and homes constrain the creek by forming high terraces. Although the creek is not straight, there is very little opportunity for it to top its bank during high flows.

- Although landscaped yards abut both sides of Tryon Creek and vegetation is present on the stream bank and instream, coarse particulate organic matter in the creek is low (less than 20 percent).

- Creek banks are moderately unstable, with significant areas actively eroding and void of stream bank vegetation. Patches of bare soil are common.

- The predominant substrate is cobbles (60 percent) and gravels (20 percent), with greater than 85 percent sediment and silt deposition on top of larger substratum.

- Riffles and pools are common, and stream gradient is low.

- Pools are of relatively good quality. The substrate is considered optimal, with mixtures of gravels and firm sands, and pools are deep compared to the prevailing creek depth.

Tryon 5: Headwaters

Floodplain condition, riparian condition, instream habitat, and hydrology are not well documented in this reach. The following evaluation is based on aerial photographs, anecdotal information, past reviews, and personal communications:

- Flooding occurs when culverts at I-5/ SW Barbur Boulevard, SW Dolph Court, SW 30th Avenue, and Spring Garden are backed up.

- Riparian areas are highly fragmented. Vegetative cover ranges from 25–50 percent downstream of SW Barbur Boulevard and then diminishes to less than 25 percent from SW Barbur Boulevard upstream through the headwater reaches.

- Riparian quality is believed to be best between SW Carson Street and SW Dolph Court. Wetlands are suspected to be present near both roadways.

- Culverts, embankments, and bank modifications are prevalent (and are dominant features) throughout the stream reach. Bank modifications are primarily in place to prevent erosion from streamside residential properties. The impact to fish passage and stream connectivity varies, depending on the culvert.

- Wetlands probably provide the most potential habitat for fish and birds, crustaceans, amphibians, and small mammals. Two tributaries flowing into Tryon Creek provide important off-channel refugia. Both tributaries have impassable roadways approximately 0.1 mile upstream; off-channel refugia is therefore probably limited, although present.

- Stream channel conditions are considered marginal to very poor (BES and Brown and Caldwell 1997). Channel substrates are mixtures of gravels, fines, and lesser amounts of cobbles. BES data show that sediment accumulates just above the Dolph Court culvert because the culvert blocks up and does not properly convey stormwater. Study results also show that the stream channel is incised and marginal-fish bearing habitat. The National Riparian Services Team assessed Spring Garden Creek on October 31, 2001 (WMSWCD 2003b). Based on the channel configuration (drainage ditch), preponderance of storm drains that enter the creek, and number of roadways and driveways that cross the creek, the team determined that the creek was no longer functioning as a stream. They further concluded that the filling of the floodplain and the expansive urban development in this headwater reach is characteristic of other headwater reaches of Tryon Creek.

- Based on the subbasin size and slope, this area is probably an important hydrologic component of the Tryon Creek drainage. Two mapped tributaries flow into Tryon Creek at approximately river mile 4.5 and river mile 4.6, respectively. These tributaries probably augment summer base flows and may provide important hydrologic inputs.

- The headwaters of Tryon Creek are not believed to support salmonids, but may provide critical habitat for other riparian-dwelling and stream-dwelling organisms.

Tributaries to Tryon Creek

Arnold Creek

At least eight intermittent creeks flow into Arnold Creek; one enters in Tryon 1B, and all others enter Arnold Creek above Arnold 1B. These tributaries are not evaluated individually, but probably provide important intermittent flows and potential off-channel refugia to Arnold Creek.

Arnold 1A (Lower Arnold) and Arnold 1B (Cascade Reach)

FLOODPLAIN

The floodway/floodplain is relatively narrow along lower Arnold Creek (VWI is 5.0 for Arnold 1A and 11.5 for Arnold 1B), and flood events are of very limited duration. Stream gradients are moderate in both Arnold 1A (3.1 percent) and Arnold 1B (3.6 percent). Floodplain interactions are not believed to be extensive within this tributary reach, except at the confluence with Tryon Creek.

RIPARIAN INTEGRITY

Riparian and wildlife values are considered high (BES and Brown and Caldwell 1997). Riparian widths are greater than 100 feet along much of the stream corridor. SW Arnold Street parallels the tributary channel and is generally within 100 feet of the creek.

STREAM CONNECTIVITY

Stream connectivity in Arnold Creek is impaired at the Arnold Creek culvert (at 0.1 river mile). This culvert is considered impassable year-round because of slope (3 percent) and perch height (36 inches). The culvert isolates the lower third of the tributary reach from upstream habitat. However, the confluence of Arnold Creek is well connected with Tryon Creek (just upstream of the SW Boones Ferry Rd culvert), and probably provides refuge and additional habitat to rearing fish.

REFUGIA

Refugia within Arnold Creek are non-existent. No off-channel areas and tributaries are present. The confluence of Arnold Creek and Tryon Creek probably provides potential refugia at high flows, but not low flows.

CHANNEL CONDITIONS AND HABITAT STRUCTURE

Channel condition is fair, and fish habitat is considered sub-optimal; stream habitat surveys show numerous areas with incised channels (BES and Brown and Caldwell 1997). Cascades are present at the upper end of Arnold 1B at the SW 16th Place culvert.

Lower Arnold Creek lacks channel complexity because of channel undercutting and low wood. For Arnold 1A, wood count is six pieces/100 meters, and wood volume is 2.9 m3/100 meters. For Arnold 1B, wood count is seven pieces/100 meters, and wood volume is 3.3 m3/100 meters. However, some boulders are present and may provide critical cover and refuge during high flows. Although the existing stream condition does not have adequate amounts and complexities of large wood, the potential for future recruitment is believed to be fair.

Most riffles have good gravel composition; 100 percent of riffles comprise 35 percent or more gravel. The reach is dominated by good riffle/pool sequences. However, all riffle habitats are embedded with fines at concentrations of 12-25 percent of substrate composition. This probably impairs habitat quality.

In Arnold 1A, pool area (52 percent) is considered desirable for fish habitat. Pool depth is largely moderate, with 82 percent of the pools having depths of less than 0.5 meter. This subreach is the only stream segment in Arnold Creek with pool depths greater than 0.5 meter (18 percent of the pools). No complex pools are present in the subreach. Arnold 1B has very low pool area (16 percent), marginal pool condition (100 percent of the pools are less than 0.5 meter deep), and no complex pools.

HYDROLOGY

Data to assess low-flow and peak-flow conditions in Arnold Creek are lacking. It is assumed that peak flows are greater than historical conditions as a result of urban development. This catchment is probably critical for maintaining suitable hydrology and water quality in lower portions of Tryon Creek. Low flows have not been documented; based on the catchment area, however, Arnold Creek probably supplies 1-2 cfs of flow during low-flow periods, and year-round channel flows are believed to contribute approximately one-third of the channel flow to Tryon Creek. One tributary enters Arnold Creek from the south. This creek has not been evaluated, but presumably provides important intermittent flows to Arnold Creek and lower Tryon Creek.

EVALUATION OF ARNOLD 1A AND ARNOLD 1B

- Arnold Creek is the largest tributary to Tryon Creek, and is important for habitat continuity and water quantity and quality. Low summer flows and peak-flow erosion (and channel incising) significantly impact instream habitat conditions and riparian and floodplain interactions in lower Arnold Creek.
- Other key problems and issues in lower Arnold Creek include: 1) The impassible SW 16th Place culvert and a series of waterfalls (both located at the upper end of Arnold 1B) compromise stream connectivity, and 2) Lack of pool area, shallow pools, and absence of complex pools is believed to limit the amount and quality of fish-bearing habitat. Riffle habitats are embedded with fine sediments (and organics) and are considered marginal fish habitat at best, with between 12 and 25 percent fines covering stream-bottom substrates.

Arnold 1C (Middle Arnold) and Arnold 1D (Lancaster)

Limited data are available to effectively characterize this reach. Briefly, the floodplain is narrow (VWI is 3.0 for Arnold 1C and 8.3 for Arnold 1D); however, several flats are interspersed with steeper hillside gradients. Stream gradient is low: 1 percent for Arnold 1C and 1.5 percent for Arnold 1D. The riparian corridor is quite fragmented as a result of residential landscaping and the presence of SW Arnold Street, which in many areas is less than 50 feet from the stream along the northern side. Wetland and hyporheic areas have not been identified. Stream connectivity is marginal, with several driveway culverts. These culverts are not considered significant blockages; however, several areas of steep gradients near river mile 5.0 may impede resident fish passage.

Refugia, channel conditions, and instream structure have not been well documented in these subreaches. ODFW surveys show that wood counts and wood densities are undesirable for fish habitat. For Arnold 1C, wood count is 1 piece/100 meters, and wood volume is 0.12 m3/100 meters. For Arnold 1D, wood count is 6 pieces/100 meters, and wood volume is 1.6 m3/100meters). Arnold 1C has the fewest number of wood pieces and the lowest wood densities in all of Arnold Creek and Tryon Creek combined.

Pool area is considered desirable: 47 percent in Arnold 1C and 41 percent in Arnold 1D. Pool depths are of marginal quality; all pools in both subreaches are less than 0.5 meter deep. No complex pools have been noted in Arnold 1C or Arnold 1D. Arnold 1C has excellent gravel composition in riffle substrates. However, fine sediments constitute more than 25 percent of the substrate in 87 percent of the riffles surveyed. The fine sediments are probably severely impairing the potential habitat quality and water quality. Arnold Creek flows year-round, but with notably shallow flow over rocky sections in some stream reaches.

Four tributaries enter Arnold Creek throughout these two reaches. These tributaries have not been evaluated, but presumably provide intermittent flows to Arnold Creek and lower Tryon Creek.

Arnold 1E (Upper Arnold) and Arnold 1F (Headwaters)

Data are generally insufficient to characterize these two subreaches. Riparian canopy is mixed because of residential development, but largely intact throughout both reaches. Wood counts and wood densities are low (wood count is 11 pieces/100 meters, and wood volume is 3.81 m3/100 meters) relative to optimal fish habitat, but are the highest for all other reaches surveyed in Arnold Creek. Pool area in Arnold 1E is very low, with pools constituting only 4 percent of the stream habitat. These pools are relatively shallow (less than 0.5 meter) and are not considered complex in terms of instream structure and associated large woody debris. Of all reaches surveyed in Arnold Creek, this subreach exhibits the least-desirable pool habitat conditions.

The primary connectivity break is the SW 35th Avenue culvert and high embankment. Both subreaches have steep gradients.

Three tributaries enter Arnold Creek throughout these two headwater reaches. These tributaries have not been evaluated, but presumably provide intermittent flows to Arnold Creek and lower Tryon Creek.

Falling Creek

FLOODPLAIN

Stream gradient is moderate at 4.5 percent, and the floodway is very narrow. The channel and surrounding floodplain were extensively flooded in 1996 (personal communications, Amin Wahab).

RIPARIAN INTEGRITY

The lower reach of Falling Creek has a relatively narrow riparian coverage (over 100 feet wide), is fragmented by residential developments, and is considered to provide low riparian habitat (BES and Brown and Caldwell 1997). The SW 35th Drive culvert and embankment significantly disrupt the riparian area. Little documentation exists about seepage and hyporheic conditions.

STREAM CONNECTIVITY

Falling Creek enters Tryon Creek in Tryon 4F. Lower Falling Creek is connected to Tryon Creek for the first 0.2 mile. SW 26th Avenue crosses the creek here and is considered seasonally passable. The culvert is long (80 feet), but has low drop height (4 inches). In addition to this roadway, SW 35th Avenue and SW Huber Street cross Falling Creek at river mile 0.9 and 1.1, respectively. SW 35th Avenue spans an extensive culverted reach (approximately 500 feet), and SW Huber Street is relatively long and steep; both are undoubtedly fish barriers. Resident fish are not believed to occupy reaches upstream of SW 35th Avenue.

Near river mile 1.5, Falling Creek is piped under Jackson Middle School playfields for approximately 1,330 feet. A trash rack spans the creek immediately before the creek drains into the underground piped network.

REFUGIA

Falling Creek does not provide significant refugia to resident fish. No tributaries converge with Falling Creek, and no other potential refugia have been identified.

CHANNEL CONDITIONS AND HABITAT STRUCTURE

Limited data exist about stream channel conditions in Falling Creek. Studies in 1993 concluded that the reach provided sub-optimal to marginal habitat conditions for fish.

Structural conditions have not been described; however, residential developments occur within 50 feet of the stream on the north side.

HYDROLOGY

Falling Creek experiences year-round flow. Summer conditions may exhibit characteristics of surface seepage and probably do not support fish. However, amphibians, reptiles, mammals, birds, and crustaceans may use the stream reach during these low-flow conditions.

EVALUATION OF FALLING CREEK

- Falling Creek is a significant headwater tributary that is impacted by extensive residential development and transportation networks. This catchment is likely to be critical for the maintenance of suitable hydrology and water quality in lower portions of Tryon Creek. Culverts on Tryon Creek and low summer flows limit direct use of Falling Creek by fish populations.

Burlingame Creek and Quail Creek

Burlingame Creek may augment low summer base flows in Tryon Creek, but probably does not provide extensive off-channel refugia to residing fish. SW Broadleaf Drive crosses the creek approximately 0.1 mile upstream of the confluence; off-channel rearing is therefore limited. Much like Burlingham Creek, Quail Creek may augment seasonal flows in Tryon Creek, but probably does not provide substantive off-channel habitat because of two major roadways.

Habitat surveys have not been conducted for either Burlingham Creek or Quail Creek.

Iron Mountain Creek

The National Riparian Services Team visited Iron Mountain Creek in October 2001 (WMSWCD, 2003b) and reported the following:

- The creek appears to have recovered from the affects of timber removal and is at an early stage of properly functioning.

- The creek experiences more normative floodplain interactions.

- Large source wood material (western red cedar) is present, and enough large wood is instream to store sediments and slow runoff.

HABITAT CHARACTERIZATION SUMMARY

Floodplain and Upland Condition

Floodplain interactions historically and currently play a critical role in maintaining watershed functions in Tryon Creek. The creek is bound by steep valley walls on the northern and southern facing hillsides. Although these hillsides constrain the creek, areas exist where the valley floor broadens, providing great opportunities for floodplain interactions. As shown in Table 9-1, these broader areas are most prominently found in the middle and upper park reaches (Tryon 3). The area in Tryon Creek State Natural Area historically functioned as a depositional reach, with deep soils and a wide historic floodplain (WMSWCD 2003b). This broader floodplain allowed the creek to adjust to high flows (by meandering from hillside to hillside), and probably augmented summer base flows via springs, seeps, hyporheic flows, and an elevated groundwater table.

Rural development currently limits potential floodplain interactions in the upper watershed (including the headwaters). Impervious area is high, roadways cross the creek, streamside vegetation is generally landscaped, banks are hard, and the channel is incised.

Table 9-1
Floodplain Attributes in Tryon and Arnold Creeks ODFW 2001

Basin	Reach	VWI (%) 1	Entrenchment Ratio 2	Stream Gradient 3 (%)
Tryon	Tryon 1	20.0	1.5	1.6
	Tryon 2	4.3	1.2	1.1
	Tryon 3A	7.8	1.3	0.8
	Tryon 3B	10.6	1.4	0.8
	Tryon 4A	5.0	1.4	3.2
	Tryon 4B	10.5	1.4	3.7
	Tryon 4C	8.0	1.4	11.1
	Tryon 4D			3.2
	Tryon 4E			0.4
Arnold	Arnold 1A	5.0	1.3	3.1
	Arnold 1B	11.5	1.3	3.8
	Arnold 1C	3.0	NA	4.5
	Arnold 1D	8.3	NA	1.1
	Arnold 1E	NA	NA	1.9
	Arnold 1F	NA	NA	3.7

[1] Valley Width Index (VWI): broad valley floor > 2.5; narrow valley floor <2.5.

[2] Entrenchment Ratio (floodprone width divided by the active channel width): Values > 1.0 signify increasing floodplain interactions.

[3] Stream Gradient (calculated from stream bed elevation / length): low < 2%; moderate 2% - 8%; steep > 8.0%.

NA = Not available

Data Source: ODFW 2001; BES 1997

Although steep valley hillsides bound Tryon Creek, the creek channel is low to moderately steep basinwide. Creeks with lower stream gradients generally interact with their riparian areas and broader floodplain areas more frequently and for longer duration than higher-gradient streams. Based on these landform characteristics, Tryon Creek would be expected to flood often and meander from hillside to hillside within the confines of the valley walls. Lower and middle portions of the basin (below Tryon 4A—SW Boones Ferry Road) are generally below 2 percent gradient, while the upper basin averages 2.3 percent, 3.1 percent, and 2.7 percent throughout (Table 9-1). Arnold Creek is moderately steep, however. Unlike mainstem Tryon Creek, the lower portion of Arnold Creek (Arnold 1A and Arnold 1B) is steeper than the middle and upper reaches (Arnold 1C and Arnold 1D). Falling Creek is moderately steep, with a 4.5 percent gradient.

Alluvial reaches in the lower and middle reaches (located within Tryon Creek State Natural Area) used to provide important summer and winter rearing habitat for juvenile salmon. Eradication and displacement of beavers, beaver dams, debris jams, and associated ponds and off-channel pools have undoubtedly reduced these alluvial stream interactions, yielding a less diverse floodway and associated processes:

> *...portions of the valley floor were likely inundated under beaver impoundments, which, along with silt transport mechanisms, may explain why much of the valley bottom is fairly level with deep soils composed of fine sediment. The annual recharge to shallow aquifers beneath these small floodplain areas likely contributed to summer base flows, helping to moderate stream temperatures. (PHS 1997).*

Substantive floodplain interactions are now severely lacking in Tryon Creek. The creek is incised and straight. Flood flows rarely extend far into the floodway, even within the protected areas of Tryon Creek State Nature Area. Frequent flood flows are not capable of reaching the relatively flat floodplain for energy dissipation, sediment deposition, and periodic flooding of riparian vegetation (WMSWCD 2003b). Disconnection of Tryon Creek from its floodplain can be attributed to several interrelated factors and processes. Notably, the channel is downcut and has been widened, so the amount of water that formerly filled the channel and spilled onto the floodplain is now held within the deeper, wider channel. In addition, the channel length is shorter, with fewer bends and meanders, and channel complexity is lacking. The National Riparian Services Team (WMSWCD 2003b) concluded that the reduction in resistance forces (e.g., loss of large wood and woody, riparian vegetation) and increases in water velocity result in an increase of flow energy that continually erodes the stream bed and stream banks. This has been significant enough to produce rapid vertical adjustments to the channel network, effectively disconnecting the channel from its floodplain. The creek seldom accesses its floodplain and is functionally confined. The result is that more water remains in the channel, and less water infiltrates into the floodplain and aquifer during moderate storm flows. Flow overtops the creek banks only during very high, infrequent floods. Observations by ODFW state biologists in 2002 confirm this phenomenon. Floodprone widths are greater than the active channel widths, indicating that flood flows periodically top the creek banks and interact with the floodway. However, the floodprone width rarely exceeds 1.5 times the active channel width (Table 9-1) and therefore does not extend far into the floodplain, as it once did.

Similar to Tryon Creek, Arnold Creek and Falling Creek do not experience regular or prolonged floodplain interactions. Their headwaters and greater portions of their mainstem habitats are enclosed in varying severity of urban development.

Riparian Condition

Riparian condition is relatively good throughout much of the lower and middle portion of the basin (Tryon Creek State Natural Area—Tryon 2 to Tryon 4A), except for the confluence of the Willamette River and Tryon Creek. In the confluence zone, the riparian corridor is narrow, grasses and vines predominate, and tree canopy cover is relatively low. Conditions improve in Tryon Creek State Natural Area, where riparian widths average 200 feet or more, tree canopy cover is high, and well-established second-growth forest dominates the landscape, averaging 15-30 cm dbh. The forest has converted from a mixed conifer-deciduous forest to deciduous trees and shrubs. Red alder and big leaf maple predominate in streamside areas, and large native conifers (western red cedar, Douglas fir, and grand fir) are rare. However, young western red cedar are beginning to predominate (above invasive blackberry) in some areas, notably mid-reach of Tryon 3B (just downstream of SW Boones Ferry Rd.) (personal communications, Cindy Studebaker).

Large conifers are most prevalent in Tryon 2, downstream from Iron Mountain Bridge. The National Riparian Services Team noted that this confluence region has the most developed (and functioning) floodplain of any area of Tryon Creek (WMSWCD 2003b). They partly attributed this to larger, more mature trees. Understory species include vine maple, western wahoo, and salmonberry, with some streamside areas lined with blackberries.

The forest stand structure (size, age, and condition) within the protected areas of Tryon Creek State Natural Area does not currently provide substantive sources of wood into the creek. Past logging and tree removal have reduced the supply of large wood into the channel (WMSWCD 2003a), but the potential for long-term sources is great. An older forest encompasses the lower canyon reach (Tryon 2), while a younger forest stand encompasses the middle and upper park reaches. This undoubtedly affects the creek's ability to interact with its riparian and floodplain area.

The riparian corridor is continuous through Tryon Creek State Natural Area (Tryon 4A), except for Highway 43, SW Boones Ferry Road, and recreational trails and bridges. As residential land use becomes more common (beginning in Tryon 4B), riparian integrity declines. Corridors are fragmented (street crossings); narrow residential dwellings encroach onto the stream bank; vegetative cover diminishes; and the proportion of impervious area increases. Overall tree size is larger in the headwater reaches than in Tryon Creek State Natural Area, but the riparian corridor is narrower and tree canopy cover is lower.

Like lower and middle Tryon Creek, lower Arnold Creek exhibits high riparian integrity, with riparian widths greater than 100 feet. Riparian condition declines upstream as the creek corridor leaves protected areas of Tryon Creek State Natural Area and enters upland residential development. Falling Creek exhibits poor riparian integrity; much of the stream corridor is surrounded by residential development.

Stream Connectivity

Table 9-2 identifies key culverts (not including all driveways) in mainstem Tryon Creek, Arnold Creek, Falling Creek, Quail Creek, and several unknown tributaries in the upper Tryon Creek basin. Marshall Cascade and Arnold Cascades are the only documented natural barriers. Other natural and manmade channel forms (e.g., steps) may seasonally impede fish movement, but are not known to block fish passage year-round. The individual reach descriptions above describe these steps and breaks in connectivity.

Access to spawning and rearing habitat is a key limiting factor affecting salmonid distributions and species diversity in Tryon Creek. As shown in Table 9-2, breaks in longitudinal stream connectivity, particularly at the State Street culvert (Reach 1), SW Boones Ferry Road culvert (Reach 3), and the SW 16th Place culvert (on Arnold Creek) severely impede resident and anadromous fish movement. Except for the two mainstem barriers, Tryon Creek is unimpeded from the mouth up to SW Maplecrest Drive (Tryon 1 to Tryon 4A: 3.1 river miles). As residential development (and street crossings) encroach onto the stream corridor, stream connectivity becomes more impaired.

The Highway 43 culvert is the roadway that most prominently impacts fish distribution and species diversity. This culvert severely limits anadromous fish from accessing spawning and rearing habitat in Tryon Creek. The culvert is a concrete box culvert that has been retrofitted with baffles to improve passage for anadromous adults; however, it remains a partial barrier, particularly for fall spawning coho salmon. During this time, flows are not high enough to allow access into the culvert (the jump height into the culvert remains too high), and passage through the long, baffled culvert is very inhospitable. Winter steelhead return to spawn in late winter to early spring when flows are higher, providing more advantageous opportunities for passage; however, passage probably remains impaired. Other fish passage barriers exist throughout the basin, but this culvert is most significant because of its closeness to the confluence and its impassability. Improving fish access into Tryon Creek by retrofitting or replacing the Highway 43 culvert could significantly increase anadromous fish productivity and species diversity throughout the watershed (WMSWDC 2003d).

Table 9-2
Roadway Culverts in the Tryon Creek Basin ODFW 2001

Stream Name	Reach	Crossing	River Mile	Passage?[1]	Impact?[1]	Length (ft)	Drop (in)	Slope (%)	Culvert Type
Tryon Creek	Tryon 1 / Tryon 2	HWY 43	0.3	seasonally passable	perched, velocity, length	200			CCL culvert
	Tryon 3A / Tryon 4A	SW Boones Ferry Rd culvert	2.6	Impassable	length, perched, velocity	150	12	2	CMP culvert
	Tryon 4A / Tryon 4B	1222 SW Maplecrest Dr	3.2	Impassable	perched, velocity	80	12	> = 2	CMP culvert
	Tryon 4B / Tryon 4C	Marshall Cascades	3.3	Impassable	slope, low flow				cascade
	Tryon 4C / Tryon 4D	SW 18th Pl	3.4	Impassable	velocity	70		> = 2	CMP culvert
	Tryon 4D / Tryon 4E	9323 SW Lancaster St	3.9	Impassable	velocity	50		> = 2	CCL culvert
	Tryon 4E / Tryon 5A	2541 SW Taylors Ferry Rd.	4.2	Passable	length	66	< 1		CMP culvert
	Tryon 5A	9209 SW 26th Ave.	4.2	seasonally passable	perched	22	24	NA	CMP culvert
	Tryon 5A	9209 SW 26th Ave.	4.2	impassable	length	150	< 1		CMP culvert
	Tryon 5A	9115 SW 26th Ave.	4.2	seasonally passable		13	<1		CCL culvert
	Tryon 5A / Tryon 5B	8909 SW Barbur Blvd. (I-5)	4.3	impassable		550			CCL culvert
	Tryon 5B	3121 SW Spring Garden St.	4.4	impassable	velocity	45	<1		CMP culvert
	Tryon 5B	3113 SW Spring Garden St.	4.4	impassable	velocity	64	<1		CMP culvert
	Tryon 5B	3113 SW Spring Garden St.	4.4	impassable	obstructions	65	<1		CMP culvert
	Tryon 5D	3060 SW Hume St	4.6	seasonally passable	length	30	< 1		CMP culvert
	Tryon 5D / Tryon 5E	3125 SW Carson St	4.9	impassable	length, perched	190	12		CMP culvert
	Tryon 5E	SW 31st and SW Carson	4.9	Passable		4	< 1		CMP culvert
	Tryon 5E	8102 SW 31st Ave.	4.9	Impassable	Length	163	< 1		CMP culvert
Arnold Cr	Arnold 1A / Arnold 1B	1056 SW Arnold Rd	0.1	Impassable	perched, velocity	60	36	3	CCL culvert
	Arnold 1B	1350 SW Arnold Rd	0.3	seasonally passable	perched	25	18		CMP culvert
	Arnold 1B	Arnold Cascades	0.4	seasonally passable	bedrock				cascade
	Arnold 1B / Arnold 1C	11005 SW 16th Pl	0.4	Impassable	Length, perched	140	18		CMP culvert
	Arnold 1C	1824 SW Arnold St.	0.5	seasonally passable	length, drop	40	4		CMP culvert
	Arnold 1C / Arnold 1D	10921 SW Lancaster Rd.	0.8	Impassable	Length, perched	140	60		CCL culvert
	Arnold 1E / Arnold 1F	11205 SW 35th Ave	1.4	seasonally passable	length	86	< 1		CMP culvert
Tryon 4B Trib	Unknown Trib 4B1	2030 SW Taylors Ferry Rd.	0.2	Impassable	length	120	< 1		CMP culvert
	Unknown Trib 4B1	2235 SW Marigold St.	0.5	Impassable	length	133	< 1		CMP culvert
	Unknown Trib 4B2	9309 SW 18th Pl.	0.2	Impassable	length	100	NA		CMP culvert
Burlingham Cr	Burlingham 1	1803 SW Broadleaf Dr	0.1	Impassable	velocity	80	< 1	5	CCL culvert
Quail Cr	Quail 1	9640 SW Lancaster Rd	0.1	Impassable	perched, velocity	80	60	11	CCL culvert
	Quail 1	9706 SW Quail Post Rd	0.2	seasonally passable	perched	35	13	1	CMP culvert
Falling Cr	Falling 1A / Falling 1B	9310 SW 26th Ave.	0.2	seasonally passable		80	4		CMP culvert
	Falling 1B / Falling 1C	9637 SW 35th Ave.	0.9	Impassable	length, velocity	500	0	2	CCL culvert
	Falling 1C / Falling 1D	3718 SW Huber St	1.1	Impassable	velocity	60	4	2	CCL culvert
	Falling 1D / Falling 1E	10808 SW 39th Ave.	1.5	impassable	length	1330			CMP culvert

		(Jackson M.S)							
	Falling 1E	4203 SW Pomona St.	1.7	seasonally passable	perched	60	10		CMP culvert
Tryon 5B Trib	Unknown Trib 5B1	2831 SW Dolph Ct	0.1	impassable	length	250	< 1	1	CCL culvert
Tryon 5C Trib	Unknown Trib 5C1	8473 SW 30th Ave / Spring Garden Rd	0.1	Impassable	length	150	< 1	1	CMP culvert

[1] If velocity barrier (based on slope > 2.0), then assume impassable year-round.
If perched, but not velocity, then assume seasonally passable during winter flows (November thru March).
If length > 100 feet, then assume impassable year-round, unless culvert is embedded with stream bottom substrate.
If drop > 6.0 inches, then presume barrier to juveniles (perched for part of the year). If drop > 12.0 –inches, then presume barrier to adults (perched for part of year)
If slope > 2.0, then presume velocity barrier.

Data Source: X:\ESA\Culverts\TryonCulverts.xls

Refugia

Off-channel refugia are primarily associated with perennial and intermittent tributaries. Some floodplain wetlands could be used during high flows if flood flows regularly topped the banks.

Lower Tryon Creek functions as off-channel refugia to the Willamette River and is used year round by Willamette Basin salmonids.

Instream structure and cover are lacking throughout Tryon Creek Basin. Notable areas and instream refugia include:

- Beaver ponds and associated wood clusters and debris jams provide important in-channel structure and refugia in reaches running through Tryon Creek State Natural Area (Tryon 2 – Tryon 3B).

- Seeps and springs provide important hyporheic flows. These areas were noted basinwide, but appear to be most prominent in Tryon Creek State Natural Area (Tryon 2 – Tryon 4A).

- Undercut banks, large cobble and boulders, and wood provide important in-channel cover basinwide wherever they are present.

Channel Conditions and Habitat Structure

Stream Bank Condition

Stream banks are actively eroding and unstable (ODFW 2001; WMSWCD 2003a), except in Tryon 2, from Highway 43 upstream to the confluence of Nettle Creek (Table 9-3). Even within this reach, areas of excess erosion are present, most notably at the confluence of an unnamed tributary flowing in from the south hillslope.

Only 9 percent of the stream banks are artificially hardened (brick, laid stone, riprap, and concrete) basinwide. The remaining 91 percent of the stream banks are composed of natural materials (earth, gravel, and sand). However, landscaping practices, road crossings, and residential development have hardened natural bank forms, particularly in the upper watershed.

From its confluence up to the upper end of a narrow rock-walled canyon (lower end of Tryon 2), Tryon Creek is believed to be a natural flume that effectively transports, but does not store, stream energy, sediments, and wood (WMSWCD 2003b). The stream's bottom and banks through this segment are composed of bedrock. However, the confluence reach up to Highway 43 has been extensively constricted by fill material, most notably along the northern bank. The southern bank is composed primarily of bedrock. Channel configuration and presence of bedrock so close to the soil surface may preclude long-term establishment of deep-rooting riparian trees.

The combination of clay soil type, presence of bedrock near the soil surface, buried large wood material, and riparian tree roots are believed to be preventing further downcutting of the creek (WMSWCD 2003b). Throughout the basin, the most effective way to prevent additional stream bank degradation will be to prevent additional increases in peak flows and sediment loads, as well as any additional losses of riparian vegetation and functions (WMSWCD 2003a).

Table 9-3
Channel Condition by Reach

Basin	Reach	% Actively Eroding [1]	Bank Slope (%) (0-10-m)
Tryon Creek	Tryon 1	69	25
	Tryon 2	36	53
	Tryon 3A	66	6
	Tryon 3B	66	6
	Tryon 4A	58	15
	Tryon 4B	58	15
	Tryon 4C	58	15
	Tryon 4D	58	15
Arnold Creek	Arnold 1A	79	21
	Arnold 1B	79	21

Note: Reaches that were not surveyed are not included.

[1] 30-60 % actively eroding = moderately unstable and signifies high erosion potential during floods (Barbour 1999).

Data Source: ODFW 2001

Large Woody Debris

The National Riparian Services Team characterizes Tryon Creek as a wood-dependent system, meaning that it developed in conjunction with a large conifer forest stand (WMSWCD 2003b). The wood provided by larger conifer tree boles historically trapped sediment and formed floodplains, retaining flood flows and promoting rich, diverse riparian vegetation. The team concluded that large wood material is the most important attribute in this stream type, and the processes associated with it are the most important to the function of the watershed.

Large woody material is lacking throughout the basin (ODFW 2001; WMSWCD 2003a, 2003b, and 2003d). As shown in Table 9-4, wood abundance is low upstream of SW Boones Ferry Road; wood volume is low throughout the basin; and key pieces are rare. The loss of accumulated large wood has resulted in channel erosion, which has further converted the stream from one that often accessed its floodplain to one that cannot. Loss of transient and buried large wood from the channel and floodplain may have had the most adverse affect on stream habitat and on riparian and floodplain connectivity.

During the 2001 ODFW stream surveys, three reaches within mainstem Tryon Creek had optimal numbers of wood pieces for fish-bearing streams (more than 20 pieces per 100 meters of stream length): Tryon 2 (42 pieces), Tryon 3A (54 pieces), and Tryon 3B (34 pieces). All three reaches lie within Tryon Creek State Natural Area and contained enough wood to provide a marginal level of protective cover. However, wood volume was poor, with less than 20.0-m3 per 100 meters of stream length (Tryon 2 – Tryon 4A), and few key pieces (over 60 cm diameter and over 10 meters long) were documented. Only Tryon 3A contained key pieces (0.91 piece per 100 meters of stream length). Wood pieces indicate riparian vegetation age and species; the presence of smaller to mid-sized single pieces indicates that wood is falling into the creek, but has not yet amassed enough to provide critical habitat function in the form of debris jams or clusters.

In addition, most tributaries of Tryon Creek (excluding Iron Mountain Creek) lack enough wood to effectively store sediments and retain water. The National Riparian Services Team noted that upland and riparian vegetation is generally less than 60 years old, too young to contribute significant amounts of large woody material needed to rebuild floodplain and channel structure (WMSWCD 2003b). Buried, large wood complexes provide important overwintering habitat to salmonids. Without this protective cover, fish are often swept downstream during higher winter and spring flows.

Past logging and tree removal during urban development, prolonged or acute peak flows, and inadvertent (or planned) maintenance removal of large wood have resulted in low large wood abundance and volume throughout the basin. In addition, the combination of high flows, incised channels, and lack of in-channel complexity limits the amount of wood that is currently retained in-channel.

The lack of large wood, combined with the prevalence of higher, flashy storm flows, significantly impacts habitat formations and the maintenance of good-quality spawning and rearing fish habitat in Tryon Creek. It is probably a prominent factor limiting fish productivity.

Table 9-4
Wood Abundance, Volume and Key pieces by Reach

Basin	Reach	# Pieces per 100 – meters [1]	Volume (m3) per 100-m [2]	# Key Pieces per 100 – meters [3]
Tryon Creek	Tryon 1	4.5 (UD)	5.06 (UD)	0 (UD)
	Tryon 2	42.3 (D)	1.40 (UD)	0 (UD)
	Tryon 3A	53.6 (D)	1.74 (UD)	0.91 (M)
	Tryon 3B	34.0 (D)	0.95 (UD)	0 (UD)
	Tryon 3C	5.0 (UD)	0.94 (UD)	0 (UD)
	Tryon 4A	17.8 (M)	3.82 (UD)	0 (UD)
	Tryon 4B	2.7 (UD)	0.39 (UD)	0 (UD)
	Marshall Cascades	0.5 (UD)	0.26 (UD)	0 (UD)
	Tryon 4C	6.4 (UD)	3.47 (UD)	0 (UD)
Arnold Creek	Arnold 1A	5.5 (UD)	3.93 (UD)	0 (UD)
	Arnold 1B	6.8 (UD)	1.31 (UD)	0 (UD)
	Arnold Cas	4.6 (UD)	5.37 (UD)	0 (UD)
	Arnold 1C	1.4 (UD)	0.28 (UD)	0 (UD)
	Arnold 1D	5.5 (UD)	1.08 (UD)	0 (UD)
	Arnold 1E	11.4 (M)	0.99 (UD)	0 (UD)

Note: Wood pieces are defined as > 3 meters x 0.15 meter.
[1] # Pieces: desirable (D): > 20; marginal (M): > 10 and < 20 undesirable (UD): <10
[2] Wood Volume: desirable: > 30; marginal: > 20 and < 30; undesirable: <20.
[3] Key pieces (> 10 meters x 0.6 meter): desirable: > 3; marginal: > 1 and < 3; undesirable: <1.
Data Source: ODFW 2001

Pool Area, Depth, and Complexity

Pool area is best in the lower and middle reaches of Tryon Creek (Tryon 1 through Tryon 3B), with pool area (lateral scour pools) constituting about half of the wetted area (Table 9-5). Tryon 2 has several beaver ponds and debris jams, which constitute approximately 25 percent of the total pool area. Pool area declines upstream of SW Boones Ferry Road, transitioning from moderate to low from Tryon 4A (34 percent) to Tryon 4B (7 percent). Arnold Creek also has very little pool habitat.

The proportion of fine sediment amassed in pools ranges from 21 to 31 percent (reach average) in mainstem Tryon Creek and Arnold Creek. Sediment deposition greater than 20 percent generally signifies above-normal deposition. A disproportionate amount of amassed sediments implies that sediment recruitment, deposition, and transport are out of balance. This dynamic is descriptive of pool habitats in Tryon Creek, indicating that sediments are disproportionately filling scoured areas in pools and effectively minimizing their functional capacity.

Table 9-5
Pool Area and Substrate Composition by Reach ODFW 2001

Basin	Reach	Total Area (m2)	Total Pool Area (m2)	% Pool Area [1]	% Gravel [3]	% Sand [3]	% Fines [2, 3]
Tryon Creek	Tryon 1	1,319	726.0	55 [4]	18	23	31
	Tryon 2	6,396	4,843.0	76 [5]	17	25	31
	Tryon 3A	11,423	7,395.0	65 [6]	25	31	27
	Tryon 3B						
	Tryon 4A	6,751	2,004.0	30	29	16	21
	Tryon 4B						
	Tryon 4C						
Arnold Creek	Arnold 1A	3,320	815.0	25	35	19	21
	Arnold 1B						

[1] % Pool Area: undesirable: <10%; marginal: >10% and <35%; desirable: >35%.
[2] 20-50% deposited fines signifies slight deposition (Barbour 1999).
[3] Substrate represents lateral scour pools - dominant pool type.
[4] 8% of 55% pool area includes a beaver pond/pool complex (25 meters x 4 meters).
[5] 25% of 76% pool area includes five beaver ponds and one backwater pool. Substrate in beaver ponds is dominated by fines (45%) and sands (28%).
[6] 8% of 65% pool area includes one backwater pool, two dammed pools, and two beaver ponds.
Data Source: ODFW 2001

The lack of deep pools, relative to the prevailing channel depth, indicates that pools are not providing protective cover and depth refugia, compared to other channel habitats. Most deep pools are present in lower and middle Tryon Creek, within the confines of Tryon Creek State Natural Area, but are lacking upstream of SW Boones Ferry Road (Tryon 4A through Tryon 4C). Pools are considered marginal (>= 0.2 meter) or desirable (>= 0.5 meter) in most mainstem reaches. Reaches in Tryon Creek State Natural Area have more than 50 percent pool area with pools at least 0.5 meter deep, which is considered optimal for fish bearing streams. As shown in Table 9-6, however, the average channel depth is quite deep for a stream of this size, yielding relatively shallow pools compared to the average channel depth within the reach; pools are rarely more than 25 percent deeper than the average channel depth. This channel structure is characteristic of a stream that has been deepened and is channelized; it does not functionally provide adequate cover and refugia, particularly during storm flows and throughout prolonged higher flows occurring in the winter.

Most deep pools are present in Tryon 3B, with more than 70 percent of the pools being at least 0.5 meter deep. Conversely, pool area and deep pool habitat is lacking upstream of Tryon Creek State Natural Area. Tryon 4A has only 35 percent pools greater than 0.5 meter deep, and Tryon 4C has only 28 percent pool habitat deeper than 0.5 meter. Remaining pool habitat in these two reaches is marginally deep, ranging from 0.2 to 0.5 meter deep. Although not much pool area is present in Tryon 4B (7 percent of total stream area), the pool area that exists is desirable; more than 60 of the pool habitat has depths greater than 0.5 meter.

Table 9-6
Deep Pools by Reach ODFW 2001

Basin	Reach	Deep Pools (> 1.0-m)		Avg Residual Pool Depth[1] (m)	Avg Channel Depth (m)	Relative Pool Depth (%)[2]
		# Deep Pools	# Deep Pools/1000 m			
Tryon Creek	Tryon 1	4.0	10.2	0.64	0.47	27
	Tryon 2	6.0	4.5	0.59	0.44	25
	Tryon 3A	18.0	6.7	0.62	0.47	24
	Tryon 3B					
	Tryon 4A	4.0	1.8	0.46	0.26	43
	Tryon 4B					
	Tryon 4C					
Arnold Creek	Arnold 1A	1.0	0.5	0.38	0.17	55
	Arnold 1B					

1 Residual Pool Depth: undesirable: <0.2 m; marginal: >=0.2 m and <=0.5 m;
desirable: >0.5 –m.
2 Pools 75-100 % deeper than prevailing channel depth provide protective cover (NRCS 1999).
Data Source: ODFW 2001

As with deep pool habitat, complex pools (with wood complexity greater than 3.0 km) is lacking throughout the basin (Table 9-7). Some are present in lower mainstem reaches: Tryon 2 (6.8), Tryon 3A (13.5) and Tryon 3B (7.6). No complex pools were documented above Tryon 4A.

Table 9-7
Pools with Wood and Boulder Complexity ODFW 2001

Basin	Reach	Complex Pools[1]		Substrate
		# Complex Pools	# Complex Pls/1000-m	% Boulders[2]
Tryon Creek	Tryon 1	0	0.0 (UD)	9
	Tryon 2	9	6.8 (D)	2
	Tryon 3A	16	13.5 (D)	1
	Tryon 3B	8	7.6 (D)	
	Tryon 3C	0	0.0 (UD)	
	Tryon 4A	2	2.1 (M)	1
	Tryon 4B	0	0.0	
	Marshall Cascade	0	0.0 (UD)	
	Tryon 4C	0	0.0 (UD)	
Arnold Creek	Arnold 1A	0	0.0 (UD)	2
	Arnold 1B	0	0.0 (UD)	
	Arnold Cascade	1	9.4 (D)	
	Arnold 1C	0	0.0 (UD)	
	Arnold 1D	0	0.0 (UD)	
	Arnold 1E	0	0.0 (UD)	

[1] Complex Pools: undesirable (UD): < 1.0; marginal (M) >=1.0 and <= 2.5; desirable (D) >2.5.
[2] Substrate for later scour pools is reported.
Data Source: ODFW 2001

Riffle Area, Gravels and Fines.

Riffles constitute 17 to 29 percent of the wetted habitat in mainstem Tryon Creek. Riffle area is moderately low for fish-bearing streams. Spawning and rearing grounds may be a limiting factor that affects population abundance and species diversity.

Riffle quality (substrate composition and proportion of fine sediments) is moderately good. Nearly all reaches (except for Tryon 2) have at least 50 percent riffle habitats with more than 35 percent gravel composition, which is considered optimal for fish-bearing habitat. However, the proportion of substrate and gravels covered or embedded with fine sediments and organics is marginally high throughout the basin. Fine sediments are least abundant in Tryon 2 and Tryon 3A. In Tryon 2, 15 percent of riffle habitats have less than 12 percent fines (considered desirable habitat condition for fish-bearing streams), and 65 percent have less than 25 percent fines (considered marginal habitat condition for fish-bearing streams). In Tryon 3A, 21 percent of riffle habitats have less than 12 percent fines, and 55 percent have less than 25 percent fines. The upper 400 meters of Tryon 3B has excellent gravel composition in riffle habitats, with low proportions of fines; 72 percent of the riffle habitat has less than 12 percent fines and is considered desirable.

Table 9-8 shows riffle area and gravel composition by reach, and Table 9-9 shows riffle area and sediment composition by reach.

Table 9-8
Riffle Area and Gravel Composition by Reach ODFW 2001

Basin	Reach	% Riffle Area	Gravel Composition (%)		
			Undesirable <15%	Marginal >=15% & <35%	Desirable >= 35%
Tryon Creek	Tryon 1	20%	0	100	0
	Tryon 2	17%	10	58	39
	Tryon 3A	29% [1]	0	25	75
	Tryon 3B		0	19	81
	Tryon 3C		0	0	100
	Tryon 4A	17% [2]	0	29	71
	Tryon 4B		0	0	100
	Tryon 4C		0	14	86
Arnold Creek	Arnold 1A	50% [3]	0	0	100
	Arnold 1B		0	40	60
	Arnold Cascade		0	0	100
	Arnold 1C		0	0	100
	Arnold 1D		0	14	86
	Arnold 1E		0	32	68

[1] Proportion for Tryon 3
[2] Proportion for Tryon 4
[3] Proportion for Arnold 1
Data Source: ODFW 2001.

Table 9-9
Riffle Area and Fine Sediment Composition by Reach ODFW 2001

Basin	Reach	% Riffle Area	Fine Sediment Composition (%)		
			Undesirable >25%	Marginal <=25% & >=12%	Desirable <12%
Tryon Creek	Tryon 1	20	100	0	0
	Tryon 2	17	20	65	15
	Tryon 3A	29 [1]	24	55	21
	Tryon 3B		74	26	0
	Tryon 3C		0	28	72
	Tryon 4A	17 [2]	15	81	4
	Tryon 4B		0	100	0
	Tryon 4C		21	76	4

Arnold Creek	Arnold 1A	50[3]	0	100	0
	Arnold 1B		37	63	0
	Arnold Cascade		0	100	0
	Arnold 1C		87	13	0
	Arnold 1D		36	61	4
	Arnold 1E		16	80	4

[1] Proportion for Tryon 3

[2] Proportion for Tryon 4

[3] Proportion for Arnold 1

Data Source: ODFW 2001.

The proportion of fine sediments that cover riffles is least desirable in Tryon 1 (100 percent of riffles have more than 25 percent fines); lower Tryon 3B (74 percent of riffles have 25 percent or more fines); and Arnold 1C (87 percent of riffles have more than 25 percent fines). All remaining reaches exhibit marginal riffle quality, based on the proportion of fine sediment that covers stream-bottom substrates (12-25 percent fines). Although riffle habitat in most reaches does not have undesirable proportions of fine sediments (more than 25 percent), the majority of riffle habitat is considered sub-optimal quality, with more than 12 percent fine sediments overlying riffle gravel substrates.

Predominant sources of sediment loading into Tryon Creek are not fully understood; they are probably a combination of sediment loads in stormwater runoff and sediments injected into the creek during erosive flows. These sediments are probably in suspension, then settle and become resuspended during high, turbulent flows, yielding a constant layer of fine silt and sediment overlying stream bottom substrates. These high silt loads overlying spawning grounds may significantly impair the carrying capacity of this system.

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CHAPTER 11

Biological Communities: Tryon Creek Watershed

This chapter characterizes biological communities in the Tryon Creek Watershed. It includes:

- Biological Communities by Reach (Target Species)
- Biological Communities Summary

FOCAL SPECIES AND POPULATIONS

Salmon are a useful indicator of environmental condition for three reasons: First, legal and social requirements for salmon recovery in the lower Willamette and lower Columbia rivers result in obligations for the city; Second, although uncertainties clearly exist, scientific knowledge of the environmental requirements for salmon far exceeds that of most other aquatic species (for example, many federal and state water and environmental quality guidelines are based on the biological requirements of salmon and trout); Third, current scientific literature suggests that environmental conditions that support native fish also provide a favorable environment for other native aquatic and terrestrial wildlife and for improved water quality. In addition, salmon have complex life histories that involve resident and anadromous traits and are sensitive to environmental change respective to hydrology, habitat, water quality and other biological communities. Coho, steelhead / rainbow and cutthroat are all native to Tryon Creek watershed, and were evaluated for this characterization report. In addition, steelhead and coho were further evaluated using Ecosystem Diagnosis and Treatment (EDT).

The following is a brief synopsis of historic and current salmon use of Tryon Creek Basin:

- Chinook spawn and rear in mainstem reaches of large river systems such as the Willamette River and the Clackamas River. Tryon Creek is a small tributary to the lower Willamette River, and it is unlikely that Chinook would have historically populated the subbasin. However, juvenile Chinook historically used the lower confluence region during yearling and subyearling development, and recent surveys shows that they continue to rear and reside here today (ODFW 2005, and City of Portland). Chinook salmon use of Tryon Creek is evaluated only for Tryon 1, the confluence reach.
- Coho historically spawned and reared throughout the Tryon Creek Basin (WMSWCD 2003d). The upstream extent of their anadromy is not known; based on the geomorphology of the channel and valley hillslopes, however, they probably spawned at least up to the confluence of Tryon Creek and Arnold Creek (Lower Tryon) and possibly up to the bottom of Marshall Cascades (Middle Tryon), a natural fish barrier.
- Steelhead (winter-run) historically spawned and reared throughout the Tryon Creek Basin. The upstream extent of their anadromy is not known; based on the geomorphology of the channel and valley hillslopes, however, they likely spawned up to (and perhaps beyond) Marshall Cascades (Middle Tryon).

ANALYTICAL APPROACH

Four population parameters were evaluated to fully assess biological performance: 1) Biological capacity (quantity of habitat); 2) Biological productivity (quality of habitat); 3) Equilibrium abundance (quantity and quality of habitat); and 4) Life history diversity (breadth of suitable habitat). Note capacity and productivity are parameters of a Beverton-Holt production function; and abundance is calculated from this relationship. Life history diversity is represented as a Diversity Index that is the percentage of viable life history trajectories or strategies: spawning, rearing and migration. These population parameters were evaluated to assess (a) species population potential, (b) limiting factors, and (c) protection and restoration value.

> **(A) POPULATION POTENTIAL** describes habitat potential respective to steelhead and coho.
>
> **(B) LIMITING FACTORS.** The effect that individual environmental attributes have on potential fish population abundance, productivity and diversity are assessed as the change in an EDT output parameter that occurs when the value for an individual attribute in a geographic area is set to its value in the restored condition. The results are summarized in “dot diagrams” in which the size of a dot is proportional to the change in productivity because of setting the EDT attribute to its restored value.
>
> **(C) PROTECTION AND RESTORATION VALUE AND PRIORITIES.** Spatial differences between geographic areas within Tryon Creek were summarized as the Protection and Restoration value of each geographic area for steelhead and coho. Protection priority is defined as the percent change in an environmental attribute when the current values for all attributes in a geographic area are set to a highly degraded condition. Restoration priority is the percent change in an environmental attribute when the current values for all attributes in a geographic area are set to a restored condition.

Reach structure and geographic areas

Geographic areas and stream reaches are coincident with Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventory Project. Generally, reaches are defined by functional characteristics such as tributary confluences, changes in valley form and channel form, major changes in vegetation and / or changes in land-use ownership (Moore et.al 1997). In addition to these landscape attributes, unique channel forms such as culverts and fish barriers were identified in order to rate each respective to its impact on fish productivity.

Mainstem Tryon Creek was broken into 11 stream reaches, five culvert reaches and one natural barrier (Marshall Cascades). Arnold Creek and Falling Creek were also characterized and evaluated using EDT. Arnold Creek was broken into seven stream reaches, five culverts and one natural barrier (Arnold Falls); and Falling Creek was broken into three stream reaches and two culverts. Mainstem Tryon, Arnold and Falling Creek were further grouped into three geographic areas that reflect watershed function, and land-use (e.g., upper subbasin in urban land-use and middle subbasin in Tryon Creek State Natural Area).

LOWER TRYON CREEK

> The lower reach extends from the confluence of Tryon Creek and the Willamette River upstream to the westside of Boones Ferry Rd, which lies immediately downstream of the confluence of Arnold and Tryon creeks (RM 0.00 – 2.68). Stream gradient is generally

low, averaging 2.3%. HWY 43 crosses the creek at RM 0.24; and functionally separates mainstem Tryon Creek from its confluence area with the Willamette River. Land use in the confluence reach is predominately residential. The remainder of Lower Tryon Creek lies within the protected area of Tryon Creek State Natural Area (TCSNA). Key tributaries include Nettle Creek, Red Fox Creek, Palatine Hill Creek, Park Creek and Arnold Creek (at the upstream extent). Hillsides were logged (predominately clear cut) from the 1940's through the 1960's, yielding a stand age of 40-60 years. The forest stand is characteristic of second-growth, even-aged forest stand, and is dominated by large maples, alders and native firs. The area is relatively undisturbed with a few exceptions: a sewer pipe runs along the valley bottom; and recreational trails used by hikers, equestrians and mountain bikers parallel and cross the creek.

MIDDLE TRYON CREEK

The middle reach begins at the confluence of Arnold and Tryon Creek and extends upstream to Marshall Cascade. Mature second growth forests surround the lower portion of this reach, with some low-density residential use in the uplands. The remainder of Middle Tryon (including Falling Creek) is predominately enclosed in residential land-use, with several small city parks. Key tributaries include Arnold, Burlingame and Quail creeks; however, several other (unnamed) tributaries enter the mainstem and may provide important off-channel and cool water refugia.

UPPER TRYON CREEK

Upper Tryon Creek begins at Marshall Cascade and extends upstream through the headwaters.

Information Sources

EDT habitat attribute ratings were based on knowledge of historic and current conditions of hydrologic regimes, physical habitat, water quality and biological communities as described in various reports comprising the Tryon Creek Watershed Characterization. The content of the watershed characterization was previously vetted through the City of Portland, Tryon and Fanno Creek Watershed Advisory Team, which includes members from Clean Water Services, Neighborhood Associations, Oregon State Parks, and other City Bureaus. Fish communities were evaluated based on the results of a fish study conducted by ODFW from 1999 through 2001 (ODFW 2001) and on past surveys and sightings. ODFW surveys included extensive (spring, summer, and fall) and intensive (summer) stream surveys. Surveys were not conducted in the winter because of high flow conditions, and consideration for the health and safety of the field sampling crew. Key data collected by ODFW included fish presence / absence, fish length, weight and condition factor, and calculated IBI per stream reach. A summary of these study findings is documented in the Appendix.

Scenario development

Using EDT, three scenarios were described to evaluate coho and steelhead productivity in Tryon Creek watershed. The first describes current conditions based on existing empirical and expert knowledge of hydrology, water quality, physical habitat and biological communities. The second scenario describes a reference or template condition. This reference condition defines fully restored conditions in Tryon Creek; it's tributaries, and the Lower Willamette River, as it relates to salmonid life history, and spawning and rearing. The third scenario describes a fully degraded condition for the subbasin. Placing the current condition between the two “bookends” (e.g., reference condition and fully degraded condition) allows us to evaluate each population and its reliance on protection and restoration measures basinwide (e.g., sedimentation) and at specific areas (e.g., fish passage improvements).

ESTIMATED POPULATION POTENTIAL

The following figures compare the estimated current abundance, productivity and life history diversity potential to similar reference or template potential based upon habitat condition and function. Indices of habitat potential (and its influence on fish abundance) do not represent actual fish abundance, productivity or diversity as measured or observed in Tryon Creek. Actual abundance, productivity or diversity is not known, but presumably varies from year to year due to factors within and outside the subbasin (e.g., changing ocean conditions). The percent change in population potential is a measure of the overall degradation of habitat conditions primarily as a result of anthropogenic changes in Tryon Creek and in the Lower Willamette River.

Coho

Coho abundance is extremely low in Tryon Subbasin, estimated at only 1.5% of reference (or historic) numbers. In addition, coho productivity is only at about 3.5% of its reference potential; however, life history diversity is estimated at about 20% the reference potential. Highway 43 culvert is the most prominent limiting factor affecting coho distribution in Tryon Creek. Flows, culvert length, and jump height into the culvert probably exclude fall-run fish from passing above this barrier. EDT suggests that a small viable population of coho salmon could persist within the Park with the removal of HWY 43. Habitat above HWY 43 remain favorable for coho spawning and rearing. The National Riparian Service Team surveyed the watershed in 2002 and concluded that the lower park is well suited for coho (WMSWCD 2003b). EDT analysis confirmed this assessment: the low gradient, slow water condition that characterize the lower portion of Tryon Creek (especially within the Park) is well suited for coho.

Figure 1. Estimated fish abundance potential as a function of habitat in the current and reference conditions for Tryon Subbasin coho population.

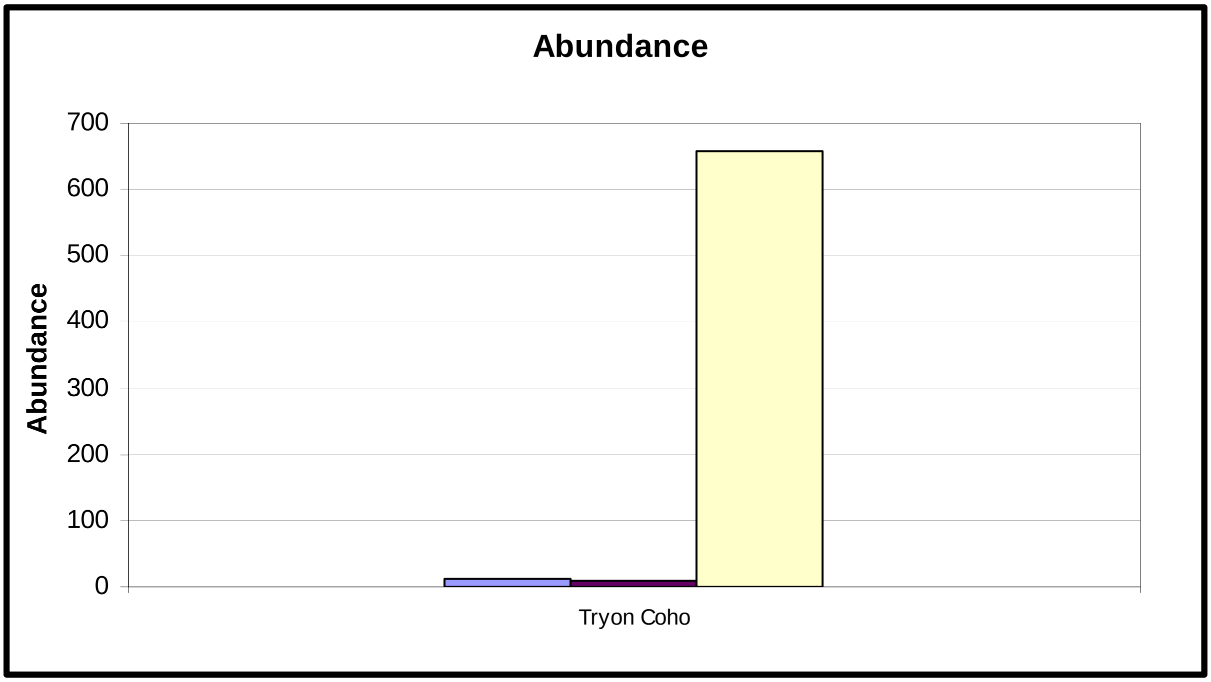


Figure 2. Estimated fish productivity potential as a function of habitat in the current and reference conditions for Tryon Subbasin coho population.

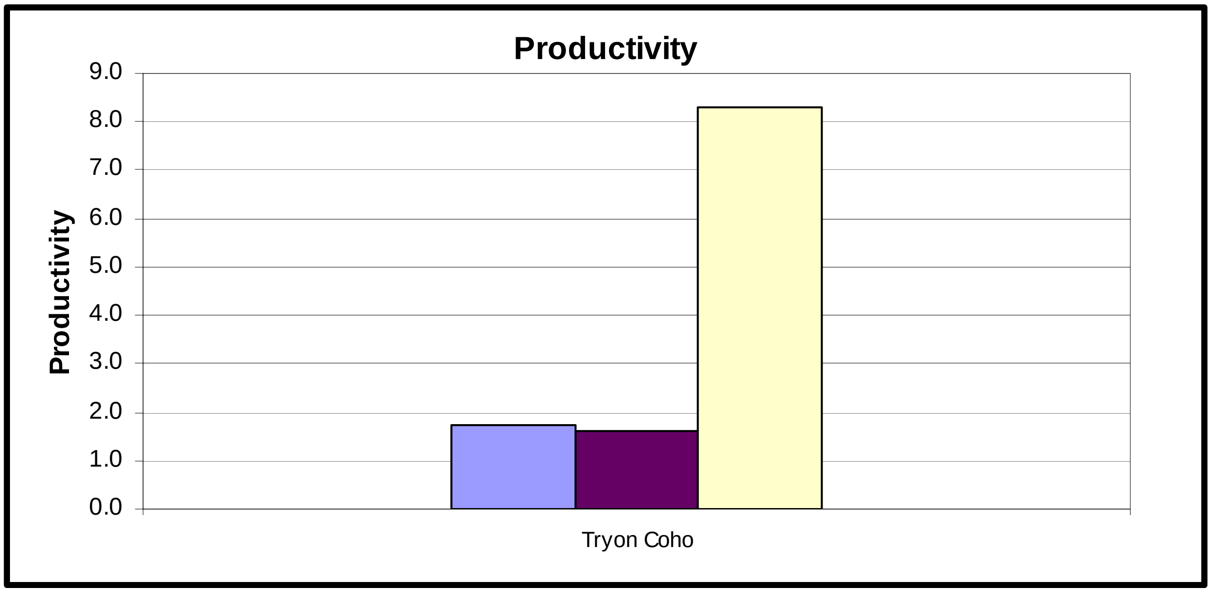
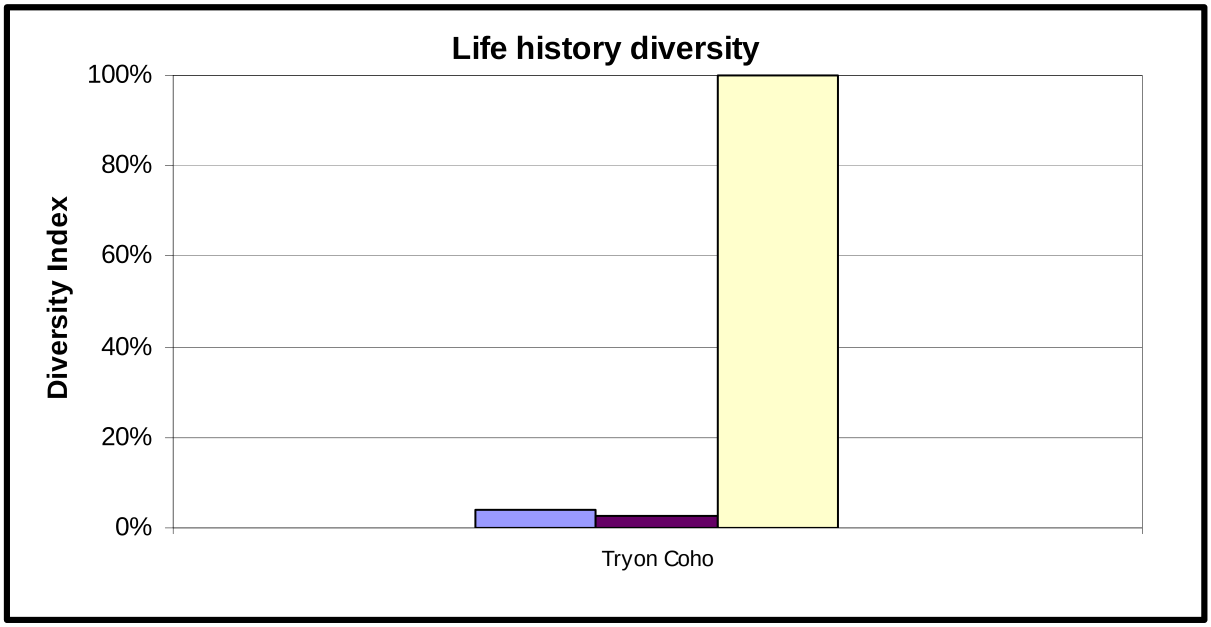


Figure 3. Estimated species diversity potential as a function of habitat in the current and reference conditions for Tryon Subbasin coho population.



3.2 Steelhead

Current winter steelhead abundance is estimated to be only 1.0 percent of reference population size (Figure 4). Current productivity is likewise low at about 3.0% of the reference condition, and life history diversity is only 7.5% of the reference condition.

During 1999–2001 fish surveys, steelhead species were present in the lower and middle portions of Tryon Creek. Based on forklength distributions, ODFW biologists determined that juvenile steelhead continue to express anadromy (e.g., smolting at around 120-mm), and concluded that anadromous steelhead spawn and rear at least up to Boones Ferry Rd. In addition to fish surveys conducted by ODFW field biologists, other surveys have documented steelhead throughout various reaches of Tryon Creek, indicating that local populations of anadromous and resident fish continue to persist (City of Portland 1992; Pacific Habitat Services 1997; Reed and Smith 2000). Juvenile steelhead from other watersheds within the Willamette River Basin are believed to rear and/or temporarily use lower Tryon Creek (up to Highway 43) during their seaward emigrations. Like coho and Chinook, juvenile steelhead use the lower confluence reach as off-channel habitat to the Willamette River; they seek refuge from high waters, avoid predators, seek food, and/or seek temporary rearing opportunities. This hypothesis is consistent with the findings of the Independent Scientific Group (2000), which found that steelhead juveniles in the Columbia Basin appear to move downstream to areas that are more productive as they grow and physiologically smolt.

As with coho, Highway 43 significantly impedes anadromous movement of steelhead up into Lower Tryon. However, winter steelhead adult migrations coincide with periods of higher flow, which probably allows for better passage through the culvert. Jump height into the culvert and the culvert length probably remain key limiting factors for fish passage above this barrier. Habitat conditions in lower and middle Tryon Creek are favorable for steelhead spawning and rearing. The National Riparian Service Team surveyed the watershed in 2002 and concluded that Tryon Creek State Natural Area is well suited for steelhead production (WMSWCD 2003b).

Figure 4. Estimated fish abundance potential as a function of habitat in the current and reference conditions for Tryon Subbasin winter steelhead population.

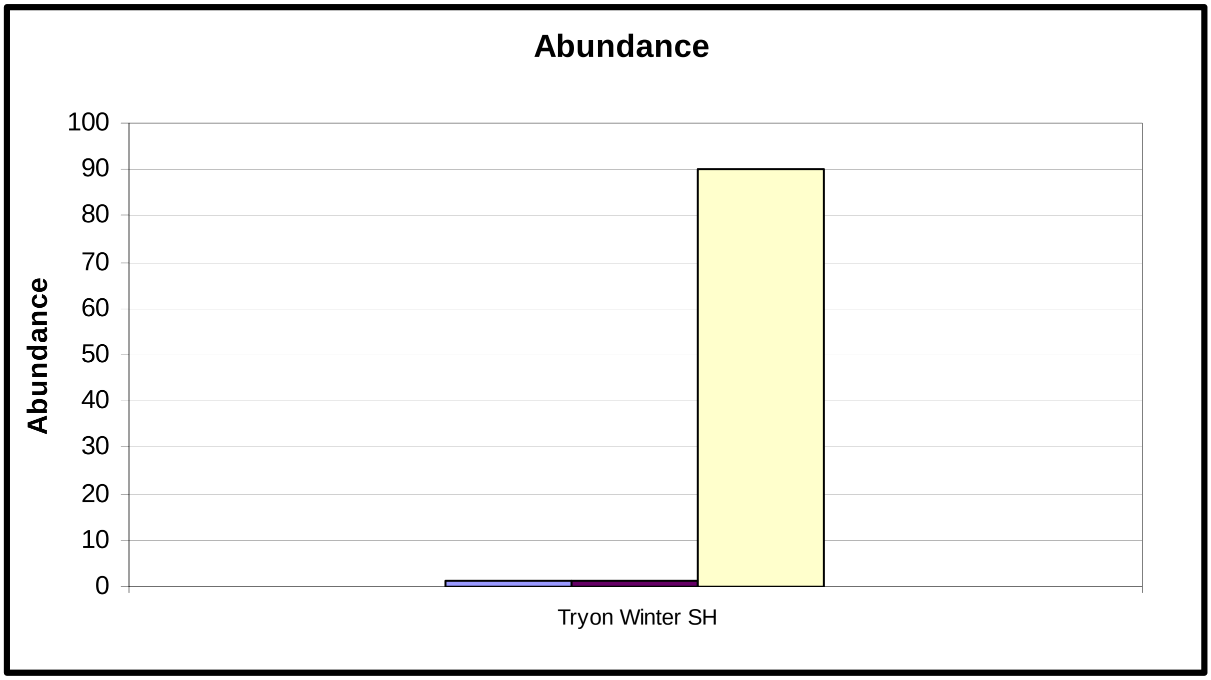


Figure 5. Estimated fish productivity potential as a function of habitat in the current and reference conditions for Tryon Subbasin winter steelhead population.

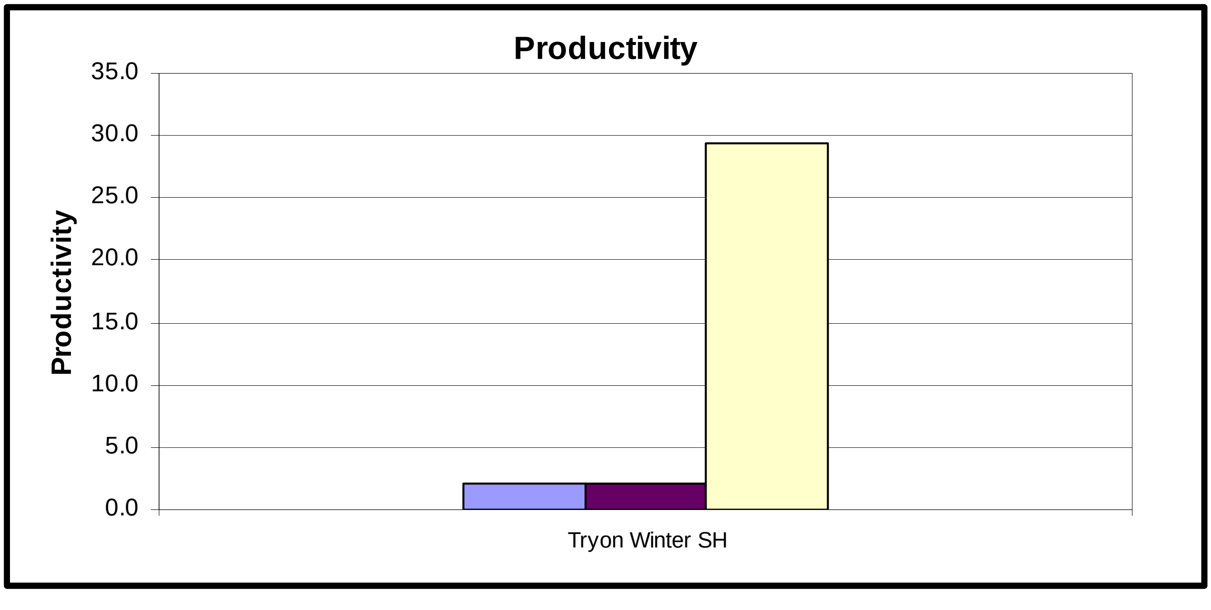
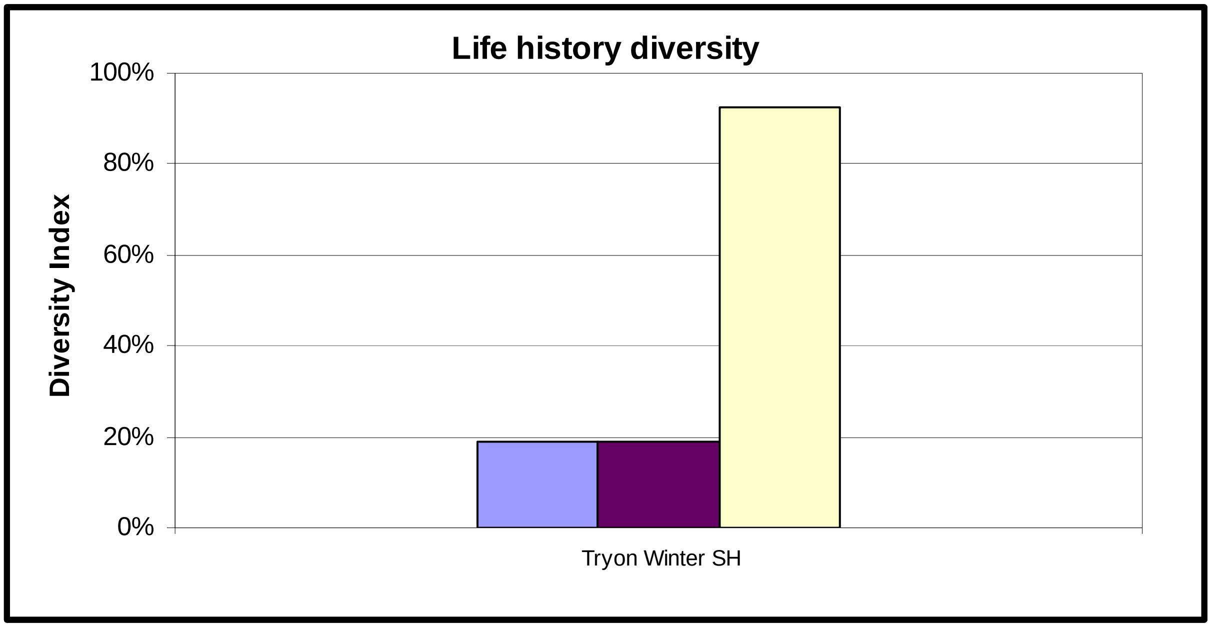


Figure 6. Estimated species diversity potential as a function of habitat in the current and reference conditions for Tryon Subbasin winter steelhead population.



Cutthroat

Cutthroat were observed in every reach and during every sampled season in Tryon Creek, indicating year-round presence and persistence basinwide. Habitat conditions support cutthroat spawning and rearing; however, habitat improvements and restoration efforts would probably enhance cutthroat abundance, diversity, and distribution. Cutthroat populations that currently reside in Tryon Creek are probably remnant populations of both searun and resident populations.

Chinook

Juvenile Chinook, like all other anadromous species were present in the lower canyon reach (Tryon 1); they were captured in the summer and fall, but were not encountered in the spring. Tryon Creek is a minor tributary to the Willamette River, and it is unlikely that Chinook historically populated this basin. Adult Chinook generally seek upper mainstem river reaches of larger, fast-flowing rivers and streams. However, juvenile Chinook use lower Tryon Creek year–round, suggesting that juvenile Chinook from other Willamette subbasins use the confluence region of Tryon Creek as off-channel habitat to the Willamette mainstem. They seek these areas for temporary refuge and/or prolonged rearing and feeding. They probably do not reside here year-round. This hypothesis is consistent with observations by the Independent Scientific Group (2000) of Chinook juvenile out-migration strategies that consist of movement from upriver tributary spawning sites into downstream mainstem areas, where they rear over the winter (Healey 1991).

LIMITNG FACTORS ANALYSIS

The EDT analysis of habitat, water quality, fish passage and other attributes influencing Tryon Creek coho and steelhead describes the factors limiting potential population productivity and the relative importance of each geographic area, as they support spawning and rearing by coho and steelhead. For example, current coho salmon productivity potential is about 1.5 percent of that under the reference habitat conditions, and current steelhead productivity is about 1.0 percent of that under the reference habitat conditions. Again, the context of reference conditions describes the species habitat potential respective to coho and steelhead productivity.

Habitat Constraints by Geographic Area

Following is a detailed description of the impacts of these habitat constraints on coho and steelhead productivity in the different geographic areas of Tryon Creek. This analysis will ultimately inform habitat restoration and protection strategies.

Lower Tryon Creek

CONFLUENCE REACH

Lower Tryon Creek prominently functions as off-channel rearing and refuge habitat to other Willamette River basin fish populations (Chinook, coho and steelhead), such as those originating from Clackamas, McKenzie and Santiam rivers. Off-channel habitats were once abundant in the lower Willamette River, but are now severely lacking. Juvenile salmon use off-channel areas for rearing and refuge during yearling and subyearling development in fall, winter and spring. Albeit present, existing habitat in the lower confluence reach is poor. Large wood and other instream structure and cover (boulders, undercut banks, overhanging vegetation) is lacking, limiting potential opportunities for prolonged rearing, and incised streambanks prevent high flows from accessing the broader floodplain area. Deep pools and general low velocity, slack water conditions (that are characteristic of lowland, large riverine confluence areas) provide the best habitat in the lower confluence reach. In addition to providing rearing and refuge habitat, the lower confluence reach provides marginal to poor quality riffle habitat for spawning and summer rearing. Note, gravels constitute only 35 percent of riffle area, and fines and organic material covers more than 35 percent of those areas; hence the functional capacity of riffle environs is generally low.

LOWER CANYON REACH

The lower canyon reach has great intrinsic habitat potential to support spawning and rearing by steelhead, cutthroat and coho salmon. In 2002, the National Riparian Service Team surveyed the watershed and concluded that the lower park is well suited for coho and steelhead production (WMSWCD 2003b). The creek is relatively low gradient through TCSNA and it provides key habitats needed to support spawning and rearing by coho and steelhead. For example, large, deep pools are present (averaging 0.60 meter in depth), providing important summer rearing habitat when surface waters warm, and providing important depth refugia during high flows in the fall, winter, and spring. In addition, riffle habitat is of good quality, with gravels to support spawning and rearing (e.g., gravels comprise more than 35 percent of pool-bottom substrate). Note, steelhead, cutthroat, and coho prefer small to large sized gravels to spawn in.

Although pool and riffle habitats provide important habitats, channel complexity and diverse habitat forms are generally lacking. Large, key pieces of wood are absent and wood densities are low. Wood is generally classified as small to medium size; and single pieces have not yet amassed to form functional wood clusters. Lack of wood-associated instream structure limits the quality of overwintering habitat and consequently the likelihood that salmon could remain instream during higher flows. However, the lower canyon reach contains some of the largest and oldest riparian trees in the basin, so near-term recruitment of larger wood pieces into the creek is good. Unlike the confluence, the lower canyon reach has some off-channel habitats (usually associated with tributary confluences and wetlands), and multiple springs and seeps enter the creek. These characteristics, along with transient beaver dams and debris jams, provide important slack water, pooled habitat. In addition, the floodplain through this lower canyon reach is believed to be intact and well connected to the creek, particularly near the confluence of Iron Mountain Creek (WMSWCD 2003b) provide high flow refugia and overwintering habitat during higher flood flows.

MIDDLE AND UPPER PARK REACH

The middle and upper park reaches provide high quality complex pools: 13.5 complex pools per 100 meters of stream length; this is the most of all the reaches surveyed in Tryon Creek, and more than five times the number considered desirable for fish-bearing habitat. Riffle habitat is considered favorable, with desirable gravel and cobble composition. However, half of the habitats surveyed had more than 25 percent fines covering riffle areas. Only 21 percent of the riffles surveyed in the middle park (Tryon 3A) were considered desirable habitat (having less than 12 percent fine sediment accumulations). This high proportion of fines and organics significantly affects the quality of spawning grounds, the egg incubation environment, and the ability of fry to successfully emerge. Only the upper 400 meters of this reach (immediately below SW Boones Ferry Road) exhibits good fish-bearing habitat, with good riffle habitat and low fines. Tryon Creek is relatively straight and incised through the middle and upper Park reach. Off-channel refugia are rare and are mostly associated with tributary junctions, ephemeral side channels, and hyporheic seeps and springs. These habitat features are important to salmonids, particularly during overwintering months and through the summer.

Although wood is present, wood densities are low and key pieces are lacking. Like the lower canyon reach, large wood pieces and associated clustered wood masses are rare. The surrounding riparian and forest provides small to medium sized pieces, but unlike the lower canyon reach, the surrounding riparian forest throughout the middle and Upper Park is relatively young (approximately 50-70 years). The implication is that there is very little source contributions of large woody debris, expect for that which may come from upstream. [Note this is unlikely since the trash rack at Boones Ferry Rd captures all large pieces of wood – eliminating source contributions of woody material into downstream reaches]. In addition, the existing forest stand is deciduous-dominated, which is not characteristic of what likely existed here prior to logging activities. With the exception of western red cedar, conifer species are noticeably lacking. Hence, wood that falls into the creek from the surrounding forest will consist mostly of deciduous species, which have a shorter lifespan than conifers (such as Douglas fir, hemlock, and cedar) once they enter the water. Short-term sources of large conifer wood is needed.

Despite these ecological limitations, the middle and upper park reach retains some of the best fish-bearing habitat in Tryon Creek. Pools are deep, and riffle gravels are present (although embedded with sediments in the lower two-thirds of the reach). Stream gradient remains low, and trails generally do not abut the creek channel. The potential for the creek to interact with its riparian and floodplain area is great throughout this reach if flood flows could top the bank and extend outside the creek channel. The National Riparian Service Team surveyed the watershed in 2002 and concluded that the middle and upper park reach is well suited for coho and steelhead production (WMSWCD 2003b).

Middle and Upper Tryon Creek

SW Boones Ferry Road, Marshall Cascades, and SW 18th Place (just upstream of Marshall Cascades) are significant fish barriers to anadromous and resident fish under most water-year conditions. SW Boones Ferry Rd completely prevents fish from moving upstream. Marshall Cascades is a natural fish barrier. It probably historically marked the upstream extent of anadromous fish movement under most flow conditions. However, winter-run steelhead may have navigated up and over the cascade reach during particularly high flows, offering discrete opportunities to spawn and rear in upper Tryon Creek.

Habitat conditions in upper and Middle Tryon Creek could support spawning and rearing by steelhead and cutthroat, but would probably not support coho. Pool abundance is relatively low (approximately 34 percent of habitat). Deep pools are few; only 35 percent of the pools have depths greater than 0.5 meter, and channel complexity, in the form of large wood and larger substrate, is notably lacking. Riffles comprise the dominant habitat type in Upper Tryon Creek. Although abundant, and with good gravel composition for spawning and rearing, silt loads are high: most riffle habitats (96 percent) have greater than 12 percent fine sediments covering the stream bottom. As a result, riffle quality is low, reducing the functional capacity of spawning and rearing habitats. Wood counts and wood densities are low, and key pieces are completely lacking. The lack of wood and large boulders instream limits the quantity and quality of overwintering habitat. Off-channel refugia are primarily found near tributary confluence regions; backwater and side-channel habitats do not exist. Lack of instream refugia (deep pools and instream structure) and lack of off-channel, high-flow refugia severely limit the potential for Middle and Upper Tryon Creek to provide key rearing habitats, particularly during the overwintering months.

Despite these conditions, cutthroat trout and rainbow trout continue to populate Middle and Upper Tryon Creek; indicating that if passage were available, anadromous steelhead might also survive. Salmonids have been reported between SW Maplecrest Drive and Marshall Cascades (Tryon 4B) during good flow years (personal communication, Maplecrest property owner, 2002).

Adequate data were not available to thoroughly assess and evaluate habitat conditions and biological community structure in the headwaters of Tryon Creek (Tryon 5), Arnold Creek, Falling Creek, and other tributary habitats.

Limiting Factors Analysis for Coho and Steelhead

Coho

For coho, fish passage blockage at HWY 43 is the most prominent limiting factor affecting population abundance and productivity. If fish passage did not limit population viability, then low habitat diversity, such as channel confinement, impaired riparian function, and lack of wood in-channel limits potential coho productivity during freshwater rearing at the egg, fry, juvenile, smolt and adult stage. Sedimentation, particularly in lower Tryon likewise limits potential coho productivity; and lack of key habitats, such as off-channel rearing areas and slack water habitats in the lower confluence area prominently affect potential coho production. Figure 7 summarizes key habitat attributes limiting potential coho production in Tryon Creek. Following is a brief description of the relative influence on coho productivity in each geographic area.

Figure 7. EDT analysis of aquatic and riparian protection and restoration priorities by attribute class for Tryon Creek **coho salmon**.

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	*Channel stability/landsc.1/*	*Chemicals*	*Competition (w/ hatch)*	*Competition (other sp)*	*Flow*	*Food*	*Habitat diversity*	*Harassment/poaching*	*Obstructions*	*Oxygen*	*Pathogens*	*Predation*	*Sediment load*	*Temperature*	*Withdrawals*	*Key habitat quantity*
Arnold Cr(TRY)	◯	◯	•		•		●	•	⬤		⬤				●			•
Lower Tryon	◯	◯	•		•		•	•	●		⬤				⬤			●
Middle Tryon	◯	◯	•	•	•		●	•	⬤		⬤				●			●
Portland	◯	◯		●	●	•	•	•	⬤	•			●	•		•		⬤

1/ "Channel stability" applies to freshwater areas; "channel landscape" applies to estuarine areas.

Key to strategic priority (corresponding Benefit Category letter also shown)

A		B		C		D & E	
◯	High	○	Medium	◦	Low		Indirect or General
⬤		●		•			

LOWER CONFLUENCE AREA (TRYON 1)

Coho area most impacted by lack of key rearing and refuge habitats and lack of habitat diversity. The confluence area historically functioned as Willamette River floodplain habitat, and off-channel habitat to the Willamette River. It still functions as the later, but presently fails to provide functional floodplain habitat that is characteristic of large, low gradient rivers. Loss of this unique habitat function and diversity significantly limits potential coho production in this reach, specifically by limiting the amount and type of confluence / Willamette River floodplain habitat that historically characterized the area.

LOWER CANYON REACH (TRYON 2)

Coho are most impacted by lack of habitat diversity, poor channel stability, lack of food, and sediment loading. Channel instability coupled with high sediment loading likely pose the greatest risk to coho production. High sediment loading not only impacts early stage development, but also likewise impairs potential macroinvertebrate production, a primary food source. In addition, lack of habitat diversity such as large key pieces of wood, deep pools, and large boulders limit potential productivity.

The above habitat conditions most prominently affect egg incubation and juvenile rearing (winter and summer). As stated previously, habitat evaluations in Tryon Creek presume that adults can pass HWY 43 – hence although fish passage into Tryon Creek is the one most important limiting factor, it was taken-out of EDT to fully evaluate the impacts of other important habitat attributes on potential coho productivity. Again, obstructions are not considered limiting factors in the Middle Park Reach.

Life Stage	**Impact**
Egg Incubation	Poor channel stability and high sediment loads most prominently effect egg incubation. Chemical contamination and lack of key habitat, such as stable riffle beds, likewise impact egg to fry survival.
Juvenile Rearing (Summer)	Lack of complex channel forms (e.g., large wood, boulders and undercut banks), lack of aquatic insects (for food) and low summer flows (and high stream temperature) most prominently effect juvenile production through the summer. In addition, chemical contamination remains a concern through the summer.
Juvenile Rearing (Winter)	As with summer rearing, lack of complex channel forms or habitat diversity significantly limits coho survival and growth through the winter. Other significant influences on overwintering survival include high winter flows, channel instability and lack of food.

MIDDLE PARK REACH (TRYON 3A)

Coho are most impacted by channel instability, lack of habitat diversity, lack of food and high sediment loading. Channel instability coupled with high sediment loading caused from higher stream flows likely pose the greatest risk to coho production. High sediment loading not only impacts early life stage development (egg incubation), but also likewise impairs potential macroinvertebrate production, a primary food source. In addition, lack of habitat diversity such as large key pieces of wood and large boulders limit potential productivity.

The above habitat conditions most prominently affect egg incubation, fry colonization and summer rearing. As stated previously, habitat evaluations in Tryon Creek presume that adults can pass HWY 43 – Hence although fish passage into Tryon Creek is the one most important limiting factor, it was taken-out of EDT to fully evaluate the impacts of other important habitat attributes on potential coho productivity. Again, obstructions are not considered limiting factors in the Middle Park Reach.

Life Stage	**Impact**
Egg Incubation	Poor channel stability and high sediment loads most prominently effect egg incubation through the winter. High flows scour the bed channel and streambanks yielding unprotected streambanks that are vulnerable to channel erosion. In addition, high flows chemical contamination may limit egg to fry survival.
Fry Colonization	Fry colonization through late winter / early spring are impacted by a variety of impaired habitat functions including: lack of habitat diversity, high flows, channel instability, high stream temperature, lack of food, and potentially high chemical contamination.
Juvenile Rearing (Summer)	Lack of complex channel forms (e.g., large wood, boulders and undercut banks), lack of aquatic insects (for food) and low summer flows (and high stream temperature) limit juvenile production and survival through the summer. In addition, chemical contamination remains a concern through the summer.

UPPER PARK REACH (TRYON 3B)

Coho are most impacted by channel instability, lack of habitat diversity, and high sediment loading in the Upper Park Reach. Channel instability coupled with high sediment loading caused from higher stream flows likely pose the greatest risk to coho production. High sediment loading not only impacts early life stage development (egg incubation), but also likewise impairs potential macroinvertebrate production, a primary food source. In addition, lack of habitat diversity such as large key pieces of wood and large boulders limit potential productivity.

The above habitat conditions most prominently affect egg incubation, fry colonization and summer rearing. As stated previously, habitat evaluations in Tryon Creek presume that adults can pass HWY 43 – Hence although fish passage into Tryon Creek is the one most important limiting factor, it was taken-out of EDT to fully evaluate the impacts of other important habitat attributes on potential coho productivity.

Life Stage	Impact
Egg Incubation	Poor channel stability and high sediment loads most prominently effect egg incubation. Chemical contamination and lack of key habitat, such as stable riffle beds, likewise impact egg to fry survival. Winter flows and its affect on bed scour may be a potential concern in the reach immediately below Boones Ferry Rd.
Fry Colonization	Fry colonization is most prominently influenced by lack of habitat diversity, high spring flows and associated channel instability. Lack of aquatic insects for feeding, and poor water quality (chemical contamination and temperature) likewise adversely affect fry to juvenile survival.
Juvenile Rearing (Summer)	Lack of deep pools (habitat diversity), lack of aquatic insects (for source food) and low summer flows (and stream temperature) most prominently effect juvenile production through the summer. In addition, chemical contamination remains a concern through the summer; and competition with other species could be a concern.
Juvenile Rearing (Winter)	Lack of off-channel, and slack water habitats is the primary limiting factor for coho during winter rearing. Other significant influences on overwintering survival include channel stability and food. Peak flows and associated water quality (chemical contamination and high sediment loads) are likewise considered important attributes affecting juvenile survival (and rearing) through the winter.

MIDDLE AND UPPER TRYON (TRYON 4)

Coho were most impacted by lack of habitat diversity, poor channel stability, lack of food, high peak flows in the winter and low flows in the summer and sediment loading. The absence of off-channel habitat, combined with high stream velocity would significantly limit coho production in this reach. Slack water habitats are most important during winter rearing and are likewise critically important as high flow refugia during peak and prolonged winter flows.

Note, historically Middle Tryon Creek likely did not provide high quality coho rearing habitat. This reach is moderately steep and bound by steeper valley walls. Areas of low gradient, slack water likely existed, however, much of the coho production likely occurred in Lower Tryon Creek. However, if coho were ever present in this reach, the most vulnerable life stages and life history strategies (e.g., habitat preferences) would include: egg incubation and juvenile rearing (winter and summer).

Life Stage	Impact
Egg Incubation	Poor channel stability and high sediment loads most prominently effect egg incubation. Chemical contamination and lack of key habitat, such as stable riffle beds, likewise

	impact egg to fry survival.
Juvenile Rearing (Summer)	Lack of deep pools and protective cover (habitat diversity), lack of aquatic insects (for source food) and low summer flows (and stream temperature) most prominently effect juvenile production through the summer. In addition, channel instability and chemical contamination remains a concern through the summer.
Juvenile Rearing (Winter)	Lack of off-channel, and slack water habitats (key habitat) and diverse habitats (e.g., deep pools, beaver dams, and channel morphology) (habitat diversity) are the primary limiting factors for coho during winter rearing. Other significant influences on overwintering survival include channel instability and lack of food. Peak flows and associated water quality (chemical contamination and high sediment loads) are likewise considered important attributes affecting juvenile survival (and rearing) through the winter.

Steelhead

As with coho, fish passage obstructions at HWY 43 prominently limits potential steelhead production in Tryon Creek. Sediment loads also affect steelhead production. This is associated with its adverse impact on spawning gravels, egg incubation environment, and summer rearing habitat. In addition, lack of key habitats, such as high quality spawning and rearing grounds (that are not embedded with high sediment loads) prominently affects steelhead productivity and life history diversity.

Figure 8. EDT analysis of aquatic and riparian protection and restoration priorities by attribute class for Tryon Creek **steelhead**.

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability/landsc.1/	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Arnold Cr(TRY)	◯	◯			•		●	•	●		⬤				●			•
Lower Tryon	◯	◯			•		•	•	•		⬤				⬤			●
Middle Tryon	◯	◯		•	•		●	•	●		⬤				⬤			●
Portland	◯	◯		●					●	•			•	•				●

1/ "Channel stability" applies to freshwater areas; "channel landscape" applies to estuarine areas.

Key to strategic priority (corresponding Benefit Category letter also shown)

A		B		C		D & E	
◯ ⬤	High	○ ●	Medium	∘ •	Low		Indirect or General

LOWER TRYON

Steelhead were impacted most by flow, sediment and lack of habitat diversity. Low summer flows, and high winter flows combined with few off-channel areas, deep pools, and instream structure are likely prominent factors. In addition, high sedimentation in the winter and summer can smother eggs and inhibit macroinvertebrate production. Channel stability and chemical contamination are likewise key attributes affecting potential steelhead production.

Most vulnerable life stages and life history strategies (e.g., habitat preferences) in Middle Tryon Creek include: egg incubation and juvenile rearing (winter and summer).

Life Stage	Impact
Egg Incubation	High sediment loading during from late winter thru early spring most prominently effect egg incubation. Chemical contamination and channel instability, such as unstable riffle beds, likewise impact egg to fry survival.
Juvenile Rearing (Summer)	Low summer flow is the primary limiting factor effecting age 0+ and age 1+ productivity. Elevated stream temperature also impacts summer rearing, particularly in the middle and upper portion of Middle Tryon Creek, where stream gradient becomes steeper. Lack of deep pools with logs and woody debris, and exposed riffle beds (habitat diversity) along with associated low aquatic insect production significantly impact steelhead productivity.
Juvenile Rearing (Winter)	Lack of deep pools and large wood (habitat diversity), high flow refugia in the form of side-channels, terraced banks, and off-channel habitats (habitat diversity), high sediment loads, high peak winter flows, and channel instability impair steelhead productivity.

MIDDLE AND UPPER TRYON CREEK

Steelhead were impacted most by flow, sediment and lack of habitat diversity. Low summer flows, and high winter flows combined with few off-channel areas, deep pools, and instream structure are likely prominent factors. In addition, high sedimentation in the winter and summer can smother eggs and inhibit macroinvertebrate production. Channel instability and chemical contamination are likewise key attributes affecting potential steelhead production in this upper, urbanized reach.

Most vulnerable life stages and life history strategies (e.g., habitat preferences) affected in Upper Tryon Creek include: egg incubation and juvenile rearing (winter and summer).

Life Stage	Impact
Egg Incubation	High sedimentation of riffle habitat most prominently affect egg to fry survival (e.g., smothering and suffocation). High peak flows through the winter and spring, channel instability and chemical contamination likewise effect egg to fry survival.
Juvenile Rearing (Summer)	Lack of deep pools (habitat diversity), lack of aquatic insects (for source food) and low summer flows (and stream temperature) most prominently effect juvenile production through the summer. In addition, chemical contamination remains a concern through the summer; and competition with other species could be a concern.
Juvenile Rearing (Winter)	Lack of deep pools and off-channel refugia (key habitats) is the primary limiting factor for steelhead during winter rearing. Other significant influences on overwintering survival include lack of large wood to provide protective cover, channel stability and lack of food. Peak flows and associated water quality (chemical contamination and high sediment loads) are likewise considered important attributes affecting potential survival through the winter.

Subbasin Summary

Fish passage obstructions, lack of habitat complexity and key habitats, poor riparian and floodplain functions and high sedimentation overlaying riffle habitats have reduced species distribution and production potential in Tryon Subbasin. In addition, lack key off-channel habitats and habitat diversity, along with chemical contamination reduce potential productivity of both salmonid populations in the lower Willamette River, specifically during early life history rearing, juvenile emigration and adult migration.

Table 3. Basin Summary of habitat constraints liming steelhead and coho production in Tryon Creek.

Habitat Attribute	Description
Stream Connectivity	▪ HWY 43 significantly blocks anadromous fish from accessing Middle Tryon Creek ▪ Boones Ferry Rd. completely blocks anadromous and resident fish from accessing Upper Tryon Creek.
Habitat complexity	▪ Lacking large wood; large and medium sized substrate; overhanging vegetation; undercut banks and terraced banks ▪ Shorter stream length with fewer meanders and simplified channel morphology (channelization).
Key habitats	▪ Lack of high quality riffles, deep pools, side channels, secondary channels, off-channel and backwater habitats.
Riparian and Floodplain forest	▪ Second growth, even-aged deciduous riparian and floodplain forests in Middle Tryon Creek do not provide large wood pieces and substantive volume of woody debris. ▪ Lack of native conifers as source woody debris will limit the longevity and function of wood forms in the creek. ▪ Lack of overhanging vegetation along the stream banks destabilizes the creek, and minimizes potential protective cover to fish and wildlife. ▪ Lack of mature native trees and shrubs in Upper Tryon Creek contribute to increased stream temperatures in the summer.
Fine Sediment	▪ High sediment loads smother spawning habitats (riffle gravels) and fill pools. ▪ Sediment associated pollutants prevalent throughout the basin. ▪ High silt cover reduces areas for macroinvertebrate production.
Hydrologic Regime	▪ Deforestation of lower Tryon thru the 1940's and 1960's and urbanization in middle and upper Tryon has significantly modified annual and peak flow regimes ▪ Change to the flow regimes prominently influences many other watershed functions and characteristics. For example, increased winter flows erode the stream channel resulting in channel instability, increased sediment loading, low macroinvertebrate production, and reduced floodplain and riparian interactions.

Following is a more detailed description of the impacts of these habitat constraints on coho and steelhead productivity. This analysis will ultimately inform habitat restoration and protection strategies.

Fish Passage

Access to spawning and rearing habitat is a key limiting factor affecting anadromous coho, steelhead and cutthroat distribution and species diversity in Tryon Creek. Breaks in longitudinal stream connectivity, particularly at HWY 43 and Boones Ferry Rd. severely impede resident and anadromous fish movement in and out of the basin.

Riparian and Floodplain Condition and Connectivity

Riparian and floodplain functions are not presently hydrologically connected as they once were. Riparian and floodplain habitats that are connected to its river channel will help attenuate stream flows and decrease peak flows, store water, recharge the groundwater and subsequently maintain base flow during the summer. In addition to helping maintain normative hydrologic processes, floodplains and wetlands filter sediments, supply organic matter (including large wood) and bed-form substrates to the channel help moderate stream temperatures (via subsurface and hyporheic flows). Notably, the role of wetlands to mitigate for downstream flooding has been recommended as a strategy for the larger Willamette Basin in <u>An Evaluation of Flood Management Benefits through Floodplain Restoration on the Willamette River, Oregon</u> (Williams and Associates, Lmtd, 1996). In addition to these processes that help maintain stream building process, floodplain and wetland environs provide important habitat to aquatic and terrestrial wildlife. Floodplain wetlands (or seasonal wetlands), oxbows, and secondary channels, provide important high flow refugia and overwintering habitat to native fish communities, particularly salmonids. Coho salmon in particular rely on these slack water, low velocity rearing areas during fall, winter and spring. Salmonids may likewise use off-channel habitats as refuge from adverse instream conditions, such as high flow velocity, large volumes of suspended solids, or large concentrations of pollutants.

The adjacent riparian environ further helps maintain these hydrologic connections and provides additional benefits that are uniquely associated with aquatic – terrestrial interactions. For example, riparian areas are essential for providing shade to the stream, providing source woody material (and leaf matter), providing protective cover (overhanging vegetation), stabilizing stream banks, and capturing and filtering sediments. Notably, providing opportunities for flood flows to top the bank and inundate the riparian area and broader floodplain area are necessary to maintain these aquatic – land interactions.

Lack of historic floodplain habitat in Lower Tryon Creek is a key limiting factor effecting the streams ability to function dynamically, particularly given the urban constraints within upland and floodplain areas and the altered hydrograph; re-establishment of the full-spectrum of historical stream/floodplain interactions is not likely feasible. However, careful management of existing floodplains in Lower Tryon could restore important ecological functions and provide a means to re-establish channel processes. Specifically, reconnecting floodplain interactions is a means to restore processes important for slowing velocities, lowering local water surface elevation, and detaining floodwaters via depression, storage, infiltration, and decreased travel time.

Habitat Complexity

Tryon Creek would be expected to have an array of pools, riffles, side channels, and backwater areas. Habitat diversity, channel stability and channel complexity (e.g., meanders, stream length, etc.) are highly influenced by <u>large wood</u> in-stream. Large wood would help protect the stream banks, allow the creek to meander, and help build key habitats, such as deep pools and backwater areas. In addition, large wood complexes buried into the stream banks likely provided important overwintering habitat to salmon. Without this protective cover, fish can be swept downstream during higher winter and spring flows.

Adding large wood instream and buried pieces in the floodplain will improve channel roughness. Benefits include attenuated erosive flows (e.g., reduce flood flow energy); it will aid channel-forming processes (habitat formation: pool and riffles), and add instream refugia. Indirect effects that could be realized include increasing stream length (sinuosity), capturing sediments, reclaiming (or enhancing) riparian and floodplain connectivity, and providing substrate (and detritus) for macroinvertebrate production. In addition, large wood instream aids formation of deep pools, backwater pools, and off-channel areas that provide key refugia to fish.

Key Habitats

Tryon Creek is straight, incised and wide and stream banks are eroded. The Creek generally flows through one primary channel; secondary channels and side channels are rare. Because of the simplified channel form, important habitats are lacking, such as undercut banks, backwater pools and off-channel habitats, deep pools and high quality riffle habitats. Lack of these important spawning and rearing areas significantly reduces potential population productivity.

Fine Sediment

Tryon Creek drains a watershed that is characterized as having naturally high levels of fine sediment and silt. However, land-uses in Middle and Upper Tryon Creek have exacerbated the natural condition of the stream to transport high sediment loads. Fine sediment from steeper stream segments (in Middle and Upper Tryon) settle out in low gradient areas of the Park (Lower Tryon). Further sediment loads increase sharply during storm flows, again originating from the more urbanized upper basin. Notably, excess (greater than 20%) sand and silt (less than 6.4-mm) in gravel can reduce both survival and emergence of fry; and amassed (or deposited) fine sediment and extreme silt loads (greater than 25-mg/L) (Bell 1973) can clog fish gills, affecting a fishes ability to “breath” (or absorb oxygen). Additionally, cobbles and gravels covered with fine sediment reduces interstitial spaces that are used by aquatic invertebrates (the primary food organisms of salmonids) and cover that is used by juvenile salmonids in the winter. Indirect effects that fish may experience include reduced feeding, avoidance reactions and delayed (or ceased) migrations (if a silt curtain persists).

Hydrology

Upper Tryon Creek is approximately 40% built-out. Impervious surfaces in the upper watershed disrupt natural hydrologic processes such as transpiration (from vegetation), evaporation and infiltration. Notably, hardened surfaces prevent rainfall from infiltrating into the ground and becoming subsurface flow through the landscape. The effects of these altered flow regimes on the creek are evident throughout the basin; sediment deposition is high, stream banks are eroded, large wood retention is low, and the channel is relatively straight, incised and uniform (morphology). The combination of these affects have disconnected the creek from the riparian and floodplain area and resulted in a lowered groundwater table (Ponce and Lindquist, 1990). In addition, peak storm flows often coincide spawning by coho and winter steelhead. Coupled with the lack of off-channel habitat and deep pools, peak flows can adversely affect spawning adult and juveniles.

Presently, hydrologic regimes do not represent historic flows: higher velocity and more frequent peak flows in the summer, and less channel flow in the winter. As a result, the channel is straight, incised, widened, eroded; and the streambed is lowered (in some cases hitting bedrock). Groundwater recharge and hyporheic flows no longer augment low, summer base flows and / or provide cool water refugia in the summer. High velocity flows in fall, winter and spring scour and move streambed material, and suspending and washing-out deposited eggs, sending emergent fry and juveniles downstream. Lower summer flows increase the capacity for stream temperatures to rise. Stormwater runoff coming from Middle and Upper Tryon Creek is considered a contributing source of chemical contamination in the Creek.

Note, the following hypothesis to improve the hydrologic regime (or move the hydrologic regime so that it more closely matches reference hydrologic cycles) are prescribed for Middle and Upper Tryon Creek where actions will effect landscape features and processes. However, any action that addresses hydrology in the middle and upper watershed will undoubtedly affect hydrologic processes in Lower Tryon Creek, and will likewise effect coho and steelhead production potential in the lower subbasin. Hence, although coho would not likely heavily populate Middle Tryon Creek, actions to improve hydrologic regimes in the upper watershed will substantively affect coho production potential in Lower Tryon Creek.

PROTECTION AND RESTORATION VALUE

EDT reach analysis was aggregated to provide an estimate of the changes to coho and winter steelhead population abundance, productivity, and diversity in each geographic area. The changes provide an estimate of the relative importance of habitat protection and restoration in each geographic area. Geographic area priorities are based on:

1) An estimate in the changes in population abundance, productivity, and diversity at each life stage under conditions of habitat degradation from the current state (protection benefit) and habitat restoration to the historic potential (restoration benefit); and
2) The extent to which the geographic area is used by each of the life stages.

Table 1 and 2 below show the relative restoration value for each geographic area, or the relative benefit that could be realized if this geographic area was restored to reference conditions; and Figure 8 and Figure 9 illustrates corresponding changes in population abundance and productivity.

Coho

Lower Tryon Creek (from the Willamette River confluence up to Boones Ferry Rd.) provides the greatest protection and restoration value for coho salmon (Table 1). This reach is well protected within Tryon Creek State Natural Area and subsequently provides the greatest expanse of functional habitat within the subbasin. The lower Willamette River provides the second greatest benefit for protection and restoration, followed by Middle Tryon Creek and Arnold Creek. The lower protection and restoration values in Middle Tryon and Arnold Creek primarily reflect low historic use by coho for spawning and rearing.

Table 1. An estimate of restoration value (changes in the Tryon Creek **coho salmon** population abundance, productivity, and diversity) for each of the geographic areas. The estimates are based on the EDT analysis.

Geographic Area	Restoration Rank	Percent Change With Restoration		
		Abundance	Productivity	Diversity
Lower Tryon	1	1150%	495%	576%
Middle Tryon	3	149%	106%	241%
Arnold Cr	4	0%	0%	0%
Lower Willamette River	2	425%	11%	300%

Steelhead

As with coho salmon, Lower Tryon (from the Willamette River confluence up to Boones Ferry Rd.) provides the greatest protection and restoration benefit to steelhead. However, unlike coho, Middle Tryon provides significant protection value (rank 2) to steelhead; winter steelhead likely migrated, spawned and reared at least up to Marshal Cascade, whereas coho did not. The lower Willamette River likewise shows important restoration value, which is likely associated with temporary refugia during adult and juvenile migrations. Relative to coho and steelhead production in Tryon Creek, historically, Middle Tryon would have favored steelhead production, whereas lower Tryon would have favored coho production.

Table 2. An estimate of restoration value (changes in the Tryon Creek **steelhead** population abundance, productivity, and diversity) for each of the geographic areas. The estimates are based on the EDT analysis.

Geographic Area	**Restoration Rank**	**Percent Change With Restoration**		
		Abundance	Productivity	Diversity
Lower Tryon	1	890%	658%	63%
Middle Tryon	2	585%	266%	76%
Arnold Cr	4	0%	0%	0%
Lower Willamette River	3	22%	10%	2%

Figure 8. Relative importance of the EDT analysis geographic areas for protection and restoration measures for the Tryon Creek coho salmon.

Geographic Area	Protection benefit		Restoration benefit	
	Category/rank		Category/rank	
Arnold Cr(TRY)	A	2	A	4
Lower Tryon	A	1	A	1
Middle Tryon	A	2	A	3
Portland	A	2	A	2

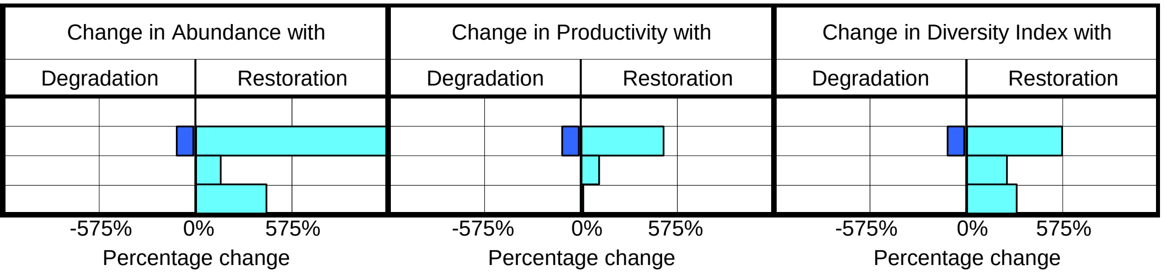
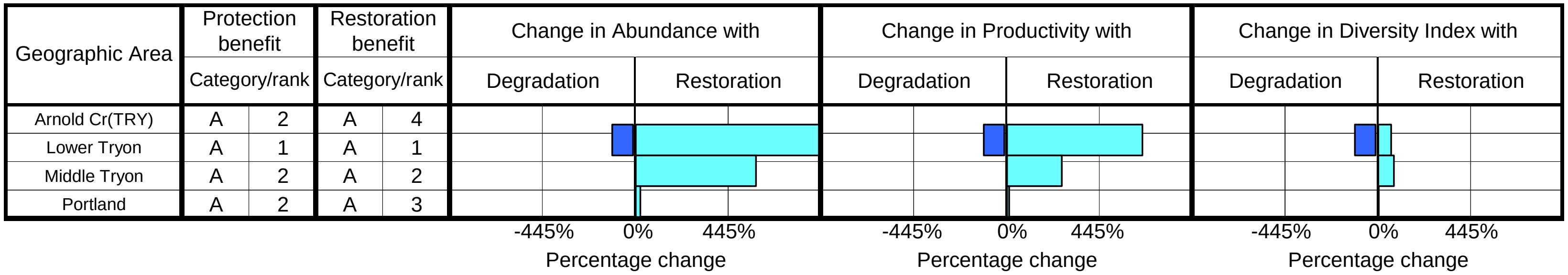


Figure 9. Relative importance of the EDT analysis geographic areas for protection and restoration measures for the Tryon Creek steelhead.



Geographic Area	Protection benefit		Restoration benefit	
	Category/rank		Category/rank	
Arnold Cr(TRY)	A	2	A	4
Lower Tryon	A	1	A	1
Middle Tryon	A	2	A	2
Portland	A	2	A	3

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CHAPTER 12

Public Involvement, Education, and Stewardship

INTRODUCTION

Much of the success of the Fanno and Tryon Creek Watershed Plan will rely on the extent to which citizens participate in the planning process and implementation. Also, since citizens cumulatively affect (and can also improve) watersheds though personal lifestyle decisions, the inclusion of education and stewardship opportunities in the watershed plan is essential to make long term progress toward watershed health. Many citizens in Fanno and Tryon Creek Watersheds are already involved in both the planning process and many stewardship activities to improve local creeks, streams and uplands.

The purpose of this report is to:

- Characterize the current SW community and level of watershed improvement commitment of citizens in the Fanno and Tryon Creek watersheds
- Define and describe outreach program elements
- Characterize current BES efforts to include citizens in decision making and stewardship activities
- Relate the Fanno and Tryon Watershed Plan's goals and objectives to current and potential activities in which citizens can help improve watershed health
- Begin to describe future actions in terms of citizen involvement

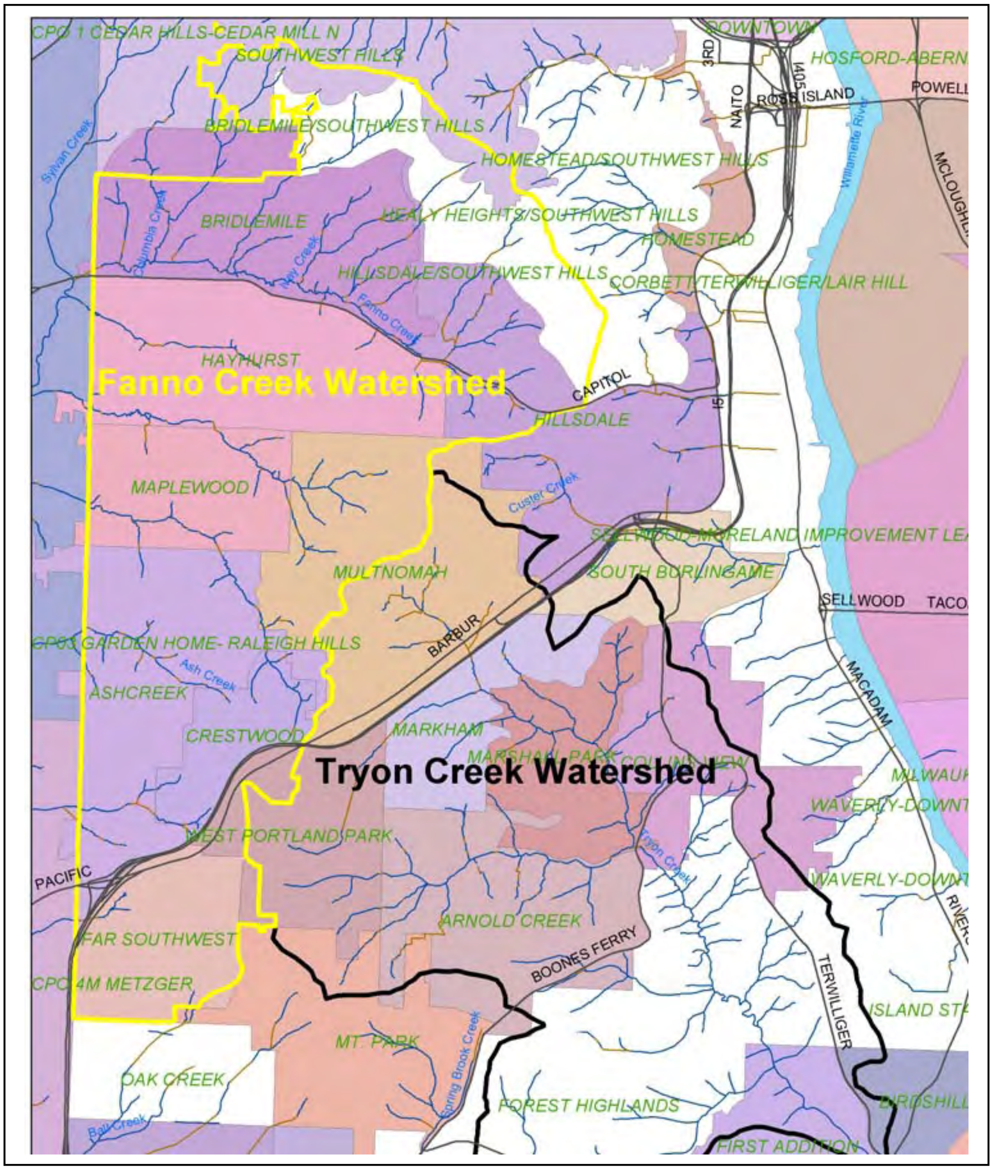
Further details for community involvement will be associated with the Fanno and Tryon Creek Watershed Plan's specific recommendations.

GENERAL COMMUNITY CHARACTERISTICS

Strategies for public participation are directed to the entire SW community as well as constituencies and stakeholders most interested in specific project proposals. The watershed plan area consists largely of neighborhoods of single-family dwellings. Offices, stores, commercial buildings and apartments line much of the main transportation corridors: I-5, Barbur Boulevard, Beaverton-Hillsdale Highway, Multnomah Boulevard, and Capitol Highway.

Watershed plan recommendations that call for stormwater facilities or pollution prevention actions in commercial areas will require a public involvement program directed toward businesses, owners of commercial and multi-dwelling properties and residential renters. Pollution prevention programs or pollution removal facilities to be proposed for residential areas will call for a public involvement program directed toward residential homeowners. Facilities or programs to be designed in rights-of-way that affect transportation modes may call for still other public involvement strategies.

Fourteen SW Portland neighborhood associations (Hillsdale, Bridlemile, Hayhurst, Maplewood, Multnomah, South Burlingame, Ashcreek, Crestwood, Far Southwest, West Portland Park, Arnold Creek, Markham, Marshall Park, Collins View) are wholly or partially within the Fanno and Tryon Creek watersheds (see Map 1 below). Three business associations (Southwest Business Association, Multnomah Village Association, Hillsdale Business and Professional Association) also operate within the watersheds. SW Neighborhoods, Inc. (SWNI), a district coalition, serves the business associations and the 14 neighborhood associations. The neighborhood associations and district coalitions are the City's recognized structure for the participation of citizens in Portland's civic affairs. Beginning October 2005, a BES staff member from the Fanno Tryon Watershed team will represent BES at regular meetings of the Multnomah Village Association.



Map 1. Southwest Portland neighborhoods in the Fanno and Tryon watersheds

The community also has many watershed efforts working in partnerships on a wide variety of issues. One effort, the Tualatin Basin Public Awareness Committee (TB-PAC) began collaborating in 1993 at the direction of the Oregon Department of Environmental Quality (DEQ). TB-PAC includes members from the Designated Management Agency Group (City of Portland BES, OR Department of Agriculture, Clackamas County Water Environment Services, Multnomah County, DEQ, Washington County, Clean Water Services, City of West Linn, and the City of Lake Oswego) and other partners (Tualatin River Watershed Council, Tualatin Hills Park and Recreation District, Washington County Soil and Water Conservation District and the Tualatin Riverkeepers). The TB-PAC increases public awareness about non-point source pollution through offering joint programs on pollution prevention and water quality issues.

Additionally, the citizens of the Fanno and Tryon Creek watersheds have formed many “Friends” groups, which focus on education and stewardship projects on their local stream reaches. Some of these include the Tryon Creek Watershed Council, the Fans of Fanno and the Bridlemile Creek Stewards. Many schools and communities of faith have also been implementing watershed projects such as naturescaping and restoring stream reaches (see description in Outreach Strategy Stewardship section).

OUTREACH STRATEGIES

Outreach staff uses a variety of involvement strategies and outreach approaches to keep the public informed and engaged. The activities listed below are tailored to the particular circumstances and needs of this project. Public outreach consists of three methods: 1) public involvement in specific projects 2) information and education, and 3) environmental stewardship.

Public Involvement

The Bureau of Environmental Services is committed to meaningful public involvement as an essential element of all bureau programs and projects. Public involvement provides opportunities for Portland's citizens to learn about watershed issues, participate in decision-making, take part in stewardship activities and help build sustainable community partnerships.

Citizen involvement is required or recommended as a strategy in various local, state and federal policies. Mirroring language in Statewide Planning Goal 1 Citizen Involvement, Goal 9, Citizen Involvement in Portland’s Comprehensive Plan provides as follows:

> Improve the method for citizen involvement in the on-going land use decision-making process and provide opportunities for citizen participation in the implementation, review and amendment of the adopted Comprehensive Plan.

In addition, Title 3 of the Portland City Code mandates city agencies to engage citizens in certain planning efforts. For example, Title 3 states that City agencies shall include affected neighborhood associations and district coalition boards in planning efforts, which affect neighborhood livability. Finally, Oregon’s Statewide Planning Goals and Guidelines, Goal 1, defines public involvement guidelines around land use permits and regulations. It also delineates the procedures required by agencies to inform the public of new proposals and issues surrounding land use planning.

Public involvement for the Fanno and Tryon Creek Watershed Plan provides consistent and timely public information on key project issues. It also provides for a variety of opportunities for the public to communicate ideas, opinions and concerns about project elements and decisions. Public involvement also helps build long-term partnerships with a variety of neighborhood, business, environmental and citizen interest groups. Meaningful public participation must begin very early in any project. Public involvement staff looks for opportunities to expand public awareness about watershed planning through media outlets and public events.

The Bureau's environmental program coordinator develops and manages the public involvement elements of all watershed programs and projects, both capital and operating. This coordinator works closely with staff from Southwest Neighborhoods, Inc. to provide the following services:

- Work with managers to develop public involvement plans.
- Provide expertise on pubic involvement methodology and techniques.
- Oversee implementation of public involvement activities.
- Act as the liaison between the community and the Bureau.
- Coordinate public involvement activities with other agencies.
- Provide facilitation services for internal project and program forums.

Public involvement activities are tailored to the particular circumstances and needs of each program or project. Project teams are asked to provide appropriate technical staff time to support these outreach activities. They assist in the development of maps, graphics, boards and alternative matrices for use at public meetings and community presentations.

Public involvement addresses issues raised by the specific projects that make up the implementation of the watershed plan. Public values and expectations regarding specific projects need to be defined. This outreach method helps to answer a question posed in the Critical Questions document: “What changes are the public willing to accept to changes in lifestyle and costs to address the changes needed?” Public involvement includes (but is not limited to):

- Public meetings such as open houses
- Continuation of the advisory committee or formation of task groups and focus groups as needed
- Establishment of relationships with particular individuals and businesses impacted by Best Management Practices (BMPs)
- Feedback from the community that addresses impacts that can be used to alter or mitigate any adverse impacts of BMPs
- Community surveys
- Guidelines for people to take action themselves for community enhancement

Citywide standards for public involvement are currently being addressed by a coalition of City staff and stakeholders. When those standards are adopted, they will be included in the Public Involvement, Education and Stewardship Plan for the Fanno and Tryon Watersheds.

Information and Education

Outreach in this category addresses the Critical/Target Questions asked in the characterization report. Education and information focuses on questions that are of interest to landowners and/or residents impacted by early actions and projects recommended in the report. Examples of questions that are current and future education and information topics are: What are major sources of pollution? What is our total output of pollutants? What BMPs are going to be considered? Are there appropriate invasive species control measures that need to be taken in the watershed? Specific education and information tools and outlets employed to this end are:

SW Watershed Resource Center – Located in the SW Community Center, the watershed center is currently staffed half time. The Center offers information, referral and meeting space for individuals and groups interested in watershed issues. Center staff coordinates the Friends of Vermont and provide programs in conjunction with the community center.

Website - The BES website is linked to those of local watershed stewards. It provides information, maps and ways the public can provide on-line feedback or help with projects via the website. The BES website include ongoing feedback from the public by way of contact information for staff.

Project information - Develop and distribute informational materials for a variety of media to provide relevant information about a specific project. For example, a project fact sheet should be both printed and distributed by email, and it would include: project purpose overview, map of the project area, project timeline and scheduled activities, contact person, announcement of project meetings and activities and feedback forms for public to express ideas and concerns.

Fact sheets and brochures – Make general information available via mailing or outreach sites such as SWNI, Tryon Creek State Natural Area and the SW Watershed Resource Center. Fact sheet topics would include: stormwater BMPs in general, ecoroofs, swales and infiltration ponds, stormwater planters, trees and native vegetation, porous pavement, roof gardens, maps of watersheds showing on the ground projects (monitoring stations, revegetation, stewardship grant projects, community group restoration projects), calendar of events and brochures on special topics (ivy removal, native plant identification, top ten watershed weeds list). Currently we are piloting ongoing distribution of watershed information at Wood's Creek and Dickinson (Ash Creek) Parks for dog walkers and other passive recreational users by using "real estate take one" type boxes.

Special Events – Promote or attend special events in partnership with community groups to provide information on watershed projects. Current special events in the watersheds include various Earth Day events, the Spirits of Tryon and the Trillium Festival.

Newsletters – Keep community up-to-date on project process via local newspapers such as the Southwest Neighborhood News.

Email List Serves – Keep community informed via list serves such as The Dirt, Naturescaping for Clean Rivers, ONI Notification and SWNI's list.

Community Bulletin Boards – Promote watershed information in highly visible sites such as Multnomah Center and the SW Watershed Resource Center.

Presentations – Present information about specific projects to key stakeholder groups. For example, presentations are offered at SWNI and neighborhood association meetings, and include:

- Project purpose, overview, and timeline
- Opportunities for community input
- Community concerns and ideas (acknowledging those previously gathered through the SW Community Planning process)

Educational workshops - These workshops, co-sponsored with a local interest group if possible, offer educational opportunities that are free and open to the public. Broadening the knowledge base of the community about watershed health and stewardship opportunities is an important step toward bureau and community goals. Examples include Naturescaping for Clean Rivers, monthly speaker series, watershed tours and streamsider workshops. Education on sources of pollution and pollution reduction is also currently provided by Metro.

Water Pollution Hotline – BES maintains a call-in hotline for citizens to report pollution concerns. The staff educates citizens, respond to spills, erosion reports and other pollution issues and provide regulatory reporting if appropriate.

Toxic Exchange and Collection Programs - Metro currently provides a toxic substance collection program in neighborhoods.

Youth Education – BES currently provides an educator to serve teachers and students in the Fanno and Tryon watersheds. The popular program includes hands-on classroom programs on topics such as riparian zones, macroinvertebrate identification, watershed awareness, water quality testing, and stormwater issues. Field trip topics include stream restoration, stormwater solutions, water sampling and aquatic invertebrate identification.

Signage – Signs placed in high traffic areas, such as major arterial and walking areas like Multnomah Village, can be used to raise awareness as to watershed geography, pollutant sources and what individuals can do to reduce impacts on watersheds. Currently the Fanno basin has signs along roadways at creek crossing indicating the larger watershed (Tualatin River) and the name of the local creek. The Tryon Creek Watershed Council has requested similar signs for the Tryon Creek Watershed. BES has recently replaced its program in which volunteers stenciled storm drains with “Dump no Waste, Drains to Fanno Creek” to a marking program that is more permanent. The markers have been in use since 2003.

Community Art – Commissioned art that highlights target wildlife species, bioaccumulation, watershed geography and community action. Could include sculpture, informational kiosks with art, stepping stones along trails with messages, etc. For example, a mural on the restoration tool shed at Gabriel Park could educate dog-walkers and families using the nearby fitness equipment about Vermont Creek, resources for checkout, community projects and Fanno Creek geography. There is currently little watershed art except at the SW Watershed Resource Center.

Television, radio and print ads – The Regional Coalition of Clean Water Providers launches annual campaigns, which include advertisements featured on buses and include radio or TV elements.

Stewardship

Stewardship is a necessary part of the long-term success of the watershed plan. Since much of the riparian land in the Fanno and Tryon Creek Watersheds is in private ownership, the City will need to continue to explore creative opportunities to encourage landowners to manage land for clean watershed values.

Little data is available on effectiveness measures of stewardship incentives. In 2002, Clean Water Services conducted a survey of public habits related to water quality to identify incentives and barriers to better water quality behaviors (Riley Research Associates). Conclusions made centered on the ideas that decisions are based on cost, effectiveness and neighbors' perceptions. It would be therefore helpful to increase stewardship incentives to include discounted products (eco car washes, native plants), workshops that demonstrate effectiveness (natural lawn care) and publicity of neighbors' positive watershed activities to inspire others.

Basic types of stewardship programs and incentives and examples of those currently used in Portland include:

Direct payments and recognition for private management- Support in the form of easements, tax credits, cost shares, awards and compensation for lost revenue.

- BES Watershed Revegetation Cost Share. Since 1999, the revegetation program has 37 sites in the Fanno and Tryon creek watersheds. Since 1996 the team has worked on 387 sites throughout the City of Portland. (See SW Portland Stewardship Map. Many projects resulted from partnerships with private property owners, most on single family or multifamily residential properties. Typical cost shares contributed by private partners range from 10-50% of project cost, with $400-500 being typical for most properties. In general, landowners in these watersheds are willing to participate in revegetation projects. However, more staff hours than are currently available will be required to plan and administrate projects that consist of many very small residential properties, which are typical of these watersheds.
- BES Community Watershed Stewardship Grant Program. Though Fanno and Tryon Creek watersheds house only 8% of Portland's population, the watersheds have been awarded over 17% of the funds. This result is due in part to receiving a larger numbers of requests than from other areas of the City and to high quality grant proposals with strong partnerships. In our Native Plant Gift Certificates program, Fanno and Tryon community groups received 27% of awards in 2002-03.
- State of Oregon riparian and forest tax credits
- Recognition events such as the Spirit of Portland Awards for watershed stewards

Public Acquisition, Conservation Easements, Land Trust Partnership, Land Exchanges

- Willing Seller Program (Johnson Creek Watershed)
- Partnerships with Trust for Public Land and other land trusts for easements and purchases (none exist in Fanno or Tryon Watersheds at this time)

Regulatory Mechanisms and Reforms - Allow landowners to transfer development rights, streamline permitting processes, remove disincentives to stewardship, etc.

- Clustering development on smaller lots in exchange for e-zone protection
- Transfer of Development Rights

Market-Based Incentives - These incentives promote economic development that considers and supports conservation. A "green label" program is an example.

- Ecological Business – certification and awards program for businesses that prevent pollution. Publicizes "Eco-biz" list so consumers can support green business. Currently, of the 20 certified automotive business on the list, none are in Fanno or Tryon watersheds.

Educational and Technical Assistance - A better understanding encourages landowners to invest in watershed restoration.

- Naturescaping for Clean Rivers Program
- Resources for stewardship groups such as check out of restoration tools and stream monitoring equipment
- Contracts for community groups such as SOLV and Friends of Trees to help private landowners with restoration and tree planting.
- Technical resource directory www.4sos.org/tad/
- Support for existing stewardship groups and cultivation of new groups. There are currently many local groups working to improve watershed health (See SW Portland Stewardship Map (figure 1)). These include:

1. <u>Southwest Neighborhoods, Inc. (SWNI)</u> – Incorporated in 1978. Sponsors annual yard debris collection and household large garbage pickup events. Acts as a clearinghouse for watershed information and liaison between the City and the neighborhood associations. Provides land use planning information and act as fiscal agent for several stewardship groups. Advertises watershed information and events through monthly newsletter.
2. <u>Tryon Creek Watershed Council</u>. Founded in 1995 as a voluntary association of citizens and representatives of stakeholder groups and agencies. The Council has active committees on watershed assessment, stewardship and land use issues. The stewardship committee's Reach for the Creek program has ongoing projects at four sites.
3. <u>Friends of Tryon Creek State Natural Area</u>. Incorporated in 1969, the Friends provide a wide variety of education and stewardship opportunities to thousands of people annually. The group is responsible for the original acquisition of the land that is now the Natural Area.
4. <u>Friends of Arnold Creek</u>. Active on projects since 1993 including water quality monitoring, land acquisition, development of the watershed council and supporting local projects.
5. <u>Fans of Fanno</u>. Established in 1990, this stream group has lead restoration and educational activities on Fanno, both inside and outside the City of Portland.
6. <u>Bridlemile Creek Stewards (Fanno Creek)</u>. Established by an active neighborhood group in 1997. The group has grown and expanded its activities to include: riparian restoration, monitoring, educational outreach, and technical assistance to other groups. Current active sites include Hamilton and Albert Kelly Parks and work with neighbors to conduct streamside restoration on private property.

7. Trillium Creek Community – Inspired by a neighbor who cleared ivy from his and neighboring property, BES and SOLV teamed up with Americorps, Nevah Shalom, Portland Christian Center, Robert Gray School, Bridlemile Creek Stewards and Boundary Street neighbors to work on a multi year stream restoration project. The Trillium Creek partnership was formed in 2002.
8. Vermont Creek "Adopt a Plot" and wetlands in Gabriel Park. City staff and community partners began stream enhancement and wetland projects in 1994. Current partners include Americorps and Two Rivers Montessori, Maimonides, Portland Jewish Academy, and Hayhurst schools.
9. Friends of Vermont Creek. Citizens, City staff, Americorps and the staff at the SW Watershed Resource Center partnership since Summer 2004. Projects include riparian restoration at Gabriel Park, storm drain markings and community art.
10. Cedar Sinai Park (Pendleton Creek). New effort, started in 2003, to restore riparian forest and provide education, access and stewardship opportunities.
11. PCC Sylvania Habitat Restoration Team (Ball Creek). Students, instructors and maintenance staff working on campus riparian and upland issues. Received grant from BES for work in 2003 – 04.
12. St Andrew's Presbyterian Church (Fanno Creek). Parking lot retrofit and riparian restoration project by church members since 1996.
13. Jackson Middle School Falling Creek Restoration Project. Teachers and students engaged in plant propagation, invasive removal and tree planting since 1997.
14. Crestwood Headwaters Group (South Ash Creek). Neighborhood association committee working on restoration project at Dickinson Park and Taylor Woods.
15. Friends of Wood's Park. Established in September 2002 to work on headwaters area of Wood's Creek including removing eroding trails, creating new trails, and protecting creek by replacing vegetation.
16. Twowbly-Washouga "Clean the Ravine" Group (Fanno). Hillsdale neighbors organizing to remove invasive plants using goats and other methods.
17. Ecoroofs Everywhere. Provides inspiration and technical assistance for the design and installation of ecoroofs throughout Portland. Also provides educational outreach to the general public.
18. Urban Water Works. Technical assistance on innovative stormwater projects city-side. Also acts as fiscal agent for Ecoroofs Everywhere and local projects.

WATERSHED PLAN VISION STATEMENT, GOALS AND OBJECTIVES

The vision statement for the planning work in the Fanno and Tryon Watersheds states: "The community maintains a strong advocacy role and is actively participating in on-going efforts to keep watersheds healthy and in balance with continued developments." Indeed, some of the stated goals and objectives will require the collective actions of residents in the watershed.

The Fanno and Tryon Watershed Plan's Goals and Objectives document provides a framework on which current programs and messages for public involvement, education and stewardship are based. Following are selected goals and objectives with current and potential actions that involve citizen initiative, input and/or participation.

Goal 1. Water quantity – Protect and improve stream flows for public health and safety and watershed health.

Objective: Identification, protection and restoration/stabilization of stream channels
Citizen groups in the Fanno and Tryon Creek Watersheds are already involved in the identification, protection and restoration/stabilization of stream channels. Many more groups are needed to work in conjunction with the BES Watershed Revegetation Program, the BES stewardship program and Portland Parks and Recreation Natural Areas team to expand protection and restoration efforts. Ideally, each stream or reach in the plan area would have a group of stakeholders, who would be included in the decision-making process and have on the ground knowledge of the conditions of their reach. The City's role is to continue to provide and expand innovative opportunities such as the Watershed Revegetation Cost Share Program, SOLV Team-Up partnership, and Naturescaping for Clean Rivers for private landowners. Additional education and stewardship activities will need to focus on invasive plant management to protect existing forests in upland and riparian areas. Land acquisition may also be considered a solution and will require public input into prioritization of land purchases and discussions of management options. Partnerships with organizations such as the Trust for Public Land and Three Rivers Land Conservancy may also be strengthened to provide expertise in the areas of acquisition and conservation easements.

Goal 2–Water Quality – Protect and improve surface water quality and meet state and federal water quality standards

Objective: Develop a Water Quality Plan for Fanno Creek Watershed to meet the TMDLs for phosphorus, temperature, dissolved oxygen and bacteria.
When sources of pollutants are identified, public outreach strategies will be developed to educate citizens about those pollutants that they can minimize via behavioral change. For example, if the pollutant source for fecal coliform is found to be pet waste, a campaign that could include education, dog walker outreach, providing scoop baggies and scoop law enforcement might be helpful to reduce bacteria input.

Objective: Develop a Temperature Management Plan in Tryon Creek to meet the water quality standard for temperature.

To address concerns regarding temperature management, local stream restoration groups will need to be fostered (as in Goal 1 above) to plant more trees along streams, both in public and private riparian zones. Active stewardship groups in the Tryon Creek Watershed could form the basis for soliciting input from their members and neighbors.

Objective: Identify and prioritize additional water quality issues of concern in the Fanno and Tryon Creek watersheds and develop strategies for addressing these issues.
Education and incentive programs for homeowners regarding fertilizer and pesticide use should be encouraged with partners such as Metro and SWNI. Currently, the only City-sponsored program aimed at achieving pollution reduction in the garden is Naturescaping for Clean Rivers, a partnership with East Multnomah Soil and Water Conservation District, DEQ and Metro.

Goal 3– Habitat –Support key ecological functions, target species, and biological communities by protecting, enhancing, and restoring aquatic and terrestrial habitat conditions.

<u>Objective: Develop a strategy for protection, enhancement and restoration of habitat conditions for the watershed.</u>

During watershed planning processes, key community leaders from neighborhood associations and Friends groups have been included on the Fanno and Tryon Watershed Plan Advisory Committee from 2001 through 2006. Their ideas and comments have been incorporated into all parts of the plan.

During implementation of watershed improvement projects, neighborhood associations and watershed stewardship groups will be briefed before projects are fully designed and implemented.

Goal 4– Biological Communities – Protect and restore target aquatic and terrestrial species and biological communities to maintain biodiversity in the watershed, and to meet applicable policies and regulatory requirements.

Restoration activities are currently underway through the BES Watershed Revegetation Program cost share and local citizen stream groups. As discussed previously, many more local groups need to be started and supported.

Educational outreach might include offering educational lectures and field tours to show biodiversity to residents of the Fanno and Tryon Watersheds and encouraging public participation in wildlife surveys.

Protection of riparian zones is being addressed via the Healthy Portland Streams program. BES and ONI staff is currently working with the Bureau of Planning staff to develop outreach strategies with community stakeholders.

Goal 5– Public Health and Safety/Infrastructure - Ensure consistency and compatibility between City watershed plans and the City's infrastructure programs to protect public health and safety.

Though it is the City's role to ensure integrity and safety of infrastructure, citizens remain a valuable source of information on public health and safety issues in their neighborhoods. Recently, staff from SWNI collected drainage problem information from neighborhood association members during regular monthly meetings. More efforts may be needed to document local citizen's concerns relating to drainage, pollution and erosion issues.

The City currently has a system though which citizens can call in to report sewage spills and drainage hazards. The pollution hotline staff deploys inspectors to the site, document problems and communicate with appropriate response agencies, such as the Bureau of Maintenance and the Oregon Department of Environmental Quality.

Goal 6– Public Involvement – Incorporate public values into watershed plan development, implementation and refinement.

The public has been invited to give input on the Watershed Planning process through open houses at the Multnomah Center since June 2001. Further, the Fanno and Tryon Watershed Plan has enlisted the assistance of an advisory committee composed of citizen representatives from neighborhood associations as well as agency representatives. These committee members receive regular updates and provide feedback to staff during the planning process. A contract with SWNI provides for an annual update to be mailed to 26,000 homes in Southwest Portland's neighborhoods.

During the alternatives analysis and implementation phases, we involved the public through a variety of methods (open houses, web site information, direct mail, etc.) to solicit concerns and incorporate citizen's ideas into projects.

Goal 7– Stewardship – Maintain long-term community-wide commitment to improve and sustain watershed health.

Objective: Establish a strategy for promoting and carrying out community stewardship projects and programs in the watershed. The strategy will identify City services to be provided, establish targeted opportunities for stewardship activities, and identify partnerships and funding opportunities for implementation of community and City initiated projects.

BES presently has an active stewardship program. Program elements include: the Community Watershed Stewardship Grant program, contracts with SOLV and Friends of Trees (FOT) to conduct streamside restoration projects and agreements with Portland State University and Americorps to provide community outreach. Current partnerships include: Portland Parks and Recreation, soil and water conservation districts, schools, churches, watershed councils, friends groups, neighborhood associations and others.

Goal 9 - Coordination and Consistency with Plans and Policies – Meet watershed goals and objectives, and achieve consistency with applicable plans and policies, through active coordination and participation with other agencies and organizations.

Include citizens with knowledge of neighborhood and other plans who could help identify conflict between the Fanno and Tryon Creek Watershed Plan and other plans. Pertinent plans with which to maintain consistency include The SW Community Plan, SW Urban Trails Plan, Healthy Portland Streams and River Renaissance. By continuing to provide consistent funding to SWNI, City staff can keep the public informed on these plans.

EVALUATION

As the projects progress, there is a benefit to evaluating public involvement services. Evaluations are specially designed for particular activities and include surveys, focus groups and feedback forms.

PUBLIC INVOLVEMENT EFFECTIVENESS INDICATORS

- Citizen comments, ideas and suggestions are incorporated into the plan and subsequent projects.
- Citizens and organized groups support the outcome of projects.
- Cost reductions and savings for the public involvement component of the project are achieved through creative and cost-effective outreach approaches.

SUMMARY

Public Involvement, Education and Stewardship are currently active and well received in the Fanno and Tryon Creek Watersheds. Requests from individual citizens and groups for support for watershed stewardship projects are currently at a higher volume and complexity than our resources can support.

Some recommendations for expansion or additions to existing outreach programs were discussed earlier, with many opportunities available. Some future actions could include:

- A BES partnership with Metro in the future to target neighborhoods identified in the planning process which contribute high levels of pollutants to streams or to educate community members at Metro hazardous waste pick-up events.
- Working in partnership with other bureaus and agencies (such as the “Healthy Portland Streams” program and conservation districts) to provide additional technical assistance for individuals and groups.
- More incentive programs like green payments, cost shares and grants can be explored.
- Public education programs, which focus on specific behavior such as: keeping dogs out of streams, reducing pollution from automobiles and forming a stream steward group.

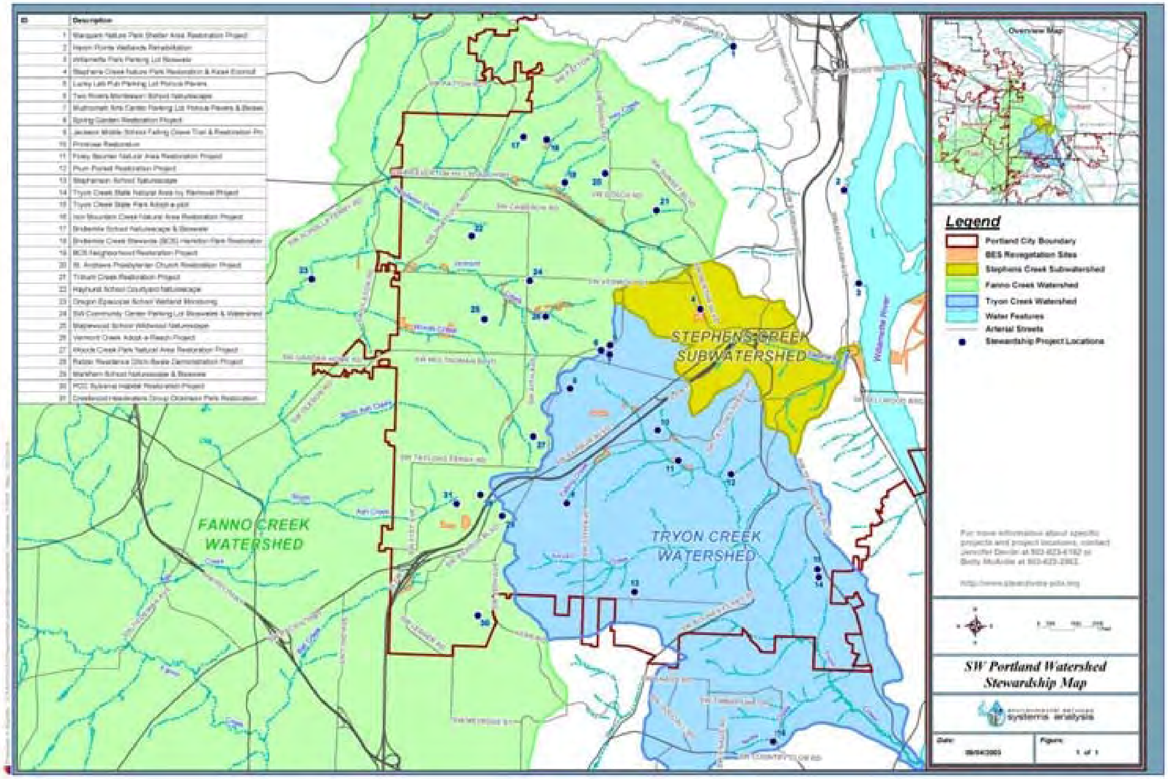


Figure 1 SW Portland Stewardship Map

CHAPTER 13

Related Plans, Policies and Programs

INTRODUCTION

Federal, state, and local plans, policies, and programs govern and guide many of the actions the City takes to provide vital services, preserve and protect natural resources and promote watershed health. This section provides an overview of these policies, plans, and programs that affect activities in the Fanno and Tryon Watersheds; however it is not intended to be a comprehensive list. Other sections of this Watershed Plan contain additional discussion about the relationship of regulatory/policy issues to planning and implementation activities.

BES watershed planning staff coordinated with many of the agencies and program staff discussed below in the development of the Watershed Plan. Projects and programs recommended in the Watershed Plan (see Part 8 Recommendations) are in general compliance with these policies and plans, and promote collaboration among various agencies and programs influencing watershed health.

FEDERAL REGULATIONS

Federal regulations protect endangered species (Endangered Species Act), water quality (Clean Water Act), and drinking water resources (Safe Drinking Water Act).

Clean Water Act

The Clean Water Act (CWA) of 1972 and later amendments regulate discharges of pollutants to waters of the United States from both point sources (such as wastewater treatment plants and industrial discharges) and non-point sources (such as stormwater runoff). The CWA calls for fishable and swimmable waters through the "restoration and maintenance of the chemical, physical and biological integrity of the Nation's water." It also states the intent "where attainable, to achieve water quality that promotes protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water." The CWA also protects jurisdictional wetlands. The City of Portland has responsibilities related to the following four sections of the CWA.

Section 303(d)

Under section 303(d) of the CWA, states are required to develop lists of impaired waters that do not meet state water quality standards designed to protect beneficial uses. Beneficial uses range from water contact recreation and fish and aquatic life to irrigation and public water supply. The Oregon Department of Environmental Quality (DEQ) has developed a statewide 303(d) list that identifies water body reaches that are "water quality limited" because they do not meet instream water quality standards set for certain pollutants to assure support for the beneficial uses designated for that reach. DEQ then establishes total maximum daily loads (TMDLs) that specify the maximum amounts of the designated pollutants the water body can receive from all point and non-point sources.

A. Tryon Creek Watershed

In 1996, DEQ added Tryon Creek to the list of waterbodies on the 303(d) list. Tryon Creek was determined to have summer water temperatures in excess of 64 degrees Fahrenheit (17.7 degrees Celsius), a critical standard for cool-water fisheries. A TMDL for this parameter is scheduled to be completed by DEQ in 2005.

B. Fanno Creek Watershed

In 2001, DEQ established new total maximum daily loads (TMDLs) for Fanno Creek for bacteria, dissolved oxygen and temperature, and revised the old phosphorus TMDL (DEQ, 2001). DEQ and the Tualatin Basin Designated Management Agencies (DMA) are responsible for and working toward the development of Implementation Plans for the new TMDLs. Portland's Bureau of Environmental Services (BES) is one of the Designated Management Agencies (DMAs) responsible for TMDL compliance within its jurisdiction. BES submitted the load allocation (LA) component of the Implementation Plan to DEQ in August 2003. The waste load allocation (WLA) component of the TMDL implementation plan will be developed in 2005/2006.

The LA is the non-point source fraction of the TMDL. Control measures evaluated and recommended as part of the Implementation Plan included the following:

- Construction site erosion control
- On-site stormwater treatment
- Retrofitting of existing public storm sewer systems
- Street sweeping
- Regional pollution reduction facilities (PRFs)
- Improved operation and maintenance practices
- Land use considerations (limit increases in constructed impervious area)
- Street construction standards (improved drainage features and filtration along roadways)
- Catch basin cleaning on private property
- Rehabilitation/refinement of design standards for sewers and septic systems
- Increased educational and stewardship programs

Overall, four categories of approaches were identified to reduce urban non-point source impacts to surface waters:

- Reduction of non-point source pollutants imported to the basin (e.g., phosphorus detergent bans)
- Preventive retention at the source (e.g., erosion reduction measures, sediment ponds, increased filtration)
- Mitigation of existing sources (e.g., high erosion sites, stream channels, leaky sewers)
- Removal in runoff (e.g., street sweeping, erosion control, porous pavement, drainage ditches and swales, and pollution reduction facilities)

Section 401

Under Section 401, applicants for a federal license or permit must certify that any discharges into waters of the United States that result from the activity will comply with state water quality standards. DEQ administers Section 401 water quality certifications, and makes the decision whether to certify, deny, or condition permits or licenses.

The major federal licenses and permits subject to Section 401 are Section 402 and 404 permits (see below), Federal Energy Regulatory Commission (FERC) hydropower licenses, and Rivers and Harbors Act Section 9 and 10 permits. Section 404 permits are by far the most common federal permits that require Section 401 certification. Examples of activities that may require a Section 404 permit and Section 401 water quality certification include:

- Fill, excavation, or construction in a wetland or on a streambank
- Construction of boat ramps
- Construction or modifications of dams, dikes, bridges, or combined sewer outfalls
- Stream channelization
- Stream diversion

DEQ retains the regulatory authority to review projects for water quality impacts, but coordinates with local jurisdictions, such as Portland, in cases involving sites that discharge to Municipal Stormwater systems prior to release into Waters of the State.

Section 402

The National Pollutant Discharge Elimination System (NPDES) permitting program (Section 402 of the CWA) requires sources of point and nonpoint pollutants to have an NPDES permit. DEQ administers several types of NPDES permits in Oregon covering municipal, industrial, and construction related operations. Permits can provide general coverage for a group of similar activities or can specifically target an individual. The permits may be issued to one or more permittees.

- An NPDES Industrial Stormwater General Permit (called a 1200 Z or in the Columbia Slough a 1200 COLS permit) regulates point source stormwater discharges from certain types of businesses and industries. The permit requires regulated facilities to develop a stormwater pollution control plan that identifies pollutant sources and specifies best management activities to minimize the impact on stormwater quality. The BES Industrial Stormwater Program staff act as a DEQ agent for the industrial Stormwater Permits issued within the City of Portland. BES administers permits for sites that discharge to the City's storm sewer and to sites discharging directly into local waterways. Staff provide the following functions: identification of sites requiring permits; assistance to sites developing stormwater management plans; oversight of monitoring and other reports; and onsite inspections for routine compliance and complaint/referral based inspections.

- The City holds two Publicly Operated Treatment Works (POTW) permits for the two City sewage treatment plants - Columbia Boulevard Wastewater Treatment Plant in the Columbia Slough watershed and the Tyron Creek Plant on the Willamette River. These permits regulate the discharge of total suspended solids (TSS), biochemical oxygen demand (BOD), *E. coli*, settleable solids, water temperature, and flow. As part of compliance with these permits the City operates an Industrial Pre-treatment Program that works with industries to limit the amount of pollutants they discharge into the City combined and separate sanitary sewer systems. These regulations also contain the requirements to control Combined Sewer Overflows (CSOs), Sanitary Sewer System (SSOs) and new regulation for collection system capacity, management, operation, and maintenance (CMOM).

- The City of Portland holds an NPDES Municipal Separate Storm Sewer System (MS4) Discharge Permit that regulates stormwater discharges through City owned outfalls. The City is in its second permit round – the first five year permit was issued in 1994 and the second in 2005. That permit requires a city-wide Stormwater Management Plan that identifies best management practices to be undertaken within the City to control pollutant discharges. The 2005 permit has a strong link and reporting requirement to demonstrate reduction of TMDL pollutants in TMDL designated watersheds (Fanno Creek and the Columbia Slough). The City reports annually to DEQ on progress implementing the BMP tasks.

- NPDES 1200-C Stormwater Discharge Permits are required for any construction project larger than one acre to control erosion and reduce sedimentation into waterways. The City while not a 1200-C agent like other jurisdictions, does obtain 1200-C coverage for all applicable construction projects. City inspectors assure that City projects comply with the NPDES 1200-C regulations. The City's Office of Transportation actually has a 1200-CA permit – that provides permit coverage for agency programs rather than individual construction projects.

Section 404

Section 404 regulates sediment removal and fill in waters of the United States, including wetlands. Oregon Division of State Lands and the federal Army Corps of Engineers both oversee portions of the removal and fill regulations and jointly administer the 404 removal/fill permits. Permits are required for activities that cause fill or removal of sediment occur within a jurisdictional wetland or below the ordinary high water mark in other waters of the State. The permit requires, in order of priority, avoiding impacts to the natural resource, minimizing impacts, and mitigating impacts. During construction water quality impacts associated with these permits are reviewed under DEQ 1200-C program, OAR 340-41, or Section 401, while post-development impacts are reviewed by the DEQ Section 401 water quality certification staff. The joint permit requires local jurisdictional sign off prior to application.

The City primarily acts as applicant and referral source for these permits. The City's many public works projects such as bridges, stream enhancement and utility line crossings may trigger the need to acquire these permits. In addition, during review of private development, many applicants are made aware that they will need state and federal permit review for their removal and fill operations.

Endangered Species Act (ESA)

The Endangered Species Act (ESA) of 1973 provides for the conservation of threatened and endangered plant and animal species and the ecosystems on which they depend. The National

Oceanic and Atmospheric Administration (NOAA) Fisheries (formerly called the National Marine Fisheries Service), has enacted regulations that make it unlawful to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect listed species, or even to attempt to engage in such conduct. The definition of "harm" includes habitat modification if the modification kills or injures fish by significantly impairing essential behavioral patterns such as feeding, sheltering, rearing, migrating, breeding, and spawning. The City of Portland is taking proactive steps to protect and aid in the ultimate recovery of ESA-listed species.

In February 2002, the National Marine Fisheries Service in NOAA Fisheries announced that it would reconsider its ESA listing determiniations for 27 populations (called evolutionarily significant units, or ESUs) of Pacific salmon and steelhead in light of court decisions. These include 13 ESUs of steelhead and salmon that may use or migrate through watercourses in the Portland Area. Ten of these 13 ESUs are proposed for listing as threatened: the upper Willamette River, lower Columbia River, Snake River fall-run and Snake River spring/summer-run Chinook salmon (Oncorhynchus tshawytscha); the upper Willamette River, lower Columbia River coho salmon (O. kisutch); and the Columbia River chum salmon (O.keta). Three of the 13 ESUs are proposed for listing as endangered: the upper Columbia River spring-run Chinook salmon (O. tshawytscha), upper Columbia River steelhead (O. mykiss) and Snake River sockeye salmon (O. nerka). At the time of this writing, NOAA Fisheries was receiving public comment and intends to publish final listing designations sometime during 2005.

In October 2002, the City entered into a federal ESA Section 7 streamlining agreement with the National Marine Fisheries Service in the National Oceanic and Atmospheric Administration (NOAA Fisheries), the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service (USFWS). This agreement establishes a cooperative process for streamlining ESA Section 7 consultations among the four parties to the agreement for City projects that require federal permit approval or funding. Every quarter, City and federal agency staff meet to simplify and streamline Section 7 consultations; develop information, documentation, formats and timeframes for biological evaluations/assessments (BE/BA) and biological opinions; develop additional compliance strategies; and improve coordination of strategies for complying with the ESA and additional regulatory requirements of other state and federal regulatory programs. The streamlining agreement facilitates early planning and coordination between the City and federal agencies for projects, programs and activities that require or would benefit from federal agency review. Benefits of the agreement include increased coordination for review, analysis and documentation of City projects, programs and activities so that they proceed in a timely manner while meeting federal agency and City goals for ensuring ESA compliance and assisting in the conservation of listed species.

Water Resources Development Act (WRDA)

The Water Resources Development Act (WRDA) of 1986, and subsequent amendments by Congress provide guidance to the U.S. Army Corps of Engineers (Corps) for conducting new dredging and environmental restoration projects. WRDA establishes a framework for a cost-sharing partnership between the federal government and non-federal interests that provide a local sponsor a role in project planning and financing. Planning for restoration projects under the

WRDA General Investigations authority are conducted using a two-phase process: a reconnaissance study and a cost-share feasibility study.

The City of Portland is the local sponsor of the Corps Lower Willamette River Ecosystem Restoration WRDA project to help formulate and implement restoration projects that will meet the City's River Renaissance's "Clean and Healthy River" vision. The objective of the feasibility study is to develop a publicly supported plan for ecosystem restoration actions throughout the Lower Willamette River. This project is intended to leverage federal funds to assist in riparian and in-water habitat restoration.

STATE REQUIREMENTS

State requirements take two forms: those that protect natural resources directly and those that affect the way development occurs to make it less damaging to natural resources.

Oregon's Removal-Fill Law (ORS 196.795-990)

This law requires people who plan to remove or fill material in waters of the state to obtain a permit from the Department of State Lands. The purpose of the law, enacted in 1967, is to protect public navigation, fishery and recreational uses of the waters. "Waters of the state" are defined as "natural waterways including all tidal and non-tidal bays, intermittent streams, constantly flowing streams, lakes, wetlands and other bodies of water in this state, navigable and non-navigable, including that portion of the Pacific Ocean that is in the boundaries of this state." The law applies to all landowners, whether private individuals or public agencies. These regulations are jointly administered with the Section 404 permits.

Permits from the Oregon Department of State Lands (DSL) are required for:

- Projects requiring the removal or fill of 50 cubic yards or more of material in waters of the state.
- The removal or fill of any material regardless of the number of cubic yards affected in a stream designated as essential salmon habitat.
- The removal or fill of any material from the bed and banks of scenic waterways regardless of the number of cubic yards affected.

Statewide Planning Goals and Administrative Rules

Oregon Statewide Planning Goals express the state's policies on land use and related topics. Locally adopted comprehensive plans, zoning and land division ordinances must be consistent with the Statewide Planning Goals and associated Oregon Administrative Rules (OAR).

Several Statewide Planning Goals address watershed health issues most directly. Goal 5 requires Oregon counties and cities to protect significant natural resources and conserve scenic and historic areas and open spaces. It calls for inventories of significant natural resources, including riparian corridors (streams, riparian areas, and fish habitat) and wildlife habitat. Local governments must then evaluate tradeoffs associated with protecting the resource or allowing development that would affect these resources and develop local protection programs. Actions that protect riparian areas and improve water quality help fulfill Goal 5 requirements. Metro is currently preparing a regional program that is intended to address the fish and wildlife habitat portions of the Goal 5 rule. Once Metro and the Oregon Department of Land Conservation and Development approves the program, Metro area local governments will be required to comply with the program within 2 years.

Goal 6 seeks to protect air, water, and land resources. Goal 7 addresses development in areas subject to natural hazards such as floods and landslides, and requires local jurisdictions to apply appropriate safeguards. Goal 11, Public Facilities and Services, outlines the need to plan and develop a timely, orderly, and efficient arrangement of public facilities and services to serve as a framework for urban and rural development. The City implements a Public Facility Plan process approximately every 5 years to stay current with these requirements. Goal 15, Willamette River Greenway, requires every urban area to evaluate its needs for land to serve commercial and industrial development and to plan for enough land to meet those needs. The City of Portland's codes and programs currently comply with the state's and Metro's requirements pertaining to Goals 6 and 7.

The City's Comprehensive Plan and various maps and codes implement these goals. In addition, Oregon's planning goals place strong emphasis on coordination of planning between cities, counties and regions. For example, Portland's Comprehensive Plan and zoning regulations must be consistent with Metro's plans and policies.

REGIONAL REQUIREMENTS

Metro's Title 3 Water Quality and Flood Management

Title 3 Metro's Urban Growth Management Functional Plan is intended to protect the beneficial water uses and functions and the resource values within designated water quality and flood management areas.

Title 3 implements the following Oregon Statewide Planning Goals:

- Goal 6: Air, Water, and Land Resources Quality
- Goal 7: Areas Subject To Natural Disasters and Hazards

Title 3 limits or mitigates the impact of development activities toward the goal of protecting life and property from dangers associated with flooding and protecting and enhancing water quality. Cities and counties in Metro's jurisdiction, including the City of Portland, must bring their planning policies and codes into conformance with Title 3 requirements. Metro has completed its program to manage water quality and flood management areas. As noted above, Portland's programs have been found in compliance with Metro's requirements.

Title 13 Nature in Neighborhoods Program

Metro is currently completing a multi-year planning process to develop a program intended to help conserve, protect and restore urban streams and waterways, riparian areas, and significant wildlife habitat. During the first step, Metro developed an inventory of regionally significant fish and wildlife habitat areas in the region. The inventory includes approximately 80,000 acres of regionally significant fish and wildlife habitat in the region. Approximately 30,000 of those acres (including land and water bodies) are in the City of Portland. The second step involved assessing the economic, social, and environmental and energy (ESEE) impacts of protecting – or not protecting – habitat areas. Metro completed this step in summer 2004. The inventory and the ESEE analyses are intended to help with the third step in the process—developing a habitat protection and restoration program. Metro has been working with stakeholders throughout the region to formulate an integrated habitat protection and restoration program that is balanced with other goals for the region (e.g., economic development).

Metro's proposed program focuses attention primarily on the highest value riparian areas. Once adopted by the Metro Council and the state Department of Land Conservation and Development, local jurisdictions, including Portland, will have two years to demonstrate compliance with regional requirements for these areas. Metro proposes to address upland resource through voluntary measures. The City of Portland is currently working to update its Natural Resource Inventory, which will provide critical information needed for Portland's compliance efforts.

The Watershed Plan incorporates Metro's inventories. BES watershed planning staff are collaborating with City staff regarding updating the Natural Resource Inventory. BES watershed planning staff will provide recommendations for areas to be included in the resource inventory. The inventories will be incorporated into the ongoing watershed management process.

CITY OF PORTLAND REQUIREMENTS

City Code

Several titles of Portland's City Code address natural resource protection and watershed health by regulating activities that affect the built and natural environments.

Title 10—Erosion and Sediment

The City created a new Title 10 Erosion Control Code in 2000 to comply with federal Municipal Stormwater NPDES regulations, Metro Title 3 Water Quality Requirements and support for the Endangered Species Act regulations. Title 10 contains requirements for development and construction-related activities to control the creation of sediment and prevent the discharge of erosion and other pollutants from construction sites. The regulations apply to public and private development. There are specific prohibitions such as releasing dirt off site and requirements for development of Erosion Control Plans, inspections and use of specified BMPs. The City also published a corresponding Erosion Control Manual in 2000 to list the accepted BMPs, their intended uses, and their maintenance requirements. Five City bureaus are active enforcers of Title 10:

- PDOT for their projects and ROW permit projects
- BDS for private development

- Parks for their CIP and Tree Permit sites
- Water for their projects
- BES for their projects and non-permit related activities

Title 17 – Public Improvements

Title 17 contains requirements for stormwater, drainage, water quality, wastewater, streets, public utilities, and other public improvements. The three main codes controlling water related discharges and administered by BES are 17.34, for the sanitary system 17.38 for post development water quality controls and 17.39 for stormwater discharges. These regulations set out the prohibitions and procedures to authorize discharges into the City's sewer and drainage systems. Discharges should be controlled for flow, for pollution reduction and shall be disposed in a manner mimicking nature. The City's Stormwater Management Manual describes many of the policies and requirements related to new development including the requirement to protect open drainageways. At development, sites are required to establish drainage reserves, which must remain in their natural topographic condition. BES's Chief Engineer must approve any modifications to, or improvements within, the drainage reserve.

Title 24 – Building Regulations

Title 24 contains requirements for the design, construction, quality of materials, use, occupancy, location, and maintenance of all buildings, structures, and land. Excavation and fill, particularly in the floodplain and floodways, is covered in this title. There are specific grading requirements for disturbing more than 10 cubic yards of material. The Title also controls requirements for appropriate onsite disposal of stormwater from new and re-development including infiltration facilities such as drywells and soakage trenches. Staff require sufficient soil infiltration capacity and stable slopes for approval of onsite facilities.

Title 29 – Property Maintenance Code

Title 29 contains requirements for the storage of materials on private property, accumulation of garbage/debris, and other private property issues. A variety of property maintenance requirements have proved to be hurdles to enhanced stormwater management (tall weed control, requirement to pave driveways). Alternatively additional controls are helpful such as requirements to control trash and debris, and prohibition of hazardous materials.

Title 33 – Planning and Zoning

Title 33 contains requirements that guide development throughout the City. There are provisions for protecting natural resources or gaining other desired outcomes, such as development, within specific areas of the City. Title 34 – Subdivision Code was incorporated into Title 33 in 2002. See "Planning and Zoning" section below for a more detailed description.

Planning and Zoning

Comprehensive Plan

The City's Comprehensive Plan provides a coordinated set of guidelines for decision-making regarding future growth and development and was prepared in part to satisfy the requirements of statewide and regional land use planning goals. Fourteen of nineteen Statewide Land Use Planning Goals apply to Portland including Goals 5, 6 and 7 mentioned above. In addition, eleven regional goals contained in the UGMFP apply to Portland including Title 3 and the pending Title 13.

The City's Comprehensive Plan includes:

- A set of land use and public facilities goals and policies to guide the development and redevelopment of the City
- A Comprehensive Plan map and set of zoning maps and regulations to carry out the policies

Comprehensive Plan Goal 8, Environment, contains the City's policies and objectives related to natural resources (including fish and wildlife), air, water, and land resources, and natural hazards (including flood and landslide hazards).

Resource Overlay Zones

Portland has established resource overlay zones to protect and conserve significant natural resources. These include environmental overlay zones, Willamette Greenway natural and "q" zones, and the scenic resource zone.

The environmental overlay zone is the City's primary tool to implement Comprehensive Plan Goal 8 and also Statewide Land Use Planning Goals 5. The environmental zones, as well as the Willamette River Greenway overlay zones also are part of the City's program to comply with State Land Use Goals 6, 7, and/or 15. The Willamette River Greenway water quality overlay zone complies with Title 3 of Metro's Functional Plan, and the Scenic Resource Zone complies with State Goal 5.

A. Environmental Overlay Zones

The environmental overlay zones are based on extensive natural resource inventories that cover areas within the City's jurisdiction. There are two types of environmental overlay zones, which currently affect approximately 20,000 acres. The environmental protection zone has been established in areas that have very high value resources and function. Development is allowed in the protection zone only in very limited circumstances. The environmental conservation zone also limits development in important resource areas. Development is allowed if it meets certain standards and approval criteria to ensure that impacts on significant resources are avoided, limited, and mitigated. (City of Portland, Title 33, Chapter 33.430). The environmental zones provide a long-term option for protection and development proposals within large ecosystems through the Natural Resource Management Plan process, discussed below in a separate section.

B. Willamette River Greenway Overlay Zones

Willamette River Greenway natural ("n") and water quality ("q") zones cover portions in the Willamette River Corridor. Development in these areas is subject to various standards and criteria intended to conserve important resources and protect water quality. The "q" zone implements the water quality performance standards of Metro's Title 3, which are intended to protect and improve water quality to support designated beneficial water uses, and to protect the functional values of the water quality resource area which include: providing a vegetated corridor to separate protected water features from development; maintaining or reducing stream temperatures; maintaining natural stream corridors; minimizing erosion, nutrient and pollutant loading into water; filtering, infiltration and natural water purification; and stabilizing slopes to prevent landslides contributing to sedimentation of water features.

C. The Scenic Resource zone

The Scenic Resource zone is intended to:

- Protect Portland's significant scenic resources as identified in the *Scenic Resources Protection Plan*
- Enhance the appearance of Portland to make it a better place to live and work
- Create attractive entrance ways to Portland and its districts
- Improve Portland's economic vitality by enhancing the City's attractiveness to its citizens and to visitors
- Implement the scenic resource policies and objectives of Portland's Comprehensive Plan

The purposes of the Scenic Resource zone are achieved by establishing height limits within view corridors to protect significant views and by establishing additional landscaping and screening standards to preserve and enhance identified scenic resources.

Natural Resources Management Plans

Within the environmental zoning chapter, natural resource management plans (NRMPs) provide an alternative to case-by-case environmental reviews (Chapter 33.430.310). NRMPs cover large ecosystems such as a forests, creeks, sloughs, or watersheds. They must address all resources and functional values (the benefits provided by the resources) to be conserved and/or protected by environmental zones within the plan boundaries. They must also address all significant detrimental impacts of the uses that are allowed by the plan. In this way, NRMPs provide the means to evaluate the cumulative effects of development or mitigation on the environmental resources of an area. There are NRMPs within several watersheds that play a large role in resource protection within the watershed; they are described below.

Plan Districts

Plan districts (Chapter 33.500) address concerns unique to an area when other zoning mechanisms (e.g., base and overlay zones) cannot achieve the desired results. An area may be unique based on natural, economic, or historic attributes; be subject to problems from rapid or severe transitions of land use; or contain public facilities that require specific land use regulations for their efficient operation. Each plan district has its own nontransferable set of regulations that apply to the area in conjunction with a base zone. The plan district provisions may modify any portion of the regulations of the base zone, overlay zone, or other regulations of Title 33, or may apply additional requirements or allow exceptions to general regulations. Some plan districts contain significant environmental regulations that supercede those of Chapter 33.430.

A. Tryon Creek Watershed
No Plan Districts are located in Tryon Creek

B. Fanno Creek Watershed
Two plan districts are partially located in the Fanno Creek Watershed: Hillsdale Plan District and Healy Heights Plan District. They do not include components that address environmental area protection directly, although the development allowed will affect stormwater runoff.

Administrative Rules

Administrative rules are binding requirements, regulations, or procedures that interpret and support implementation of City code. A number of administrative rules address natural resource protection and watershed health including:

- The City of Portland Stormwater Management Manual (1999; revised 2002 and 2004), which identifies requirements for reducing the impacts of stormwater runoff quantity and pollution resulting from new development and redevelopment.

- The City of Portland Erosion Control Manual (2002), which specifies measures for temporary and permanent erosion prevention and sediment control. An erosion, sediment, and pollutant control plan is required when doing City-permitted ground-disturbing activity (such as building, clearing, grading, public works, or street opening), and must be submitted with the permit application.

- The City of Portland Plant List (last revised in 2004), which establishes lists of native, nuisance and prohibited plants. The Portland Zoning Code establishes provisions outlining the use of these lists.

- Bureau enforcement rules. Various bureaus have rules that utilize technical assistance and education to prevent disturbance of natural areas and control materials and discharges. Controls are the strongest for off-site impacts such as to the right of way, City sewers and local stream systems.

LOCAL WATERSHED MANAGEMENT INFRASTRUCTURE

Local agencies and programs with significant roles and interests in the management of the watershed that were not discussed in detail earlier are summarized below. The Bureau of Environmental Services (BES) and watershed planning staff work collaboratively with these to improve watershed health.

The City of Lake Oswego, similar to the City of Portland, has many development codes and standards designed to protect watershed health including soil erosion and hillside standards, tree removal regulations, and residential development densities. In addition, Lake Oswego has an Open Space Grant Program, established to enhance the native character and habitat values of open spaces in Lake Oswego. Lake Oswego also contracts with BES to provide wastewater treatment at the Tryon Creek Wastewater Treatment Plant.

City staff from the City of Lake Oswego and the City of Portland participate in each others watershed planning processes. This participation ensures coordination on issues of mutual interest in lower Tryon Creek.

Clackamas County is the lead agency for land use regulation in unincorporated areas of the county. Recognizing the importance of preserving water resources, Clackamas County includes watershed management goals and policies in its Comprehensive Land Use Plan. These include a buffer or setback for construction within 150 feet of a river or perennial stream, provisions to avoid citing in natural hazard areas, and development constraints for significant natural areas.

Multnomah County is involved with land use regulation in the Tryon Creek Watershed. The county has Significant Environmental Concern Zones (SEC zones) that are monitored and regulated more intensely than other lands. The Planning and Development Department has stated a commitment to work with the Tryon Creek Watershed Council.

Multnomah County normally defers to Portland's regulations on matters concerning land within Portland, such as land use review of proposed developments. BES comments on these cases. In addition, BES makes recommendations on land use proposals in some areas of unincorporated Multnomah County.

Oregon Department of Fish and Wildlife (ODFW) has worked with the City of Portland to conduct habitat and fish surveys for many of the remaining streams in Portland. The survey data is used extensively in Chapters 7, 8, and 9 of the Watershed Plan.

BES will work with ODFW to conduct habitat and fish surveys in the future. In addition, BES works with ODFW to obtain permits for stream enhancement projects.

Oregon Parks and Recreation Department owns, manages, and maintains state land and the facilities of Tryon Creek State Natural Area. Park rangers, who often collaborate with groups of citizen volunteers, perform trail maintenance and habitat restoration.

A staff member of Oregon State Parks serves on the Fanno/Tryon Advisory Committee, providing advice during development of the Watershed Plan and opportunities for collaboration on project and programmatic recommendations. In addition, BES is currently working with State Parks to implement a stream enhancement project in Tryon Creek State Natural Area. BES will continue to work with Oregon State Parks in the future to enhance stream and riparian habitat in Tryon Creek State Natural Area.

Portland's Bureau of Environmental Services (BES) manages the public sanitary sewer collection and treatment facilities, monitors the watershed for water quality, and is responsible for the stormwater facilities located within Portland. Wastewater from the watershed is treated at the Tryon Creek Wastewater Treatment Plant, which is managed by BES and located within Lake Oswego. BES also contracts with the Portland Bureau of Maintenance (BOM) to perform operation and maintenance activities on the sanitary and stormwater system facilities within the city.

The BES **Maintenance Engineering** group is responsible for upgrading and repairing the City's sewer infrastructure. BES watershed planning staff work closely with maintenance engineering staff on projects.

BES also implements **Public Education and Outreach for Youth and Community Groups.** This includes a variety of public education programs about watershed health. Examples include classroom and field studies on water chemistry, macroinvertebrate identification and stormwater issues and solutions. Educators offer canoe and jetboat tours to groups that have taken on a significant stewardship project. The City's education programs also provide community service projects and curriculum resources.

The BES **Watershed Revegetation Program** works to form partnerships with pubic and private landowners to restore degraded stream banks, wetlands, and upland areas to improve watershed health. Potential revegetation sites are identified watershed plans.

BES watershed planning groups develop and submit revegetation project proposals for funding as part of their efforts to improve watershed health. BES watershed planning staff also works with the revegetation program staff to evaluate past revegetation projects in order to improve long-term success.

The BES **Watershed Stewardship Program** is a joint effort with Portland State University, Americorps, local watershed councils, neighborhood associations, Friends of Trees, SOLV and the community to raise awareness of watershed health City-wide. BES offers education and restoration grants, educational workshops (e.g., Naturescaping for Clean Rivers), restoration project technical assistance, and informational resources. Watershed stewardship grants provide up to $5,000 to citizens and organizations to encourage watershed protection and enhancement at the local level. Grant money can be used for supplies, materials, equipment, room rentals, feasibility studies or technical assistance. Each year, BES watershed stewardship awards total $55,000.

The BES **Public Facilities Plan (PFP)** (City of Portland BES, 1999) was developed to address major sewerage infrastructure needs for the City of Portland through the year 2015. The PFP summarizes past work, current conditions, and provides recommendations for the City's wastewater and stormwater systems. The next version of the PFP is currently being developed. BES watershed planning staff will participate in this process and ensure that relevant recommendations from the Watershed Plan are incorporated into the updated PFP.

The watershed characterizations will contribute to the update of the PFP. In addition, watershed planning staff will provide technical guidance during the update and help formulate recommended improvements.

Portland's Bureau of Development Services (BDS) administers on-site septic system requirements, enforces building standards, including soil erosion ordinances, and oversees the City's geotechnical regulations.

BES works with BDS in all land use and development reviews and provides technical advice for stormwater management and application of drainage reserves over open drainageways (discussed earlier in this chapter). BES staff use data from the watershed characterizations to help formulate and support recommendations. BES and BDS also coordinate monitoring of activities with potential impact on water quality and stormwater runoff.

Portland's Bureau of Maintenance (BOM) performs maintenance of the storm and sanitary systems under agreements with BES. This includes street shoulder work, street cleaning, storm drain cleaning, jet cleaning of culverts, trash rack cleaning, ditch maintenance, detention pond cleaning and other storm drainage system cleaning efforts. Maintenance of drainage facilities in state highways is the responsibility of the Oregon Department of Transportation. Maintenance of private drainage facilities, stream and tributaries located on private property is the responsibility of individual property owners. BES reviews most private facilities prior to construction.

Program related recommendations in the final Watershed Plan could suggest changes and improvements to maintenance practices to improve watershed health. BES will provide technical memos describing improvements and benefits to watershed health. In some cases, additional funds may be requested to change or expand maintenance practices.

Portland's Bureau of Planning (BOP) works alongside citizens to create long-range goals, plans, and strategies that guide Portland's future.

As mentioned earlier, BOP is currently updating its Natural Resource Inventories. BES is collaborating with BOP in this work. In particular, BES helped to identify Special Habitat Areas throughout Fanno and Tryon watersheds. BES and planning also routinely coordinate on land use issues to ensure resource protection. An example of this coordination was the development of the Southwest Community Plan. The Southwest Community Plan covers most of Southwest Portland. BES provided technical information to BOP about stream hydrology, soils, slope stability, stream channel and corridor processes, water quality, conveyance system capacity, stormwater quality and impacts, and other resource and habitat values. BOP used this information to finalize the Southwest Community Plan in late 2001. The Plan includes polices and objectives addressing land use and urban form, public facilities, citizen involvement, parks and open space, and the watershed. These policies and objectives establish a framework for improving watershed health.

The River Renaissance Initiative calls for a new way of approaching the challenges facing a growing urban environment. During the past two years, City bureaus have worked to integrate the City's river- and watershed-related programs and services and have studied the natural and economic systems related to the river, forged public-private partnerships, leveraged resources, and engaged the community. Numerous collaborative efforts involving residents, businesses, industry, community groups, property owners, City bureaus, and government agencies have resulted in a wealth of information, analysis, ideas, energy and commitment. While focusing on the Willamette River, the River Renaissance Vision also acknowledges and reflects the interconnectedness between the Willamette and Columbia Rivers; their tributary streams and watersheds; the parks, open space and trail system; and the freight and human transportation network.

River Renaissance is a comprehensive vision that encompasses the entire City of Portland. The River Renaissance Initiative seeks to realize the vision through a partnership of residents, businesses, industry, not-for-profit organizations, and public agencies. Areas of focus include planning (e.g., developing the River Renaissance Plan and continuing work that advances River Renaissance); showcasing early actions; solidifying partnerships; engaging the public; and developing a sustainable funding strategy to implement River Renaissance projects.

A draft plan was available for public review in May 2004. Following a public review, staff revised the draft and published a Proposed River Renaissance Plan in October. Following community and stakeholder discussions on the proposal, City Council hearings will take place in November and a Council decision is expected soon after.

BES provided data and recommendations for the Clean and Healthy River vision theme. The BES watershed plans will describe specific actions and programs that help improve watershed health and achieve the River Renaissance Clean and Healthy River vision theme. In addition, BES watershed plans will provide technical guidance to other city bureaus to improve watershed health.

Portland's Bureau of Parks and Recreation (Parks) maintains city parks, park facilities, urban natural resources, and trails that are not under Oregon State Park jurisdiction. In coordination with Metro, Parks acquires and manages open space and maintains some of the inventory as natural areas. Metro and Parks have purchased nearly 25 - 30 acres of open space in the Tryon Creek Watershed through the Metro Greenspaces Program. Since most parks located in these watersheds are located near streams, Parks has undertaken water quality sensitive maintenance practices.

The Urban Forest Division of Parks implements Portland's **Urban Forestry Management Plan** (UFMP) (City of Portland Parks and Recreation, 1995). The UFMP recommends methods and actions to protect and promote urban trees and vegetation. The plan makes recommendations in broad areas including assessment, planting opportunities, planting design guidelines and standards, maintenance, education, incentives, regulations, and administration and management.

BES routinely supports Parks in its efforts to acquire vacant land that is critical to expanding open space and improve water quality. In the past few years, Parks has acquired a number of land parcels in the Fanno Creek Watershed mainly to protect significant natural resource areas. Parks and BES also collaborate on environmental enhancement projects.

Portland's Department of Transportation (PDOT) plans, builds, manages and maintains the City's transportation system including streets, traffic signals, and other transportation structures.

The Transportation System Plan (TSP) is the long-range plan to guide transportation investments in Portland. The TSP meets State and regional planning requirements and addresses local transportation needs for cost-effective street, transit, freight, bicycle, and pedestrian improvements. The plan provides transportation choices for residents, employees, visitors, and firms doing business in Portland, making it more convenient to walk, bicycle, take transit, and drive less to meet their daily needs. The TSP also includes transportation goals, policies, and objectives for districts throughout the City including the Southwest and a Master Plan for the Southwest.

A PDOT staff member has been on the Fanno/Tryon Advisory Committee throughout the development of the Watershed Plan. This participation promotes collaboration between BES and PDOT.

The City's **Stormwater Advisory Committee (SAC)** was appointed by Commissioner Dan Saltzman on behalf of City Council in September 2000 to guide City compliance with federal clean water regulations. The SAC has met monthly since September 2000, with additional meetings of the full SAC and subcommittees as needed. The SAC's members represent environmental, neighborhood, and community groups; engineering, transportation, and landscape architecture consultants; and industry, development, and large commercial interests. The Bureau of Environmental Services (BES) and other bureaus provided significant staff assistance. The SAC's three major areas of concern are new development/redevelopment (implementation and evaluation of the City's Stormwater Management Manual, or SWMM), existing development, and transportation-related development.

The SAC's recommendations will be incorporated into the on-going watershed management process and reflected in recommended projects and programs.

The **Tryon/Fanno Watershed Advisory Committee** is composed of local citizens and agencies representatives and provides guidance on the development of the Watershed Plan and recommended projects and programs to improve watershed health.

The **Tualatin Basin Designated Management Agencies (DMAs)** are local agencies responsible for total maximum daily loads (TMDLs) in the Tualatin Basin. DMAs include a variety of jurisdictions, such as municipal and agricultural.

The DMAs usually meet monthly to share ideas, coordinate water quality activities, and foster joint working relationships. In addition, each year DMAs take part in an inter-laboratory quality control sample split with eight other laboratories that are analyzing samples from the Tualatin Basin, in order to supplement their individual quality control programs. The results are submitted each year to DEQ. BES' water pollution control laboratory performs well in the sample split.

Washington County's Clean Water Services (CWS) is a public utility committed to protecting water resources in the Tualatin River Watershed through wastewater and stormwater services, flood management projects, water quality and stream enhancement projects, and fish habitat protection.

Staff from CWS and the City of Portland participate in each others watershed planning processes. This participation ensures coordination on issues of mutual interest.

West Multnomah Soil and Water Conservation District (WMSWCD) functions in the 80,000-acre area of west Multnomah County under the auspices of the Natural Resources Conservation Service. The district has an elected seven–member board that advises on issues related to the conservation of soil and water resources.

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CHAPTER 14

Fanno Creek Watershed Problem and Opportunity Summaries

INTRODUCTION

This chapter summarizes watershed problems and opportunities by watershed goal for each Fanno Creek subwatershed. These summaries are based on the watershed characterizations, Chapters 3-11 of this document, and the detailed problem and opportunity tables that follow.

These descriptions summarize Tier 1 problems and assets, described in detail in Chapter 16 of this document. Tier 1 problems and assets are those that are directly related to one or more of the following four criteria: critical limiting factors that impair ecological health functions, Endangered Species Act (ESA) listed species, regulatory requirements, and the degree to which a condition is well characterized and the link to watershed health is clear. Watershed objectives, described in Chapter 18 of this document, were developed to address primarily Tier 1 problems and assets.

FANNO CREEK MAINSTEM SUBWATERSHED

Problem Summaries

Habitat

Physical habitat throughout the Fanno Creek mainstem has been altered due to development. The riparian corridor is narrow and vegetation cover is low along most of the creek. The creek does not substantively interact with the floodplain. In-stream habitat suffers from lack of structure (e.g. wood, boulders) and high proportions of sand and silt substrate, contributed by eroding stream banks due partly to increased stormwater runoff from upland development. Fish passage is severely constrained by numerous culverts. For example, the 200 m culvert under the Raleigh Hills Shopping Center is a fish barrier during most times of the year.

Biological Communities

Biological communities are limited in Fanno Creek. Sensitive macro invertebrate populations are lacking throughout the subwatershed, largely due to a lack of suitable substrate and potentially water quality impairment. Index of Biotic Integrity (IBI) assessments indicate that upper Fanno Creek lacks diverse fish communities and is severely impaired in the summer, fall, and winter. However, coho, steelhead, and cutthroat have all been observed in mainstem Fanno Creek. Data determined abundance, productivity, and diversity is lacking.

Water Quality

Water quality in Fanno Creek is impaired for certain water quality parameters. Stormwater runoff from existing sources and development may contribute a number of pollutants.

Monitoring indicates that summer in-stream temperatures exceed the water quality standard of 64 degrees F necessary for protection of salmonid rearing. E. coli levels exceed the water quality standard in 50 percent of samples in summer and 25 percent during winter. Fanno Creek was ranked as poor on the Oregon Water Quality Index due to high levels of nutrients (TP, ammonia+nitrate nitrogen), total solids, and bacteria. High silt and sediment loads are transported from upland urban sources to the stream and accumulate in depositional areas in lower portions of the subwatershed. Channel erosion also contributes to high levels of total suspended solids (TSS).

Hydrology

Development throughout the subwatershed has increased impervious surfaces and resulted in the loss of vegetation. Impervious surface coverage is highest along Fanno Creek, where commercial development and transportation routes (e.g., Beaverton Hillsdale Highway) predominate. These changes contribute to increased stormwater runoff volumes and velocities that can cause stream bank instability, undercutting, erosion, in-stream sedimentation, and channel incision.

Public Involvement

People living in the subwatershed affect watershed health everyday by the choices they make. For example, choosing to landscape riparian areas with grass and other non-native vegetation degrades natural functions of the subwatershed. Choosing to dump liquid wastes such as automotive fluids down storm drains and pesticide use increases pollutants in streams. Raising people’s awareness about the impacts that their actions have on watershed health can help to reduce non-point source pollutants and restore natural functions to the subwatershed.

Opportunity Summaries

Habitat

While habitat throughout the subwatershed has been degraded by urban development, opportunities for protection and restoration exist. Riparian habitat is relatively good below Oleson Road and between 45th Avenue and 39th Drive, in some cases yielding a functioning riparian corridor. In-stream habitat is also relatively good in places, providing critical rearing and refuge habitat for fish during winter and summer periods.

Biological Communities

Biological communities are generally limited in the Fanno Creek subwatershed. Coho, steelhead, and cutthroat have all been observed in mainstem Fanno Creek. However, data to determine abundance, productivity, and diversity is lacking. Sensitive macroinvertebrate populations are low, but present. Index of Biotic Integrity (IBI) assessments indicate that upper Fanno Creek is only marginally impaired in the spring. Natural areas also provide habitat for many small and adaptive mammal species, many species of birds, and a number of amphibian and reptile species.

Water Quality

Water quality in Fanno Creek is only impaired for some water quality parameters. The seven-day average maximum daily temperature in Fanno Creek only exceeded the standard from 29 to 48 days each summer. Fanno Creek only exceeds the single sample standard for E. coli in half of the samples in summer and 25 percent in winter. Monitoring indicates that Fanno creek is generally below the target concentration of 0.13 mg/l of total phosphorus. Shade cover from trees over Fanno Creek averages 90 percent, helping to keep the stream cool. Data shows an improving water quality trend in Fanno Creek.

Hydrology

While development has altered the habitat and hydrology in the Fanno Creek subwatershed, there remain opportunities to protect and restore natural watershed functions and minimize the impact of development. Seeps and springs provide critical summer flows to streams throughout the subwatershed. Low-density single-family residential development, which predominates in the northern portion of the subwatershed, retains higher levels of vegetation cover and lower levels of impervious surfaces. Opportunities are present throughout the subwatershed to retrofit the built environment to improve watershed health. Stormwater management strategies could include detention ponds, roadside ditch enhancements, ecoroofs, and improved maintenance practices such as street sweeping.

Public Involvement

Active neighborhood groups provide collaborative restoration, education and technical assistance opportunities for local area residents. Partners include SW Neighborhoods, Inc (SWNI), Bridlemile Creek Stewards (BCS), Fans of Fanno, Southwest Watershed Resource Center, Portland Parks and Recreation, BES Community Watershed Stewardship and Revegetation programs, SOLV, schools and congregations. Active stewardship sites include St. Andrews Presbyterian Church parking lot bioswales (St Andrews members and BES), Trillium Creek restoration (neighbors, SOLV, congregations, BES), Albert Kelly and Hamilton Parks stream restorations (BCS, Parks, BES, neighbors), Bridlemile School Naturescape and bioswales (students, teachers, parents). BES' Revegetation Program has several active sites along the mainstem and in Hamilton Park. Free programs such as Naturescaping for Clean Rivers are available to raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. Additional public outreach steps could include placing curb markings to discourage dumping in storm drains and encouraging Beaverton/Hillsdale Hwy businesses to become "Eco-logical Business" (a certification program for automotive and landscape services to meet watershed friendly standards and to encourage residents to support those businesses).

PENDLETON CREEK SUBWATERSHED

Problem Summaries

Habitat

Riparian integrity and wildlife habitat upstream of SW Shattuck Road is impaired due to development and road crossings. Very little riparian vegetation remains, and shade cover is lacking. Floodplain connection is also poor above SW Shattuck Road. Road culverts disrupt stream connectivity and likely isolate resident fish. Channel conditions and habitat structure have not been well documented.

Biological Communities

Biological communities are limited in Pendleton Creek by habitat degradation, including impassable culverts. Salmonid and trout have not been documented.

Water Quality

Little water quality data are available for Pendleton Creek. Stormwater runoff from development may contribute a number of pollutants. Monitoring indicates that E. coli levels exceed the water quality standard in 50 percent of samples in summer and 10 percent during winter.

Hydrology

Single-family residential development predominates throughout the subwatershed. Impervious surfaces, from development, contribute to high stormwater runoff volumes and velocities that can cause stream bank instability and undercutting, erosion, in-stream sedimentation, and channel incision. These conditions can contribute to problems downstream in Fanno Creek.

Public Involvement

People living in the subwatershed affect watershed health everyday by the choices they make. For example, choosing to landscape riparian areas with grass and other non-native vegetation degrades natural functions of the subwatershed. Choosing to dump liquid wastes such as automotive fluids down storm drains and pesticide use increases pollutants in streams. Raising people’s awareness about the impacts that their actions have on watershed health can help to reduce non-point source pollutants and restore natural functions to the subwatershed.

PENDLETON CREEK SUBWATERSHED

Opportunity Summaries

Habitat

Despite development, riparian integrity and habitat is considered fair to good downstream of SW Shattuck Road. Floodplain conditions are also relatively intact downstream of SW Shattuck Road. An undeveloped patch of forest exists near SW 61st Avenue. Channel conditions have not been well documented.

Biological Communities

Remaining natural areas, including riparian habitat, provide habitat for many small and adaptive mammal species, up to 60 species of birds, and a number of amphibian and reptile species.

Water Quality

Water quality in Pendleton Creek is only impaired for some water quality parameters. Monitoring indicates that Pendleton Creek only exceeds the single sample standard for E. coli in 10 percent of samples in winter. Pendleton creek is generally below the target concentration of 0.13 mg/l of total phosphorus.

Hydrology

While development has altered the habitat and hydrology in the Pendleton Creek subwatershed, there remain opportunities to protect and restore natural watershed functions and minimize the impact of development. Low-density urban development throughout much of the subwatershed retains a high degree of vegetation cover and minimizes impervious surfaces. There are opportunities throughout the subwatershed to retrofit the built environment to improve watershed health. Stormwater management strategies could include detention ponds, roadside ditch enhancements, ecoroofs, and improved maintenance practices such as street sweeping.

Public Involvement

There is no active Friends of Pendleton Creek group, however other community groups provide collaborative restoration and education opportunities for local area residents. Active projects include the Cedar Sinai Park/Hayhurst neighborhood Watershed Project and the naturescaped courtyard project at Hayhurst Elementary School. Acquisition of the forested land west of Shattuck along Pendleton Creek would provide a large public Green space, involve the community and help protect the creek. Free programs such as Naturescaping for Clean Rivers are available to raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. Additional public outreach steps could include placing curb markings to discourage dumping in storm drains.

VERMONT CREEK SUBWATERSHED

Problem Summaries

Habitat

Riparian habitat and connectivity is impacted roads, homes, and private landscaping in the lower and middle reaches of the creek. Riparian habitat in Gabriel Park is protected but still impacted by recreational use. Numerous road culverts have disconnected the creek. In particular, the Vermont Street and 52 Avenue culverts likely completely block fish passage. Over 70% of the banks are eroding throughout the creek. In-stream riffle habitat is degraded by fine sediment and organics overlaying the substrate, and is lacking overall in the lower and middle stream reaches. In-stream wood is severely lacking in the lower creek. While riffles are more common in the upper reaches of the creek, the habitat is covered with fine sediments and organics. Pools are also lacking in the upper reaches.

Biological Communities

Biological communities are limited in Vermont Creek by habitat degradation stemming from urban development. In particular, road culverts severely limit fish access through much of the creek. No salmonids have been documented in the upper reaches of the creek. Macroinvertebrate production in the creek is low.

Water Quality

Water quality in Vermont Creek is impaired for certain water quality parameters. Stormwater runoff from development may contribute a number of pollutants. Monitoring indicates that E. coli levels exceed the water quality standard in 50 percent of samples in summer and 25 percent during winter. Summer median total phosphorus concentration was 0.22 mg/l, far above background levels. Vermont Creek was ranked as very poor on the Oregon Water Quality Index due to high levels of nutrients (TP, ammonia+nitrate nitrogen), total solids, and bacteria. High silt and sediment loads are transported from upland urban sources to the stream and accumulate in depositional areas in lower portions of the subwatershed. Channel erosion also contributes to high levels of total suspended solids (TSS). These pollutants tend to increase in concentration in lower portions of the creek, and may contribute to water quality problems downstream in Fanno Creek.

Hydrology

Single-family residential development predominates throughout most of the subwatershed. Gabriel Park, a large open space tract, is located in the eastern portion of the subwatershed. Commercial and multi-family development is concentrated in the southeast along SW Multnomah Boulevard, exhibiting the highest level of impervious surface cover in the subwatershed. Impervious surfaces contribute to high stormwater runoff volumes and velocities that can cause stream bank instability and undercutting, erosion, in-stream sedimentation, and channel incision. These effects are greatest in lower portions of the subwatershed and can contribute to problems downstream in Fanno Creek.

Public Involvement

People living in the subwatershed affect watershed health everyday by the choices they make. For example, choosing to landscape riparian areas with grass and other non-native vegetation degrades natural functions of the subwatershed. Choosing to dump liquid wastes such as automotive fluids down storm drains and pesticide use increases pollutants in streams. Raising people’s awareness about the impacts that their actions have on watershed health can help to reduce non-point source pollutants and restore natural functions to the subwatershed.

Opportunity Summaries

Habitat

Despite development, the riparian corridor habitat is relatively good, particularly in the upper creek reaches in Gabriel Park. Established conifers and deciduous trees are common. A number of beaver ponds are scattered in the lower and middle reaches of the creek, which resident fish likely rear and seek refuge in. The upper reaches of the creek are relatively protected in Gabriel Park, and large woody debris is abundant. Quality in-stream pools in the lower and middle creek reaches and provide limited refuge for fish. Generally, in-stream fish habitat is considered marginal.

Biological Communities

Remaining natural areas, including riparian habitat and Gabriel Park, provide habitat for many small and adaptive mammal species, up to 60 species of birds, and a number of amphibian and reptile species. Cutthroat trout have been observed in lower portions of the Creek. Sculpin have been noted in the upper reaches of the creek.

Water Quality

Water quality in Vermont Creek is only impaired for some water quality parameters. Fanno Creek only exceeds the single sample standard for E. coli in half of the samples in summer and

25 percent in winter. Shade cover from trees over Vermont Creek averages 91 percent, helping to keep the stream cool.

Hydrology

While development has altered the habitat and hydrology in the Vermont Creek subwatershed, there remain opportunities to protect and restore natural watershed functions and minimize the impact of development. Seeps and springs provide critical summer flows to streams. Low-density urban development throughout much of the subwatershed retains a high degree of vegetation cover and minimizes impervious surfaces. There are opportunities throughout the subwatershed to retrofit the built environment to improve watershed health. Stormwater management strategies could include detention ponds, roadside ditch enhancements, ecoroofs, and improved maintenance practices such as street sweeping.

Public Involvement

The SW Watershed Resource Center is located in Vermont Creek and provides collaborative restoration, education and technical assistance opportunities for local area residents. The resource center is currently helping to launch a Friends of Vermont Creek in partnership with SW Neighborhoods, Inc (SWNI), Americorps, Portland Parks and Recreation, and BES Community Watershed Stewardship program. Other stewardship projects include the Maplewood Elementary asphalt removal and Naturescaping projects and the Gabriel Park Adopt a Plot program (Portland Parks, BES and schools). BES' watershed revegetation program has active projects at Gabriel Park, the Birkland site and private properties along Vermont near SW 49th. Free programs such as Naturescaping for Clean Rivers are available to help to raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. Additional public outreach steps could include placing curb markings to discourage dumping in storm drains and encouraging Multnomah Blvd. businesses to become “Eco-logical Businesses” (a certification program for automotive and landscape services to meet watershed friendly standards and encourage residents to support those businesses).

WOODS CREEK SUBWATERSHED

Problem Summaries

Habitat

Riparian habitat and connectivity is impacted by development, particularly in the lower and middle reaches of the creek. Floodplain interaction is very limited. Numerous road culverts and a dammed pool at the Portland Golf Club have severely disconnected the stream, preventing fish access to some isolated good habitat. In-stream riffle habitat is severely lacking in the lower and middle stream reaches and silt covers much of the substrate, degrading the habitat. While riffle habitat is better in the upper portions of the creek, pool habitat is lacking.

Biological Communities

Biological communities are limited in Woods Creek by habitat degradation, including impassable culverts. Salmonids have not been documented. Only Sculpin were observed in 2001 ODFW habitat surveys.

Water Quality

Water quality in Woods Creek is impaired for certain water quality parameters. Stormwater runoff from development may contribute a number of pollutants. Monitoring indicates that summer in-stream temperatures exceed the water quality standard of 64 degrees F for protection of salmonid rearing. E. coli levels exceed the water quality standard in 50 percent of samples in summer and 10 percent during winter. Woods Creek was ranked as poor on the Oregon Water Quality Index due to high levels of nutrients (TP, ammonia+nitrate nitrogen), total solids, and bacteria. High silt and sediment loads are transported from upland urban sources to the stream and accumulate in depositional areas in lower portions of the subwatershed. Channel erosion also contributes to high levels of total suspended solids (TSS). These pollutants tend to increase in concentration in lower portions of the creek and may contribute to water quality problems downstream in Fanno Creek.

Hydrology

Single-family residential development predominates throughout most of the subwatershed. Commercial land uses are concentrated in the south near Interstate 5, exhibiting the highest level of impervious surface cover in the subwatershed. Impervious surfaces contribute to high stormwater runoff volumes and velocities that can cause stream bank instability and undercutting, erosion, in-stream sedimentation, and channel incision. These effects are greatest in lower portions of the subwatershed and contribute to problems downstream in Fanno Creek.

Public Involvement

People living in the subwatershed affect watershed health everyday by the choices they make. For example, choosing to landscape riparian areas with grass and other non-native vegetation degrades natural functions of the subwatershed. Choosing to dump liquid wastes such as automotive fluids down storm drains and pesticide use increases pollutants in streams. Raising people’s awareness about the impacts that their actions have on watershed health can help to reduce non-point source pollutants and restore natural functions to the subwatershed.

Opportunity Summaries

Habitat

Despite development, the riparian corridor habitat is relatively good. In the lower and middle portions of the creek, large conifers and hardwoods are common and numerous springs, seeps and wetland habitat exists near Oregon Episcopal School. In the upper portions of the creek, riparian habitat is very good and tree canopy cover averages 74 percent within 10 m of the creek. Much of the upper portions of the creek are within an open space tract. Banks are stable all along the creek, indicating properly functioning conditions. In-stream habitat is good in places. Upper portions of the creek likely contribute woody debris, nutrients, and macroinvertebrates to lower portions of the creek.

Biological Communities

Remaining natural areas, including riparian habitat, provide habitat for many small and adaptive mammal species, up to 60 species of birds, and a number of amphibian and reptile species. Sculpin, but no salmonids, were observed in the creek during 2001 ODFW habitat surveys.

Water Quality

Water quality in Woods Creek is only impaired for some water quality parameters. The seven-day average maximum daily temperature in Fanno Creek only exceeded the standard from 8 to 21 days each summer. Woods Creek only exceeds the single sample standard for E. coli in 10 percent of samples in winter. Monitoring indicates that Woods creek is generally below the target concentration of 0.13 mg/l of total phosphorus. Shade cover from trees over Fanno Creek averages 85 percent, helping to keep the stream cool.

Hydrology

While development has altered the habitat and hydrology in the Woods Creek subwatershed, there remain opportunities to protect and restore natural watershed functions and minimize the impact of development. Seeps and springs provide critical summer flows to streams. Low-density urban development throughout much of the subwatershed retains a high degree of vegetation cover and minimizes impervious surfaces. There are opportunities throughout the subwatershed to retrofit the built environment to improve watershed health. Stormwater management strategies could include detention ponds, roadside ditch enhancements, ecoroofs, and improved maintenance practices such as street sweeping.

Public Involvement

Active neighborhood groups provide collaborative restoration, education and technical assistance opportunities for local area residents. Partners include SW Neighborhoods, Inc (SWNI), Crestwood Neighborhood Association, Friends of Woods Park, Portland Parks and Recreation, and BES Community Watershed Stewardship Grants and Watershed Revegetation programs. Active stewardship sites include Woods Park. BES’ revegetation program has active sites at April Hill and Woods Park and in cooperation with homeowners just downstream of April Hill. Free programs such as Naturescaping for Clean Rivers are available to raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. Additional public outreach steps could include placing curb markings to discourage dumping in storm drains.

NORTH ASH CREEK SUBWATERSHED

Problem Summaries

Habitat

Riparian habitat and connectivity is impacted by development. The effective riparian corridor does not extend beyond 10-20 m of the creek. Development and landscaping near the creek has reduced floodplain interaction. Banks in the middle of the creek are actively eroding. Four road culverts east of Multnomah County impair stream connectivity; nearly one-quarter of the mainstem is piped. Additionally, the creek is disconnected from Ash Creek and Fanno Creek by an in-stream structure and dammed pool near the confluence of Ash Creek. Stream banks are slightly eroding. In-stream habitat lacks wood and pool area is low and degraded by fines.

Biological Communities

Biological communities are limited in South Ash Creek by habitat degradation, including impassable culverts. Generally, the Index of Biotic Integrity (IBI) for Ash Creek indicates that upper Ash Creek is severely impaired year-round. Sculpin were observed during the 2001 ODFW habitat surveys, but trout have not been documented.

Water Quality

Little water quality data are available for North Creek. Stormwater runoff from development may contribute a number of pollutants. Monitoring indicates that E. coli levels exceed the water quality standard in 50 percent of samples in summer and 10 percent during winter.

Hydrology

Single-family residential development predominates throughout the subwatershed. Impervious surface cover is highest in the eastern portion of the subwatershed. Impervious surfaces contribute to high stormwater runoff volumes and velocities that can cause stream bank instability and undercutting, erosion, in-stream sedimentation, and channel incision. These conditions can contribute to problems downstream in Fanno Creek.

Public Involvement

People living in the subwatershed affect watershed health everyday by the choices they make. For example, choosing to landscape riparian areas with grass and other non-native vegetation degrades natural functions of the subwatershed. Choosing to dump liquid wastes such as automotive fluids down storm drains and pesticide use increases pollutants in streams. Raising people’s awareness about the impacts that their actions have on watershed health can help to reduce non-point source pollutants and restore natural functions to the subwatershed.

Opportunity Summaries

Habitat

Despite development, the riparian corridor is fairly wide and consistent. Dominant plant species include second growth deciduous trees and shrubs. Tree canopy cover averages 58 percent within 10 m of the creek. Additionally, a wooded residential development provides a relatively extensive forest canopy between SW 52nd and SW 57th Avenues. The creek interacts with the immediate floodplain. In-stream habitat includes abundant quality riffle habitat and a small portion of pools. Pools likely provide important protective cover. Summer low flows in North Ash Creek are about 0.02 cubic feet per second.

Biological Communities

Remaining natural areas, including riparian habitat, provide habitat for many small and adaptive mammal species, up to 60 species of birds, and a number of amphibian and reptile species. Sculpin were observed during 2001 ODFW habitat surveys. Trout have not been documented.

Water Quality

Water quality in North Ash Creek is only impaired for some water quality parameters. Monitoring indicates that North Ash Creek only exceeds the single sample standard for E. coli in 10 percent of samples in winter. The creek is generally below the target concentration of 0.13 mg/l of total phosphorus. Shade cover from trees over the creek averages 89 percent, helping to keep the stream cool.

Hydrology

While development has altered the habitat and hydrology in the North Ash Creek subwatershed, there remain opportunities to protect and restore natural watershed functions and minimize the impact of development. Seeps and springs provide critical summer flows to streams. Low-density urban development throughout much of the subwatershed retains a high degree of vegetation cover and minimizes impervious surfaces. There are opportunities throughout the subwatershed to retrofit the built environment to improve watershed health. Stormwater management strategies could include detention ponds, roadside ditch enhancements, ecoroofs, and improved maintenance practices such as street sweeping.

Public Involvement

There are no active neighborhood groups to provide collaborative restoration, education and technical assistance opportunities for local area residents. Potential partners include SW Neighborhoods, Inc (SWNI), Smith Elementary School and the Ash creek Neighborhood Association. Free programs such as Naturescaping for Clean Rivers are available to help to raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. Additional public outreach steps could include placing curb markings to discourage dumping in storm drains.

SOUTH ASH CREEK SUBWATERSHED

Problem Summaries

Habitat

Riparian habitat and connectivity is impacted by homes, which often abut or cross the creek, roads and trails. Shade cover over the creek from large canopy trees is lacking. The creek only occasionally interacts with the immediate floodplain. Banks are eroding all along the creek. Stream connectivity is impaired by seven road crossings. The SW 62nd Avenue culvert is believed to completely block fish passage. In-stream cascades and steps may also limit stream connectivity and resident fish movement. In-stream habitat lacks wood and pool area is relatively low.

Biological Communities

Biological communities are limited in South Ash Creek. Generally, the Index of Biotic Integrity (IBI) for Ash Creek indicates that upper Ash Creek is severely impaired year-round. Unidentified trout (steelhead and/or cutthroat) were observed during 2001 ODFW habitat surveys, but no data on distribution or abundance is available. As mentioned above, populations are limited by habitat degradation, including impassable culverts.

Water Quality

Little water quality data are available for South Creek. Stormwater runoff from development may contribute a number of pollutants. Monitoring indicates that E. coli levels exceed the water quality standard in 10 percent of samples in summer and winter.

Hydrology

Single-family residential development predominates throughout the subwatershed. Impervious surface cover is highest along the Interstate 5 corridor in the southwestern portion of the subwatershed. Impervious surfaces contribute to high stormwater runoff volumes and velocities that can cause stream bank instability and undercutting, erosion, in-stream sedimentation, and channel incision. These effects are greatest in lower portions of the subwatershed and contribute to problems downstream in Fanno Creek.

Public Involvement

People living in the subwatershed affect watershed health everyday by the choices they make. For example, choosing to landscape riparian areas with grass and other non-native vegetation degrades natural functions of the subwatershed. Choosing to dump liquid wastes such as automotive fluids down storm drains and pesticide use increases pollutants in streams. Raising people's awareness about the impacts that their actions have on watershed health can help to reduce non-point source pollutants and restore natural functions to the subwatershed.

Opportunity Summaries

Habitat

Riparian vegetation is considered good along most of the creek. Mixed conifer and deciduous (second growth) trees, and grasses are common. Tree canopy cover is about 96 percent within 20 ft of the creek. The creek occasionally interacts with the immediate floodplain. In-stream habitat includes good riffle and pool habitat. Pools likely provide important cover and rearing habitat for resident fish. Several large open spaces are located above SW 55th Avenue, which may be potential restoration sites.

Biological Communities

Remaining natural areas, including riparian habitat, provide habitat for many small and adaptive mammal species, up to 60 species of birds, and a number of amphibian and reptile species. Trout, sculpin, minnows, beavers, and fresh water clams were observed during 2001 ODFW habitat surveys.

Water Quality

Water quality in South Ash Creek is only impaired for some water quality parameters. Monitoring indicates that North Ash Creek only exceeds the single sample standard for E. coli in 10 percent of samples in summer and winter. The creek is generally below the target concentration of 0.13 mg/l of total phosphorus. Shade cover from trees over the creek averages 90 percent, helping to keep the stream cool.

Hydrology
While development has altered the habitat and hydrology in the South Ash Creek subwatershed, there remain opportunities to protect and restore natural watershed functions and minimize the impact of development. Seeps and springs provide critical summer flows to streams. Low-density urban development throughout much of the subwatershed retains a high degree of vegetation cover and minimizes impervious surfaces. There are opportunities throughout the subwatershed to retrofit the built environment to improve watershed health. Stormwater management strategies could include detention ponds, roadside ditch enhancements, ecoroofs, and improved maintenance practices such as street sweeping.

Public Involvement
Active neighborhood groups provide collaborative restoration, education and technical assistance opportunities for local area residents. Partners include SW Neighborhoods, Inc (SWNI), Crestwood Neighborhood Association, Dickinson Park Stewards, Portland Parks and Recreation, and BES Community Watershed Stewardship Grants and Watershed Revegetation programs. Active stewardship sites include Dickenson Park, Taylor’s Woods and a stormwater swale at a private residence. BES’ revegetation program has active sites at Dickinson and Taylor’s Woods. Free programs such as Naturescaping for Clean Rivers are available to raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. Additional public outreach steps could include placing curb markings to discourage dumping in storm drains.

RED ROCK CREEK SUBWATERSHED

Problem Summaries

Habitat
The headwater reach of Red Rock Creek is highly constrained and steep. Floodplain interactions are limited. Aerial photos and observations indicate that the riparian zone is narrow. The creek is fragmented by SW 68th Avenue and at Interstate 5. Neither has been evaluated for fish passage, but both are expected to completely prevent fish movement. Habitat characteristics have not been well documented.

Biological Communities
Biological communities are limited in Red Rock Creek by habitat degradation, including impassable culverts. Salmonid and trout have not been documented in the headwaters reach.

Water Quality
No specific water quality data for Red Rock Creek is available. However, stormwater runoff from development in this subwatershed may contribute to water quality problems downstream in Fanno Creek.

Hydrology
A mix of single-family, multi-family, and commercial land uses predominate in this subwatershed. Commercial land uses are concentrated in the north along Interstate 5 and multi-

family residential development is located in the southwestern portion of the subwatershed. These areas exhibit the highest levels of impervious surface cover. Impervious surfaces contribute to high stormwater runoff volumes and velocities that can cause stream bank instability and undercutting, erosion, in-stream sedimentation, and channel incision. These conditions can contribute to problems downstream in Fanno Creek. Red Rock Creek is considered perennial, but it is likely that the tributaries east of Interstate 5 are seasonally intermittent.

Public Involvement

People living in the subwatershed affect watershed health everyday by the choices they make. For example, choosing to landscape riparian areas with grass and other non-native vegetation degrades natural functions of the subwatershed. Choosing to dump liquid wastes such as automotive fluids down storm drains and pesticide use increases pollutants in streams. Raising people's awareness about the impacts that their actions have on watershed health can help to reduce non-point source pollutants and restore natural functions to the subwatershed.

Opportunity Summaries

Habitat

Despite development, a narrow riparian corridor exists along portions of the creek. Vegetation cover is highest in the south and central portions of the subwatershed. An open space tract is located along SW 59th Avenue. A small wetland pool exists downstream of SW 68th Avenue, outside the City. Generally, creek flow is considered adequate in this headwaters reach to support a viable riparian fringe. Red Rock Creek is considered perennial, but it is likely that the tributaries east of Interstate 5 are seasonally intermittent.

Biological Communities

Remaining natural areas, including riparian habitat, provide habitat for many small and adaptive mammal species, up to 60 species of birds, and a number of amphibian and reptile species.

Water Quality

No specific water quality data for Red Rock Creek are available.

Hydrology

While development has altered the habitat and hydrology in the Red Rock Creek subwatershed, there remain opportunities to protect and restore natural watershed functions and minimize the impact of development. Low-density urban development, comprising about half of the subwatershed, retains a high degree of vegetation cover and minimizes impervious surfaces. There are opportunities throughout the subwatershed to retrofit the built environment to improve watershed health. Stormwater management strategies could include detention ponds, roadside ditch enhancements, ecoroofs, and improved maintenance practices such as street sweeping.

Public Involvement

Staff members coordinate restoration and education opportunities for students at Portland Community College (PCC) Sylvania. Other watershed partners include BES Community Watershed Stewardship Grants and Watershed Revegetation programs. Active stewardship sites include the PCC Sylvania Habitat Restoration Project at Ball Creek and a BES revegetation project along Red Rock Creek. Potential partners could include the Far Southwest and West Portland Park neighborhoods. Free programs such as Naturescaping for Clean Rivers are available to raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. Additional public outreach steps could include placing curb markings to discourage dumping in storm drains and providing incentives for PCC to continue to retrofit the parking lot to reduce and clean stormwater runoff.

CHAPTER 15

Tryon Creek Watershed Problem and Opportunity Summaries

INTRODUCTION

This chapter summarizes watershed problems and opportunities by watershed goal for each Tryon Creek subwatershed. These summaries are based on the watershed characterizations, Chapters 3-11 of this document, and the detailed problem and opportunity tables that follow.

These descriptions summarize Tier 1 problems and assets, described in detail in Chapter 17 of this document. Tier 1 problems and assets are those that are directly related to one or more of the following four criteria: critical limiting factors that impair ecological health functions, Endangered Species Act (ESA)-listed species, regulatory requirements, and the degree to which a condition is well characterized and the link to watershed health is clear. Watershed objectives, described in Chapter 18 of this document, were developed to address primarily Tier 1 problems and assets.

TRYON CREEK MAINSTEM SUBWATERSHED

Problem Summaries

Habitat

Physical habitat in Tryon Creek varies, with better conditions in Tryon Creek State Natural Area (TCSNA) and poorer conditions throughout the rest of the watershed. The area around the mouth of Tryon Creek has narrow riparian corridors, degraded and poorly connected floodplains, and provides poor rearing and spawning habitat due to a lack of channel complexity and silt covering riffles and pools. This area serves as off channel habitat to the Willamette River. Fish passage above the Highway 43 culvert is restricted during most times of the year. The riparian corridor throughout TCSNA is wide and relatively contiguous. Floodplains are narrow. While degraded by sediment deposition and lacking channel structure, this portion of the channel provides the best fish habitat. The Boones Ferry Road culvert completely prevents fish passage to the upper portions of Tryon Creek. In these upper areas, channel connectivity, riparian integrity, and floodplains are degraded by development and other uses. In-stream channel structure is lacking throughout.

Biological Communities

Biological communities are limited in Tryon Creek. Sensitive macroinvertebrate populations are low throughout the subwatershed. Coho salmon, Chinook salmon, steelhead, and cutthroat, have recently been observed in different parts of Tryon Creek, but abundance is low. Generally, the Index of Biotic Integrity (IBI) indicates much of the watershed is severely impaired throughout most times of the year.

Water Quality

Water quality in Tryon Creek is impaired for certain water quality parameters. Stormwater runoff from development in upper portions of the subwatershed may contribute a number of pollutants. Monitoring indicates that summer in-stream temperatures exceed the water quality standard of 64 degrees F for protection of salmonid rearing. E. coli levels exceed water quality standard in about 20 percent of samples. Tryon Creek was ranked as poor on the Oregon Water Quality Index due to high levels of nutrients (TP, ammonia+nitrate nitrogen), total solids, and bacteria. High silt and sediment loads are transported from upland urban sources to the stream and accumulate in depositional areas in lower portions of the subwatershed. Channel erosion also contributes to high levels of total suspended solids (TSS). Very limited water quality data are available for toxics. Available data are limited to six metals sampled three times in 1999 and early 2000 at Boones Ferry Road.

Hydrology

Development in the upper Tryon Creek subwatershed above Boones Ferry Road has increased impervious surfaces and resulted in the loss of vegetation and drainage complexity.

Public Involvement

People living in the subwatershed affect watershed health everyday by the choices they make. For example, choosing to landscape riparian areas with grass and other non-native vegetation degrades natural functions of the subwatershed. Choosing to dump liquid wastes such as automotive fluids down storm drains and pesticide use increases pollutants in streams. Raising people’s awareness about the impacts that their actions have on watershed health can help to reduce non-point source pollutants and restore natural functions to the subwatershed.

Opportunity Summaries

Habitat

Physical habitat varies in the subwatershed. Nearly 37 percent of the subwatershed is a mix of forested areas, with closed canopy forest (33 percent) dominating the landscape. The wooded areas have both coniferous and deciduous trees. Riparian integrity is largely intact and greater than 250 feet wide throughout much of the lower portion of the watershed above the Highway 43 culvert, particularly in TCSNA. Well-established second-growth forest dominates the landscape, providing habitat, stream temperature moderation, and a source of wood for streams. Riparian integrity varies upstream within Marshall Park, but is generally considered fair. Important habitat features that benefit fish include riffle gravels, deep pools, beaver ponds, and access to intermittent and perennial tributaries. The highest-quality in-stream habitat is within TCSNA.

Biological Communities

Biological communities are generally limited in the Tryon Creek watershed, but are richest in the TCSNA. Natural areas provide habitat for many small and adaptive mammal species, over 60 species of birds, and a number of amphibian and reptile species. Coho salmon, Chinook salmon, steelhead, rainbow and cutthroat have recently been observed in different parts of Tryon Creek basin.

Water Quality

Water quality in Tryon Creek is only impaired for some water quality parameters. The seven-day average maximum daily temperature in Tryon Creek ranges from 20.0 to 21.9 degrees C, only exceeding the standard from 27 to 42 days each summer. Monitoring in Tryon Creek shows the Dissolved Oxygen (DO) standard is met except for the period from May through June, when the DO concentrations average about 10 mg/L, which is below the applicable 11.0 mg/L standard. Tryon Creek only sometimes exceeds the single sample standard for E. coli, most often during periods of precipitation and increased stream flows.

Hydrology

While development has altered the habitat and hydrology in the Tryon Creek subwatershed, there remain opportunities to protect and restore natural watershed functions and minimize the impact of development. Seeps and springs provide critical summer flows to streams. Tryon Creek meanders through much of Tryon Creek State Natural Area (TCSNA), helping to reduce stream velocity. Forested areas moderate storm water runoff through detention, infiltration and evapotransporation. Low-density urban development throughout much of the subwatershed retains a high degree of vegetation cover and minimizes impervious surfaces. The upper portion of the subwatershed is more developed but there are opportunities throughout the upper subwatershed to retrofit the built environment to improve watershed health. Stormwater management strategies could include detention ponds, roadside ditch enhancements, ecoroofs, and improved maintenance practices such as street sweeping.

Public Involvement

Collaborative restoration, education and technical assistance opportunities for local area residents are provided through partnerships between agencies and community groups. Partners in the Tryon Creek subwatershed include the Tryon Creek Watershed Council, Friends of Tryon Creek State Park, SW Neighborhoods, Inc (SWNI), neighborhood associations, SOLV, NOAA, Portland Parks and Recreation, Tryon Creek State Natural Area, Lewis and Clark College, BES' Watershed Planning, Revegetation and Stewardship Grant programs, schools and neighbors. Active stewardship sites include: Tryon Creek State Natural Area, Marshall Park, Tryon "Headwaters," Foley Balmer Natural Area and four private property sites coordinated by SOLV (Primrose, Plum Pocket, Quail Creek and Spring Garden). In Multnomah Village there are examples of stormwater solutions such as porous pavement at the Lucky Lab and bioswales with porous parking lot at the Multnomah Center. The Tryon Creek Watershed Council ranked Reach 4 of Tryon mainstem as a high priority for restoration on private land. Free programs such as Naturescaping for Clean Rivers are available to help raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. Additional public outreach steps could include placing signs to identify the subwatershed, installing curb markers to discourage dumping in storm drains and drains and encouraging Barbur Blvd. and Multnomah Blvd. businesses to become "Eco-logical Businesses" (a certification program for automotive and landscape services to meet watershed friendly standards and encourage residents to support those businesses).

ARNOLD CREEK SUBWATERSHED

Problem Summaries

Habitat

Physical habitat varies throughout Arnold Creek. In the lower portions of the creek, peak flow erosion and channel incision have significantly degraded in-stream habitat. Shallow and complex pools are limited and riffle habitats are embedded with fine sediments and organic material and considered only marginal fish habitat. Residential development and roads have had some impact on riparian habitat along most of the lower portions of the creek. Stream connectivity is compromised due to an impassable culvert at 16th Place. Floodplains are generally narrow. In the middle portions of the subwatershed, the floodplain is narrow, the riparian corridor is relatively narrow and fragmented, and in-stream habitat is considered poor, particularly because fine sediments have impaired potential habitat. In the upper portions of the subwatershed, the riparian corridor along Arnold Creek is largely intact. In-stream habitat lacks deep and complex pools, important for providing protective cover and holding areas for fish. The primary stream connectivity break in the upper portion of the subwatershed is the 35th Avenue culvert, which is only seasonally passable by fish. Arnold cascade at river mile 0.4 is also a natural barrier.

Biological Communities

Biological communities are limited by development. Culverts on the creek limit use of the creek by migratory fish and restrict resident fish movement. Development has also degraded much of the riparian habitat. However, amphibians, reptiles, mammals, birds and crustaceans may use the stream and riparian areas.

Water Quality

Stormwater runoff from development may contribute a number of pollutants. Specific water quality data for Arnold Creek are lacking. Arnold Creek is the largest tributary to Tryon Creek and may contribute to water quality problems.

Hydrology

Steep slopes and residential development dominate the landscape in this subwatershed. These features, along with continuing development, lead to relatively high stormwater runoff volumes and velocities that can cause stream bank instability and undercutting, erosion, in-stream sedimentation, and channel incision. These effects are present throughout Arnold Creek and may contribute to degraded conditions further downstream, such as Tryon Creek State Natural Area (TCSNA). Data to assess low flow conditions in Arnold Creek are lacking.

Public Involvement

People living in the subwatershed affect watershed health everyday by the choices they make. For example, choosing to landscape riparian areas with grass and other non-native vegetation degrades natural functions of the subwatershed. Choosing to dump liquid wastes such as automotive fluids down storm drains and pesticide use increases pollutants in streams. Raising people’s awareness about the impacts that their actions have on watershed health can help to reduce non-point source pollutants and restore natural functions to the subwatershed.

Opportunity Summaries

Habitat

Physical habitat varies throughout the subwatershed. Riparian vegetation cover is relatively consistent and wide along much of Arnold Creek, particularly along the lower reaches of the creek that are within Tryon Creek State Natural Area. Good floodplain interactions occur at the confluence of Arnold Creek and Tryon Creek. A few areas above Lancaster Road also allow good interaction between the creek and floodplain. In-stream habitat, such as pools and gravel and riffle substrates are adequate in many of the upper reaches of the creek, but are unfortunately degraded by fines.

Biological Communities

Biological communities are generally limited in the Arnold Creek subwatershed. Arnold Creek is the largest tributary to Tryon Creek, and is important because it helps provide habitat continuity and it augments low summer base flows. Vegetated areas, such as wide and intact riparian habitat, provide habitat for many small and adaptive mammal species. Up to 60 species of birds, and a number of amphibian and reptile species may inhabit some of these areas. Rainbow and cutthroat are present in the creek. Portions of Arnold Creek may provide important spawning and rearing habitat to resident fish species.

Water Quality

Water quality data is lacking for Arnold Creek. Monitoring indicates that Arnold Creek did not exceed the E. coli single sample standard in any samples.

Hydrology

While development has altered the landscape and hydrology in the Arnold Creek subwatershed, there remain opportunities to protect and restore natural watershed functions and minimize the impact of development. Low density urban development, characteristic of this subwatershed, retains a relatively high degree of vegetation cover and minimizes impervious cover, both of which help to retain some natural watershed functions. Opportunities to retrofit the built environment to improve watershed exist throughout the subwatershed. These stormwater management strategies could include detention ponds, roadside ditch enhancements, ecoroofs, and improved maintenance practices.

Public Involvement

Collaborative restoration, education and technical assistance opportunities for local area residents are provided through partnerships between agencies and community groups. Partners in the Arnold Creek subwatershed include the Tryon Creek Watershed Council, SW Neighborhoods, Inc (SWNI), neighborhood associations, Portland Parks and Recreation, BES' Watershed Planning, Revegetation and Stewardship Grant programs, schools and neighbors. Active stewardship sites include: Maricara Nature Park and Stevenson Elementary School (naturescaped garden). West Portland Park and the Kerr Site are additional Portland Parks sites that could host community stewards. BES' revegetation program is working with private landowners along Oak Creek, a tributary to Arnold Creek. The Tryon Creek Watershed Council ranked Arnold Creek as a high priority for restoration on private land. Free programs such as Naturescaping for Clean Rivers are available to help raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. Additional public outreach steps could include placing signs to identify the subwatershed and curb markers to discourage dumping in storm drains.

FALLING CREEK SUBWATERSHED

Problem Summaries

Habitat

Detailed descriptions of habitat in this subwatershed are lacking. The floodplain along most of Falling Creek is narrow. The riparian corridor is generally less than 100 feet wide and fragmented by residential development, providing degraded habitat. Stream connectivity is best in the lower portions of the creek. The lower and middle portions of Falling Creek are relatively well connected to Tryon Creek; however, the Lancaster Road culvert immediately downstream of the confluence with Tryon Creek is considered impassable for fish. In addition, the culvert at SW 35th Avenue is a significant fish passage barrier. Trees are lacking along much of the creek, particularly along the upper portions near Jackson Middle School.

Biological Communities

Culverts on Tryon Creek and low summer flows limit direct use of Falling Creek by migratory fish populations. However resident fish may continue to populate some reaches and some movement likely occurs during higher flows. Development has degraded riparian habitat. However, amphibians, reptiles, mammals, birds and crustaceans may use the stream and riparian areas, particularly during summer low flow conditions.

Water Quality

Water quality in Falling Creek is impaired for certain water quality parameters. Stormwater runoff from development may contribute a number of pollutants. Monitoring indicates that E. coli levels exceed the water quality standard in about 20 percent of samples during summer and 36 percent during winter. Data for other water quality parameters are lacking. However, Falling Creek may contribute to water quality problems in Tryon Creek.

Hydrology

Steep slopes and residential development dominate the landscape in this subwatershed. These features, along with continuing development, lead to relatively high stormwater runoff volumes and velocities that can cause stream bank instability and undercutting, erosion, in-stream sedimentation, and channel incision. Detailed information on stream channel conditions however is lacking. These effects may contribute to degraded conditions further downstream, such as Tryon Creek State Natural Area (TCSNA).

Public Involvement

People living in the subwatershed affect watershed health everyday by the choices they make. For example, choosing to landscape riparian areas with grass and other non-native vegetation degrades natural functions of the subwatershed. Choosing to dump liquid wastes such as automotive fluids down storm drains and pesticide use increases pollutants in streams. Raising people's awareness about the impacts that their actions have on watershed health can help to reduce non-point source pollutants and restore natural functions to the subwatershed.

Opportunity Summaries

Habitat

Riparian corridors are narrow throughout much of the subwatershed due to residential development. However, vegetation cover is highest in the lower portions of Falling Creek. Numerous aquatic and riparian dwelling wildlife species likely use the stream and riparian habitat.

Biological Communities

Vegetated areas provide habitat for many small and adaptive mammal species. Up to 60 species of birds, and a number of amphibian and reptile species may inhabit some of these areas. While Falling Creek only provides marginal fish habitat, amphibians, reptiles, mammals, birds and crustaceans likely use the stream, particularly during summer when the creek retains some water.

Water Quality

Water quality data is lacking for Falling Creek. Monitoring indicates that Falling Creek only exceeds the E. coli single sample standard in 20 percent of samples in summer.

Hydrology

While development has altered the landscape and hydrology in the Arnold Creek subwatershed, there remain opportunities to protect and restore natural watershed functions and minimize the impact of development. Low density urban development, particularly in the lower portions of the subwatershed along Arnold Creek, retains a relatively high degree of vegetation cover and minimizes impervious cover, both of which help to retain some natural watershed functions. Opportunities to retrofit the built environment to improve watershed exist throughout the subwatershed. These stormwater management strategies could include detention ponds, roadside ditch enhancements, ecoroofs, and improved maintenance practices.

Public Involvement

Collaborative restoration, education and technical assistance opportunities for local area residents are provided through partnerships between agencies and community groups. Partners in the Falling Creek subwatershed include the Tryon Creek Watershed Council, SW Neighborhoods, Inc (SWNI), neighborhood associations, BES' Watershed Planning, Revegetation and Stewardship Grant programs, Jackson Middle School and neighbors. Active stewardship sites include: Jackson Middle School revegetation and a BES' revegetation site along Falling Creek at Indian Hills. The Tryon Creek Watershed Council identified upper Falling Creek as a high priority for restoration on private land. Free programs such as Naturescaping for Clean Rivers are available to raise awareness about how individual actions, such as landscaping practices and pesticide use, influence watershed health. Additional public outreach steps could include placing signs to identify the subwatershed and curb markers to discourage dumping in storm drains.

CHAPTER 16

Fanno Creek Watershed Problem and Opportunity Tables

INTRODUCTION

These tables compile problems and opportunities identified in the Fanno Creek watershed characterizations (Chapters 3-11 of this document). Problems are in two broad categories, Tier 1 and Tier 2. Criteria for these two categories are listed below.

Tier 1 problems are:

1. Directly related to water quality.
2. Critical limiting factors identified in the characterization that impair ecological functions in the watershed.
3. Directly related to Endangered Species Act (ESA) listed species.
4. Well-characterized problems and sources with appropriate solutions. Benefits to watershed health are clear.

Tier 2 problems are:

1. Not directly related to critical limiting factors identified in the characterization that impair ecological functions of the watershed.
2. Non-critical culverts e.g., impassable fish culverts that exist upstream of other impassable culverts.
3. Problems ranked low in other studies or plans.
4. Poorly characterized problems and sources. Further analysis, data, and supporting documentation needed.

As Tier 1 problems are addressed some Tier 2 problems may be elevated to Tier 1 problems. For example, if the highway 43 culvert in Tryon Creek is replaced to allow fish passage, the upstream Boones Ferry Road culvert may be elevated from Tier 2 to Tier 1 because it becomes the next major fish barrier.

Opportunities are also divided into two tier categories. Criteria for these two categories are listed below.

Tier 1 Opportunities are:

1. Existing high value resource areas and assets. Particularly areas that will provide a clustering of positive watershed attributes.
2. Opportunities/Assets that help protect existing resource areas, improve Tier 1 problems, and help further objectives identified in the subwatershed and reach (e.g., retain low-density residential development).
3. Opportunities that enhance habitat connectivity, particularly in areas that directly improve Tier 1 problems and help further objectives identified in the subwatershed and

reach.

4. All open drainageways, wetlands, seeps, and springs throughout the watershed, particularly in areas not currently protected in environmental zones.
5. Areas of relatively high vegetation cover not currently protected in environmental zones.

Tier 2 Opportunities are:

1. Opportunities/assets that improve Tier 2 problems.
2. Opportunities/assets to enhance habitat connectivity throughout the watershed that indirectly improve Tier 1 problems and further objectives identified in the subwatershed and reach.

Fanno Creek Subwatershed - Problems

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	**Hydrology & Infrastructur**	**Physical Habitat**	**Biological Communities**	**Water Quality**		
	Basin-Wide							
	Throughout the Subbasin	✓	✓	✓	✓	✓	1. Water Quality monitoring results indicated impaired water quality, OWQI (Oregon Water Quality Index) rating is poor: a. Summer instream concentrations for total phosphorus are elevated and exceed TMDL during storm events [T1] b. Summer instream temperatures exceed the water quality standard of 64 degrees F for protection of salmonid rearing[T1] c. Dissolved oxygen concentrations are of concern during the summer (falling below standard of 11.0 mg/L) [T1] d. E. Coli levels exceed water quality standard (406 counts/100 ml) in over half the samples, instream bacteria concentrations are higher during runoff (rainfall) events and in the summer 2. Mainstem channel is constrained by high terraces and does not substantively interact with its riparian corridor and floodplain [T2] 3. Eroding banks throughout the basin especially near SW 59th, upper and lower portions of Reach 2, and Reach 4 [T1] 4. Lack of shade except near headwater reaches [T1] 5. Continuous development in riparian zone along Beaverton-Hillsdale Highway [T1] 6. Low macroinvertebrate production due to lack of good sized cobble and gravel, preponderance of substrate, and runoff with degraded water quality from Beaverton-Hillsdale Highway **DATA GAP** [T2] 7. Lack of instream wood – wood abundance and volumes are low throughout, wood recruitment and retainment [T2] 8. Lack of access to spawning and rearing habitat for fish: a. Poor stream connectivity – poor fish passage through the culverts [T2] b. Preponderance of pools, deep glide habitat and low riffle area (except in Reaches 2 and 5) – impedes habitat carrying capacity and diversity [T2] c. Disconnected floodplain [T2] d. High proportions of sand, silts, and organics [T2] 10. Incentive requests by residents exceed available resources for grants and revegetation cost share programs [T2] 11. No Eco-business certified in Fanno Watershed for Automotive and Landscaping Services so residents have no opportunity to support "green" business [T2] 12. Current maintenance practices, such as street sweeping, may not be timed or frequent enough to remove accumulated pollutants on city streets [T2]	1. Development within riparian zones and existing geography 2. Eroding streambanks (GIS map) due to increased runoff volume from upland areas, steep slopes, low vegetation, moderate root density, and a preponderance of sand and silt in stream channel 3. ODFW Summary: Percent shade is between 89-91% 4. Low tree canopy cover and lack of medium and large sized trees 6. Lack of substratum, toxins, a lack of plant diversity and transportation runoff with degraded water 7. With the exception of pools, wood abundance and volume are critically low (ODFW Summary); and very few key pieces greater than 3 m are present due to the loss of channel complexity 8. a) Roadway infrastructures b) Scour pools predominate; riffles comprise only 20% of the wetted area c) Transportation corridors, commercial developments, high terraces, and apartments that abut the creek d) Local and upstream bank erosion 9. a) Combination of land use effects and instream processes b) Shading of the stream is a major factor controlling instream temperatures c) Caused by a combination of increased water temperatures and the decay of organic matter. The TMDL for DO requires a reduction of organic material and total suspended solids (TSS) delivered to the stream d) Non-point sources (pets, wildlife) faulty septic systems, potential cross-connections, sanitary system leakage 10. Coordination with Maintenance Bureau
	Beaverton Hillsdale Highway throughout the basin		✓	✓	✓	✓	1. High impervious areas cause increased runoff volume [T1] 2. High traffic volume maybe indicative of potential high pollutant loading [T1]	1. Development, high imperviousness
Reach Specific – Citizen identified problems								

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructur	Physical Habitat	Biological Communities	Water Quality		
R-1	Reach 1– Confluence of Vermont Creek to the first tributary upstream of Beaverton-Hillsdale Shopping Center. Most of Reach 1 is located outside of City boundary							
R-2	Reach 2 -Begins at the first tributary upstream from the long culvert of the shopping mall, and ends at the confluence of the tributary near SW Shattuck Road							
R-3	Reach 3 - Begins at the tributary near SW Shattuck Road and ends at the tributary near SW 45th Avenue							
R-4	Reach 4 - Begins at the tributary near SW 45th and ends at the tributary near SW 39th Drive						1. Channelization and bank slump has occurred. Poorly engineered keystone retaining wall in the channel. There are additional potential bank failures Behind 5032 SW 39th Dr. [T1] 2. Stormwater collects and drains from Bridlemile land to Bridlemile Ct. and dumps into a deeply incised channel. [T2] 3. Runoff drains from 38th Pl; collects drainage for large street area. There is a lot of downcutting within the channel from 38th downstream to the 38th/39th intersection. [T2] 4. Stormwater from several properties collects and is eroding the bank. A 15" diameter tree was lost due to erosion undercutting the bank. 4126 SW 54th Pl. [T1] 5. Heavy erosion and bank failure due to undercut banks and heavy incision. Asphalt was placed in the stream channel as erosion control. [T1] 6. A house sits on the creek border. Banks are eroding under the house and there is a potential for structural damage at 3400 SW Hamilton Ct. [T1] 7. There is inadequate filtration for the Albertson's Parking Lot at Beaverton-Hillsdale Hwy. [T1] 8. A water runoff catch basin is not maintained as to what the City mandated for plants, getting filled with yard debris at the vacant lot on SW 62nd Ave. (East side of the road) [T1]	
R-5	Reach 5 - Begins at the tributary near SW 39th Drive and ends at the tributary near SW 30th Avenue							
Reach Summary								

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructur	Physical Habitat	Biological Communities	Water Quality		
R-1	**Reach 1**– Confluence of Vermont Creek to the first tributary upstream of Beaverton-Hillsdale Shopping Center. Most of Reach 1 is located outside of City boundary		✓	✓	✓	✓	1. Two culverts within the City are expected to have roadway flooding during design storms based on hydraulic modeling results (refer to site specific information listed below) [T1] 2. Riparian habitat and stream connection is good in lower reach but poor in upper reach [T1] 3. Narrow riparian corridor throughout [T1] 4. Poor channel condition and lack of spawning and rearing habitat for fish: [T1] a) Lack of instream structure, poor riffle habitat, long deep pools with high deposition, and erosive banks [T1] b) Floodplain and stream connectivity degrades towards upper end Fish passage barrier at driveway culverts and roadway crossing at Beaverton Hillsdale Shopping Center (Eighteen percent of creek bed is piped) [T1] c) Exposed sewer pipe may impede fish movement, especially during summer low flow season [T1] d) Culverts and roadway disconnect stream throughout - especially the Shopping Center culvert [T1] 5. Riffle area low end of questionable quality [T1] 6. All other issues listed under 'Basin-Wide' [T1]	
	Site Specific						•	
1-1	Raleigh Hills Shopping Center			✓	✓	✓	• Culvert is a fish barrier most times of year [T2] • Concentrated impervious area and commercial land use can be a potential pollutant source – high imperviousness, TSS, and TP [T1]	Length of culvert is 200 m; creek flows under the concentrated impervious area
1-2	Confluence of Sylvan Creek				✓	✓	• Low levels of DO – 10% of May-October flows [T2]	Impaired water quality (high temperature and nutrient loadings)
1-3	Apartment Complex Driveway Culverts		✓				• The 102-in driveway culvert (61ft long) in the apartment complex is expected to have roadway flooding problem for 25-year design storm [T2] • The double 72-in driveway culverts (31ft long) in the apartment complex are expected to have roadway flooding problem for 25-year design storm [T2]	Hydraulic Summary Table – Mike She/11 models on Fanno main stem
1-4	Storm pipes at SW Seymour Street		✓				• The 18 in storm pipes crossing SW Seymour Street is expected to be surcharged under the 10-year design storm [T2]	Hydraulic Summary Table – Mike She/11 models Fanno_14428 chainage 3155.5
R-2	**Reach 2** -Begins at the first tributary upstream from the long culvert of the shopping mall, and ends at the confluence of the tributary near SW Shattuck Road		✓	✓	✓	✓	1. Generally low riparian integrity (small tree, saplings) and very narrow riparian corridor (0-10-m), with very little fringe habitat, except at confluence with Columbia Creek [T2] 2. From Columbia Creek to Patton Creek: stream integrity poor and narrow (averaging 50 ft wide) and steep stream banks and low tree canopy (canopy diminishes from 10 to 30 m) [T2] 3. Floodplain interactions low (within 50-year floodplain), habitat constrained by terraces [T2] 4. The fish passage impact is unclear for several roadway crossing and across some natural 'steps' - **DATA GAP** [T2] 5. Water quality degradation from nonpoint sources [T2] 6. Portion of the channel appears to have been straightened, natural floodplain interactions have been lost [T2] 7. All other issues listed under 'Basin-Wide'	1-3 Development encroachment 5. DATA GAP 6. Beaverton Hillsdale Highway and the commercial/industrial areas which runs parallel to the mainstem 7. Development practices
	Site Specific							
2-1	SW Shattuck Road Culvert		✓		✓		1. The 6x6 ft box culvert (37ft long) is expected to be surcharged under the 10-year storm and have roadway flooding under the 25-year event [T2] 2. The culvert may impede fish passage (severity unknown) [T2]	Hydraulic Summary Table – Mike She/11 models
2-2	Detention pond in Upper Columbia Creek				✓	✓	1. Temperature concentrator within Columbia Creek, a tributary to mainstem [T2] 2. Temperature concentrators within tributary to Columbia Creek [T2] 3. Temperature concentrators within West branch of Columbia Creek [T2]	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructur	Physical Habitat	Biological Communities	Water Quality		
2-3	Mainstem near Shattuck Rd			✓	✓	✓	1. Riparian area integrity poor and narrow (averaging 50 ft wide) [T2] 2. Steep stream banks and low tree *canopy diminishes from 10 to 30 m* [T2] 3. High imperviousness, TSS, and TP [T1]	High imperviousness, development encroachment
2-4	Fanno tributary at Shattuck Rd		✓				1. The 30 in driveway culvert (140 ft long) at a driveway to SW Shattuck Rd. is expected to be surcharged under the 2-year storm and have roadway flooding under the 10-year storm [T2] 2. The 54 in driveway culvert (22 ft long) at a driveway to SW Shattuck Rd. is expected to be surcharged under the 10-year storm and have roadway flooding under the 25-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_10909 at chainage 6926
2-5	Fanno tributary near Hewett Blvd		✓				1. The two 15 in culverts combined (402 ft long) at SW Greenleaf Dr. and Hewett Blvd. is expected to be surcharged under the 10-year storm [T2] 2. The 16 in culvert (63 ft long) at Hewett Blvd. is expected to be surcharged under the 10-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_10909_3890
2-6	Fanno tributary at SW Patton Rd		✓				1. The 12 in culvert (68 ft long) at SW Patton Rd is expected to be surcharged under the 2-year storm and have roadway flooding under the 10-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_10909_3890 at chainages 1706 and 2399
2-7	Fanno tributary at SW Windsor/SW Thomas		✓				1. The 12 in culvert (63 ft long) at SW Windsor/SW Thomas is expected to be surcharged under the 2-year storm and have roadway flooding under the 100-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_10909 at Shattuck Rd
2-8	Fanno tributary at a driveway near Lowell St.		✓				1. The 12 in driveway culvert (164 ft long) at an unknown driveway near SW Lowell Rd is expected to be surcharged under the 2-year storm and have roadway flooding under the 100-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_10909_Shattuck at chainage 756
2-9	Fanno tributary at SW Bancroft St		✓				1. The 12 in culvert (218 ft long) at SW Bancroft is expected to be surcharged under the 2-year storm and have roadway flooding under the 10-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_10909_Shattuck at chainage 1434
2-10	Fanno tributary along Shattuck Rd		✓				1. The 12 in culvert (26 ft long) along Shattuck Rd is expected to be surcharged under the 2-year storm and have roadway flooding under the 2-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_10909_Shattuck at chainage 1776
2-11	Fanno tributary at Shattuck Rd		✓				1. The 15 in culvert (57 ft long) at Shattuck Rd is expected to be surcharged under the 2-year storm and have roadway flooding under the 25-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_10909_Shattuck at chainage 2016.5
2-12	Columbia Creek at SW Patton		✓				1. The 24 in culvert crossing (150 ft long) at SW Patton is expected to be surcharged under the 10-year design storm [T2]	Hydraulic Summary Table – Mike She/11 models – Fanno mainstem at chainage 2510
2-13	Columbia Creek at SW Thomas		✓				1. The 36 in culvert crossing (103ft long) at SW Thomas is expected to be surcharged under the 10-year design storm [T2]	Hydraulic Summary Table – Mike She/11 models Fanno main stem at chainage 4059
2-14	Columbia Creek at SW Hamilton		✓				1. The 3x4 ft box culvert crossing (85ft long) at SW Hamilton is expected to be surcharged under the 10-year design storm [T2] 2. The 48 in culvert crossing (11ft long) just upstream of SW Hamilton is expected to be surcharged under the 10-year storm and have roadway flooding under the 100-year storm [T2]	Hydraulic Summary Table – Mike She/11 models Fanno main stem at chainages 5841/6020 Fanno_14428 at chainage 3155.5
2-15	Columbia Creek Tributary at SW Hewett Blvd.		✓				1. The 10 in culvert crossing (100 ft long) at SW Hewett Blvd. is expected to be surcharged under the 10-year storm [T2]	
2-16	Columbia Creek tributary at SW Patton		✓				1. The 24 in culvert crossing (123 ft long) at SW Patton is expected to be surcharged under the 10-year storm and have roadway flooding under th 100-year storm [T2]	
2-17	Columbia Creek West Fork at SW Patton Road		✓				1. The 2x4 ft box driveway crossing (24 ft long) to SW Patton is expected to be surcharged under the 10-year design storm [T2]	
2-18	Columbia Creek west fork at SW 58th Ave.		✓				1. The 21 in double culvert crossings (63 ft long) at SW 58th Ave. is expected to have roadway flooding under the 100-year storm [T2] 2. The 30 in unknown driveway culvert (63 ft long) just upstream of SW 58th Ave is expected to be surcharged under the 10-year storm and have roadway flooding under the 100-year storm [T2]	
2-19	Columbia Creek Confluence to Fanno Mainstem			✓	✓	✓	1. Bank Erosion 90- 100% [T1]	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructur	Physical Habitat	Biological Communities	Water Quality		
R-3	**Reach 3** - Begins at the tributary near SW Shattuck Road and ends at the tributary near SW 45th Avenue		✓	✓	✓	✓	1. The culvert crossing at SW 45th Avenue is expected to be deficient under design storms[1] (refer to site specific information listed below) [T2] 2. Floodplain interactions low at mid-reach and narrow riparian corridor [T2] 3. Fish passage may be impacted by the following: 1) Culvert crossing at SW 45th Avenue (unknown impact, DATA GAP) [T2] 2) Many small culverts crossing throughout [T2] 3) Beaver pond and natural "steps" may seasonally impede fish movement [T2] 4. All other issues listed under 'Basin-Wide'	1. 2. Development encroachment 4. Culvert sizes
	Site Specific							
3-1	Mainstem at SW 45th		✓		✓		1. The 4x4 ft box culvert crossing (30ft long) at SW 45th Ave. is expected to be surcharged under the 2-year storm and have roadway flooding under the 10-year storm [T2] 2. The culvert may impede fish passage (severity unknown) [T2] 3. High imperviousness, TSS, and TP [T1]	Hydraulic Summary Table – Mike She/11 models
3-2	Mid-reach			✓	✓		1. Floodplain interactions are low (within 50-year floodplain) due to a narrow riparian corridor in this portion of the reach [T2]	Habitat Characterization Report
3-3	Fanno tributary at SW 47th		✓				1. The 18 in X 28 in box culvert crossing (50 ft long) just upstream of SW 47th Ave. is expected to be surcharged under the 10-year storm [T2]	Fanno_10646 at chainage 2405; near SW 47th
3-4	Fanno tributary at SW 47th						1. The 27 in (24 ft long) private driveway culvert near Seymour Ct is expected to surcharge under the 10-year storm and have flooding under the 25-year storm [T2]	Fanno_010646 at chainage 2625,
3-5	Fanno tributary at a private driveway		✓				1. The 24 in culvert (78 ft long) surcharges under the 10-year storm and has roadway flooding under the 100-year storm [T2]	Fanno_010646 at chainage 2947
R-4	**Reach 4** - Begins at the tributary near SW 45th and ends at the tributary near SW 39th Drive		✓	✓	✓	✓	1. The culvert crossings at SW 43rd and SW 39th are expected to be deficient under design storms (refer to site specific information listed below) [T2] 2. Poor channel conditions [T2] 3. Riparian zone is heavily impacted Lower reach has very narrow floodplain due to some steep slopes and urban and rural residential developments [T2] 4. Himalayan Blackberry is the most common vegetation within riparian zone [T2] 5. Fish passage barrier [T2] 6. All other issues listed under 'Basin-Wide'	1. 2. Lack of riffle habitat and pool habitat with slight deposition 3. Due to development, but trees are large and occur throughout the riparian corridor (0-30m) 4. Lack of Native plant species 5. Fish passage is mpeded by numerous roadway crossings; perched culverts at SW 43rd and SW 39th Dr
	Site Specific						1.	
4-1	Mainstem at SW 43rd		✓		✓		2. The 60 in culvert crossing (36ft long) at SW 43rd Ave is expected to be surcharged under the 2-year storm and have roadway flooding under the 10-year storm [T2] 3. Roadway flooding at 38th-39th intersections reported. [T2] 4. Fish passage barrier during summer and low flows [T2]	Hydraulic Summary Table – Mike She/11 models Fanno_07135 at chainage 587.5
4-2	Mainstem at SW 39th		✓		✓		1. The 60 in culvert crossing (170ft long) at SW 39th Ave is expected to be surcharged under the 10-year storm [T2] 2. May be fish passage barrier during summer and low flows [T2]	Hydraulic Summary Table – Mike She/11 models
4-3	Fanno tributary at SW Washouga Ave		✓				1. The 12 in culvert crossing (41 ft long) at SW Washouga Ave is expected to be surcharged under the 2-year storm and have roadway flooding under the 100-year storm [T2]	Hydraulic Summary Table – Mike She/11 models
4-4	Fanno tributary at SW Washouga Ave		✓				1. The 18 in storm pipe (830 ft long) is expected to be surcharged under the 2-year design storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_07135 at chainage 3311.5
4-5	Fanno tributary at SW 37th		✓				1. The 24 in culvert crossing (55 ft long) at SW 37th is expected to be surcharged under the 2-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_07537S at chainages 1578.5
4-6	Fanno tributary at a driveway		✓				1. The 15 in culvert crossing (325 ft long) at Beaverton Hillsdale Highway is expected to be surcharged under the 2-year storm and have roadway flooding under the 100-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_07537S at chainage 749

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructur	Physical Habitat	Biological Communities	Water Quality		
4-7	Fanno tributary at SW Cullen Blvd		✓				1. The 12 in culvert crossing (72 ft long) at SW Cullen Blvd is expected to be surcharged under the 10-year storm and have roadway flooding under the 100-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_07537S at chainage 1010 On Fanno_07537S tributary
4-8	Fanno tributary at two driveways near SW 42nd Ave		✓				1. The 18 in culvert crossing (131 ft long) at SW Fairvale Dr/42nd Ave. is expected to be surcharged under the 10-year storm and have roadway flooding under the 25-year storm [T2]	
4-9	Fanno tributary at SW Fairvale/42nd Ave		✓				1. The 12 in culvert crossing (79 ft long) driveway at 42nd Ave. is expected to be surcharged under the 2-year storm and have roadway flooding under the 10-year storm [T2] 2. The 12 in culvert crossing (31 ft long) driveway near 42nd Ave. is expected to be surcharged under the 2-year storm and have roadway flooding under the 10-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_07135 at chainage 5024
4-10	Fanno tributary at SW 39th Dr		✓				1. The 21 in culvert crossing (122 ft long) at SW 39th is expected to be surcharged under the 2-year storm [T2]	Hydraulic Summary Table – Mike She/11 models Ivey Creek at chainage 210
4-11	Ivey Creek at SW Fairmont		✓				1. The 15 in culvert (9 ft long) surcharges under the 2-year storm [T2]	Hydraulic Summary Table – Mike She/11 models Ivey Creek at chainage 210.5
4-12	Ivey Creek at SW Dosch Rd		✓				1. The 24 in culvert crossings (87 ft long) at SW Dosch Rd is expected to be surcharged under the 10-yr storm and have roadway flooding under the 25-year storm [T2]	Hydraulic Summary Table – Mike She/11 models Ivey Creek at Chainage 1882.5
4-13	Ivey Creek at SW 36th		✓				1. The 36 in driveway culvert (213 ft long) just upstream of SW 36th Ave. is expected to be surcharged under the 2-year storm and have roadway flooding under the 25-year storm [T2]	Hydraulic Summary Table – Mike She/11 models Ivey at chainage 3076.5
4.14	Ivey Creek at SW 45th		✓				1. The 36 in X 56 in box culvert crossing (115 ft long) just upstream of SW 45th Ave is expected to be surcharged under the 10-year storm [T2] 2. The 48 in driveway culvert (55 ft long) at SW 45th is expected to be surcharged under the 10-year storm and have roadway flooding under the 10-year storm [T2]	Hydraulic Summary Table – Mike She/11 models at Ivey Creek at chainage 5979.5 and 6139.5
4-15	Ivey Creek (West) at SW Dosch Ct		✓				1. The 12 in culvert (282 ft long) at SW Dosch Rd is expected to be surcharged under the 10-year storm and have roadway flooding under the 100-year storm [T2]	Hydraulic Summary Table – Mike She/11 models Ivey Creek West at chainage 675
4-16	Ivey Creek (West) at SW Bridlemile Ln		✓				1. The 18 in culvert (44 ft long) at SW Bridlemile Ln is expected to be surcharged under the 2-year storm and have roadway flooding under the 100-year storm [T2]	Hydraulic Summary Table – Mike She/11 models at Ivey Creek West at chainage 2370
4-17	Ivey Creek (West) at SW Hamilton St		✓				1. The 24 in culvert (132 ft long) at SW Hamilton is expected to be surcharged under the 10-year storm [T2]	Hydraulic Summary Table – Mike She/11 models – Ivey Creek West at chainage 3864
4-18	Ivey Creek West		✓				1. The 18 in culvert (745 ft long) storm pipe is expected to surcharge under the 10-year storm [T2]	
R-5	**Reach 5** - Begins at the tributary near SW 39th Drive and ends at the tributary near SW 30th Avenue		✓	✓	✓	✓	1. Private culvert crossing to Beaverton Hillsdale Highway is expected to be deficient under design storms (refer to site specific information listed below) [T2] 2. Poor channel conditions - most problematic of all other reaches [T2] 3. Limited refugia and rearing area potential [T2] 4. Riparian zone is heavily impacted in lower reach but trees are large throughout the riparian corridor (0-30 m) [T2] 5. Some blackberry present in riparian zone [T2] 6. Fish passage and habitat potential impeded [T2] 7. All other issues listed under 'Basin-Wide' [T2]	1. High percentage of stream (21%) that is piped and of long roadway culverts that break stream connectivity to upstream reaches 2. Low summer flows and high stream gradient 3. Development encroachment 4. Lack of native plant species 5. Numerous roadways, long culverts, and natural stream bed material 6. The culvert at 39th Ave and low summer flows
	Site Specific							
5-1	Mainstem at private crossing to Beaverton Hillsdale Hwy		✓		✓		1. The 60 in culvert crossing (114ft long) at a private crossing to Beaverton Hillsdale HWY is expected to be surcharged under the 10-year storm and have roadway flooding under the 100-year storm [T2] 2. The culvert may impede fish passage [T2]	Length (severity of seasonal impacts unkown)
5-2	Lower reach			✓	✓		1. Riparian zone is heavily impacted specifically in lower reach [T2]	Development encroachment

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructur	Physical Habitat	Biological Communities	Water Quality		
5-3	Fanno tributary along 31st and Dosch Rd		✓				1. The 8 in storm pipe (565 ft long) between 33rd and Dosch Dr along 31st and Dosch Rd surcharges at 2-yr storm [T2]	Fanno_05591 at chainage 954
5-4	Fanno tributary at SW Mitchell		✓				1. The 15 in storm pipe (336 ft long) surcharges at 10-yr storm [T2]	Fanno_05591 at chainage 1654
5-5	Fanno tributary at SW Boundary St		✓				1. The 18 in storm pipe (206 ft long) surcharges at the 10-yr storm [T2]	Fanno_05591 at chainage 1968.5
5-6	Fanno tributary		✓				1. The 12 in culvert crossing (46 ft long) at SW Seymour Ct/Dosch Rd is expected to be surcharged under the 2-year storm and have roadway flooding under the 100-year storm [T2]	Fanno_06546 at chainage 433
5-7	Fanno tributary at an SW Hamilton		✓				1. The 12 in culvert crossing (46 ft long) at a private crossing is expected to be surcharged under the 2-year storm and have roadway flooding under the 100-year storm [T2] 2. The 12 in culvert crossing (40 ft long) at a private crossing is expected to be surcharged under the 2-year storm and have roadway flooding under the 100-year storm [T2]	Fanno_06546 at chainage 433 Fanno_06546 a chainages 302 and 175
5-8	Fanno tributary at a private driveway		✓				1. The 15 in culvert crossing (30 ft long) at a private driveway is expected to be surcharged under the 10-year storm [T2]	
5-9	Fanno tributary at SW Sunset Blvd/SW Dosch		✓				1. The 12 in culvert crossing (337 ft long) at SW Sunset and SW Dosch Rd surcharges under the 2-yr storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_06546 at chainage 827
5-10	Fanno tributary at Beaverton-Hillsdale highway		✓				1. The 18 in culvert crossing (166 ft long) at Beaverton Hillsdale Highway is expected to be surcharged under the 10-year storm and have roadway flooding under the 100-year storm [T2]	Hydraulic Summary Table – Mike She/11 models - Fanno_06546 at chainage 786.5 at SW Sunset Blvd/SW Dosch Rd
R-6	**Reach 6** - Begins at the tributary near SW 30th and ends at the springs adjacent to Robert Grey Middle School A portion of Reach 6 is a tributary to Fanno Mainstem		✓	✓	✓	✓	1. No storm system capacity deficiencies are identified for this tributary to Fanno main stem [T2] 2. Poor channel conditions [T2] 3. The riparian zone, although fragmented, is better compared to other reaches [T2] 4. Floodplain is constrained and floodway connections impaired [T2] 5. Fish passage may be impeded by steep [T2] 6. All other issues listed under 'Basin-Wide'	1. 2. Minimal channel complexity 3,4 Development and Beaverton Hillsdale Highway embankment 5. Sloped culverts located SW 30th Avenue and SW Bertha Avenue (both on tributaries of the Fanno main stem)
	Site Specific							
6-1	30th Ave at Beaverton Hillsdale Highway			✓	✓		1. Fish passage impeded due to steep concrete culvert with small wetted perimeter and high velocities – **DATA GAP?** [T2] 2. High imperviousness, TSS, and TP [T1]	
6-2	SW Bertha Ave			✓	✓		1. Fish passage impeded due to steep concrete culvert [T2]	
6-3	Fanno tributary at SW Boundary & Mitchell Ct		✓				1. The 24 in culvert crossing (371 ft long) at SW Boundary & Mitchell Ct is expected to be surcharged under the 10-year storm [T2] 2. The 24 in storm pipe (918 ft long) at SW Richardson & SW Mitchell surcharges at 10-yr storm [T2]	
6-4	Fanno tributary to Mainstem		✓				1. The 7 in storm pipe (1214 ft long) along Seymour St surcharges at 2-yr storm [T2]	
6-5	Hillsdale Shopping Center – near SW 18th and Capitol Hwy		✓				1. High imperviousness, high traffic volumes, and limited parking	
R-7	**Headwaters** – Begins near 30th Ave and ends at the Fanno Creek Watershed Boundary		✓	✓	✓	✓	1. No storm system capacity deficiencies are identified for this tributary to Fanno mainstem 2. Large wood is present but is a DATA GAP [T2] 3. All other issues listed under 'Basin Wide'	

Fanno Creek Subwatershed – Opportunities

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources	Recommendations (Placeholder)
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality			
	Subbasin-Wide								
1	Throughout the Subbasin		✓	✓	✓	✓	10. Street ditch maintenance and preservation provides stormwater detention and filtration. The stormwater manual includes practices and timing. O&M opportunities will come out of the process of comparing the guidelines within the manual to the field practices. The revegetation team can be influenced by this activity. [T2] 11. Swales and ecoroof for businesses along Beaverton-Hillsdale Highway [T2] 12. Wood volume – look for acquisition, easement, SOLV sites, and Revegetation Cost Shares opportunities [T2] 13. Some good riparian areas throughout basin – Resident Steelhead/Rainbow Trout up to the headwaters, habitat protection recommended. Coho observed up to the culvert at 45th, habitat protection recommended [T1] 14. Coordinate with River Renaissance efforts to achieve a Clean and Healthy River including the Bureau of Planning's ongoing work to identify and rank remaining riparian and upland wildlife habitat areas [T2] 15. Support/Coordinate with completion of the City's update to its Environmental Land Use Planning Program including the Bureau of Planning's work to update the City's existing environmental zones and codes [T2] 16. Support/Encourage/Facilitate restoration of riparian areas along streams in the watershed [T1] 17. Educate citizens about the importance of healthy, small intermittent and headwater streams and watersheds [T2] 18. Create incentive programs to encourage low-impact and green development practices [T2] 19. Use outlets for information that currently exist (Website, SWNI, SW Watershed Center) [T2] 20. Encourage "Dump no waste" storm drain curb marker program [T2] 21. Many active stewardship groups – continue to support and foster new groups (Fans of Fanno, Bridlemile Creek Stewards, St. Andrews Presbyterian, Trillium Creek Community) [T2]	1. Some ditches were not efficiently maintained for stormwater detention and filtration (not in char). 2. Look at the dynamics of system (not in char) and consider immediate and long-term sources of wood - riparian vegetation age, type, and structure and the probability for retention. 3. Riffles are of good quality, provide important spawning and rearing grounds, and likely sustain much of the macroinvertebrate production in the upper creek. 4-8. Placeholder – Coordination with Planning Bureau not in char 11. Ongoing development of creative opportunities to encourage landowners to manage land for clean watershed values is needed. 12. Goal 2 -Public outreach strategies are to be developed to inform citizens about pollutants they can minimize through behavioral change. 13. Goal 7 -Stewardship – Maintain long-term community-wide commitment to improve and sustain overall watershed health.	• Identify locations of unimproved streets in Fanno Creek Watershed – the unimproved streets may be providing filtering in areas where there is a significant need (however unimproved streets may be adding to the sediment problems) not in char - **DATA GAP**
	Reach Summary								
R-1	**Reach 1**– Confluence of Vermont Creek to the first tributary upstream of Beaverton-Hillsdale Shopping Center. Most of Reach 1 is located outside of City boundary	✓	✓	✓	✓	✓	1. Existing low stream gradients and limited number of road crossings with no culverted reaches should be maintained. [T2] 2. Riparian zone protection, bank stabilization, and both protection of existing and creation of new refugia (boulders and wood). Opportunity to maintain viable trout populations. [T2] 3. Riparian habitat and connections should be preserved through acquisitions and easements (not in char) 4. All other issues listed under 'Basin-Wide'	1. Creek is longitudinally connected downstream of Beaverton-Hillsdale Shopping Center 2. Coho assumed to use up to RM 5.3 for adult rearing and *migration*. Cutthroat trout observed every sample season – reach wide and year round use 3. Riparian condition is good downstream of Oleson Rd. with the exception of some houses that are near the stream bank.	• Identify locations of and protect seeps and springs - **DATA GAP** • Wetland creation and enhancement opportunities. Stormwater detention/infiltration opportunities in open areas to improve floodplains and connections. Strategic site location recommendations?
1-1	Columbia Creek		✓	✓	✓		• Location of seeps and springs identified [T1]		
1-2	South end of 48th		✓	✓	✓		• Location of seeps and springs identified [T1]		
1-3	South end of 39th, on the hillside		✓	✓	✓		• Location of seeps and springs identified [T1]		
R-2	Reach 2 -Begins at the first tributary upstream from the long culvert of the shopping mall, and ends at the confluence of the tributary near SW Shattuck Road	✓	✓	✓	✓	✓	1. The immediate 10-m of stream bank should be prioritized for protection; areas beyond the immediate 10-m are comprised of landscape plants and shrubs. [T1] 2. Mitigation opportunity for stormwater runoff from specific impervious areas – parking lot swales along Beaverton-Hillsdale Highway [T1] 3. All other issues listed under 'Basin-Wide'	1. The riparian corridor is very narrow (effectively 0-10-m from the stream bank). The portion of the reach near the confluence of Columbia Creek might provide the best opportunities for habitat protection. 2. Albertson's Parking lot, apartment complexes that abut the creek provide most potential for restoration	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources	Recommendations (Placeholder)
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality			
2-1	Albertson's parking lot	✓	✓	✓	✓	✓	1. Swales and ecoroof for Albertson's can be installed [T1]		
2-3	Confluence of Columbia Creek		✓	✓	✓		1. Opportunity for riparian habitat/connection through the revegetation program (land acquisition) [T2]		
R-3	Reach 3 - Begins at the tributary near SW Shattuck Road and ends at the tributary near SW 45th Avenue		✓	✓	✓	✓	1. Moderate canopy cover 0-10 m, refugia likely exists at the Columbia Creek confluence, pool depth is considered desirable for fish but count is low, protection of these areas recommended for resident fish [T1] 2. Riffle habitat is moderate; boulders are present and degraded by fines. These areas may provide critical spawning habitat and should be protected from further degradation. [T1] 3. All other issues listed under 'Basin-Wide'	1. Resident steelhead throughout upper basin 2. Riffle area is three times more here than what occurs in R2 and R4, comprising 37% of all habitat units.	
3-1	St. Andrews Presbyterian	✓	✓	✓			1. Opportunity to support and monitor parking lot retrofit project [T2]		
R-4	Reach 4 - Begins at the tributary near SW 45th and ends at the tributary near SW 39th Drive	✓	✓	✓	✓	✓	1. Low fines in substrate [T1] 2. Mitigation opportunity for stormwater runoff from specific impervious areas – parking lot swales along Beaverton-Hillsdale Highway (land acquisition – WQ facility) [T1] 3. Floodplain connection in the upper and lower portions of stream is good and should be protected. [T1] 4. Ecological functions are relatively intact; much of the land base on both sides of the creek is undeveloped and should be protected. (land acquisition) [T1] 5. Good instream habitat (deep complex pools and good riffles), natural ecological functions relatively intact, likely provides rearing and refuge habitat for fish during winter and summer periods. [T1] 6. All other issues listed under 'Basin-Wide'	1. Gravel and cobble are high, fines are low, and boulders are present. 2. Parking lots at SW 42nd and near 39th Dr. 3. Both stream banks are relatively developed but properties are removed from the immediate stream channel by at least 10 m. 4. This reach is considered good habitat relative to other areas along Fanno. 5. Deep, complex pools, along with undercut banks and presence of boulders, are particularly important for salmonids in the winter. These habitat features provide cool water refugia and cover from predators during summer months	
4-1	Bridlemile Elementary School grounds						1. Opportunity to involve students from Bridlemile Elementary on restoration projects and to support swale and naturescaping projects on school site [T2]		
R-5	Reach 5 - Begins at the tributary near SW 39th Drive and ends at the tributary near SW 30th Avenue		✓	✓	✓	✓	1. Riffle habitat is low but high quality; these areas should be protected. Low fines in substrate [T1] 2. Tree size and potential for large wood recruitment is fair throughout the reach, with the average1diameter of deciduous species ranging from 30-50 cm., and the restoration of wood volume is needed instream [T1] 3. Large established trees in the continuous riparian corridor provide continuous shade 0-30 m from streambank and should be preserved. (land acquisition) [T1] 5. Upper floodplain is relatively undeveloped and connectivity is considered moderate to good and should be preserved. Channel likely intersects with floodplain during high flows. (land acquisition) [T1] 6. All other issues listed under 'Basin-Wide'	1. Pools are abundant and moderately deep, three complex pools provide critical spawning habitat for fish 2. Key pieces of wood found in upper end of reach only 4. The upper floodplain portions are relatively undeveloped and increased floodprone width signifies increased interactions. 5. Riparian width varies from being greater than 100 feet in some areas, to having apartments abutting the stream bank in others.	
5-1	Albert Kelly Park	✓	✓	✓	✓	✓	2. Support Bridlemile Creek Stewards in restoration of the riparian area of the park [T2] 3. Location of seeps and springs identified [T1]		

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources	Recommendations (Placeholder)
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality			
R-6	Reach 6 - Begins at the tributary near SW 30th and includes the headwaters ends at the springs adjacent to Robert Grey Middle School Reach 6 is a tributary to Fanno Mainstem		✓	✓	✓	✓	1. Riffle habitat is abundant and of excellent quality and there are low fines in substrate; opportunity for protection [T1] 2. Large well-established trees along the highway embankment provide sources of large and medium sized wood to the creek and much of the area has 90-100% shade cover. These trees should be preserved. [T1] 3. Riparian habitat continuous in some areas, large established trees are present within riparian corridor providing continuous shade 0-30m from streambank [T1] 4. All other issues listed under 'Basin-Wide'	1. This reach could provide critical spawning habitat if it were accessible to salmonids. 2. Large wood volume and abundance is low but higher than any other reach 3. ODFW data shows that this reach exhibits the highest potential for floodplain interactions 4. Shrubs and vines vegetate the riparian corridor although canopy coverage is considered good.	
6-1	Nevah Shalom Congregation	✓	✓	✓	✓	✓	1. Parking lot swales [T2] 2. Downspout disconnection [T2] 3. Move parking lot away from stream to address the downcutting of the parking lot [T2]		
6-2	Portland Christian Center	✓	✓	✓	✓	✓	1. Parking lot swales [T2] 2. Downspout disco if connected to land near playing field [T2]		
6-3	Robert Gray Middle School	✓					1. Opportunity to engage students in watershed projects [T2]		
6-4	Trillium Neighborhood	✓	✓	✓			1. Opportunity to continue to involve and support neighbors in riparian forest protection and enhancement [T2]		
6-5	Twobly/Washuga Neighborhood	✓	✓	✓			1. Opportunity to support neighbors in riparian restoration [T2]		

Pendleton Creek Subwatershed – Problems

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	**Hydrology & Infrastructure**	**Physical Habitat**	**Biological Communities**	**Water Quality**		
	Subbasin-Wide							
1	Throughout the Subbasin		✓	✓	✓	✓	1. Water Quality monitoring results indicated impaired water quality and TMDLs are exceeded for temperature, bacteria, DO, and TP a) High summer TP [T2] b) High bacteria during summer and runoff (rainfall) events [T2] 2. Overall channel conditions are considered poor – **DATA GAP** [T2] 3. Lack of shade [T2] 4. Lack of access to spawning and rearing habitat for fish [T2] 5. Water Quality monitoring results indicated impaired water quality and TMDLs are exceeded for temperature, bacteria, DO, and TP [T2] c) High summer TP [T2] d) High bacteria during summer and runoff (rainfall) events [T2]	1. a) a. TP due to increased sediment loading and transport from upland urban areas and erodible banks 2. Sewage, illegal sanitary connections, dumping, failing septic systems, animal and wildlife wastes 3. Development encroachment – roadways, residential development along much of the upper reach 4. Low tree canopy cover and lack of medium and large sized trees 5. Sequence of narrow runs (channelized ditches) with culverts upstream of Shattuck Rd and a disconnected floodplain is suspected Data Gap
	Site Specific							
1-1	Upstream of Shattuck Rd.			✓	✓		1. Very little riparian vegetation; the riparian habitat is fragmented [T2] 2. Lack of access to spawning and rearing habitat for fish [T2] 3. Observations of substrate mix of sediment, fill, rock, and coarse debris [T2]	
1-2	SW 56th Model North Branch Tributary		✓				1. The 8-in culvert (233 ft long) north of Cameron Rd is expected to surcharge under the 2-year storm and have roadway flooding at the 10-year storm [T2] 2. The 12-in culvert (187 ft long) is expected to surcharge under the 2-year storm [T2] 3. The 15-in culvert (112 ft long) is expected to surcharge under the 10-year storm [T2]	
1-3	Mainstem at SW Fairvale Ave		✓				1. The 20 in Culvert (95 ft long) is expected to surcharge under the 10-year storm [T2]	
1-4	Near SW 50th below SW Cameron Pendleton Creek North Branch tributary		✓				1. The 16 in culvert (18 ft long) is expected to surcharge under the 2-year storm and have roadway flooding under the 2-year storm [T2] 2. The 12 in culvert (36 ft long) is expected to surcharge under the 10-year storm and have roadway flooding under the 10-year storm [T2]	
1-5	SW Fairvale Pendleton Creek North Branch		✓				1. The 12-in driveway culvert (33 ft long) is expected to surcharge under the 10-year storm [T2]	
1-6	Mainstem at SW 48th		✓				1. Three 18 in culverts in rapid series (171 ft long) are expected to surcharge under the 10-year storm and have roadway flooding under the 100-year storm [T2]	

Pendleton Creek Subwatershed – Opportunities

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
	Subbasin-Wide							
1	Throughout the Subbasin	✓	✓	✓	✓	✓	1. Habitat conditions have not been well documented [T2] 2. Floodplain conditions seem relatively intact – aerial photographs allow for some anecdotal information [T2] 3. Use outlets for information that currently exist (Website, SWNI, SW Watershed Center) [T2] 4. Encourage "Dump no waste" storm drain curb marker program [T2] 5. Support active stewardship project at Cedar Sinai [T2] 6. Acquire open space along Pendleton Creek (west of Shattuck Rd) [T2] 7. Encourage Naturescaping for creek side residents [T2] 22. Support/Coordinate with completion of the City's update to its Environmental Land Use Planning Program including the Bureau of Planning's work to update the City's existing environmental zones and codes [T2] 23. Support/Encourage/Facilitate restoration of riparian areas along streams in the watershed [T2] 24. Educate citizens about the importance of healthy, small intermittent and headwater streams and watersheds [T2]	
	Site Specific							
1-1	Near SW 61st Ave.			✓	✓		1. Location of an undeveloped patch of forest [T2]	
1-2	Immediately Upstream of the Fanno Creek/Pendleton Creek confluence			✓	✓		1. Aerial photos suggest that a pond/wetland exists [T2]	
1-3	Downstream of SW Shattuck Rd			✓	✓		1. Riparian integrity and associated wildlife habitat (and tree canopy condition) are considered fair to good [T2]	

Vermont Creek Subwatershed – Problems

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
	Subbasin-Wide							
1	Throughout the Subbasin		✓	✓	✓	✓	1. Water Quality listed for temperature, bacteria, dissolved oxygen TMDLs, OWQI rated very poor, and the monitoring results indicate impaired water quality: a) High TSS, increased sediment loading and transport from upland urban areas, low vegetation, and erodible banks [T2] b) Increased summer temperature and BOD; Vermont Creek is rated poor in OWQI due to bacteria, TP, and total solids [T2] c) High bacteria – E. coli levels exceed water quality standard (406 counts/100ml) in over half the samples especially during runoff (rainfall) events [T2] d) Summer instream concentrations of total phosphorus exceed TMDL requirements [T2] e) Ammonia + nitrate nitrogen and BOD also influence the low OQWI index, OQWI slightly lower during the summer season [T2] 2. Eroding banks (70%) throughout the basin [T2] 3. Lack of shade throughout the basin [T2] 4. Lack of Wood – abundance and volume severely low, key pieces rare [T2] 5. Low macroinvertebrate production [T2] 6. The areas of the creek running through residential areas are slightly to moderately entrenched and have low sinuosity [T2] 7. Lack of access to spawning and rearing habitat for fish – lack of high quality rearing grounds, deep pools, and boulders [T2] 8. More staff hours are needed to coordinate BES revegetation cost shares on small private properties [T2]	1. a) increased sediment loading and transport from upland urban areas, low vegetation, and erodible banks b) Temperature concentrators – beaver dams at Vermont and Shattuck Rds as well as upstream from Shattuck Rd c) Sewage, flooding/deficient sanitary pipes along the creek, dumping, failing septic systems, animal wastes d) Landscape practices, soil erosion, and sewage 2. Increased runoff volume from upland areas, steep slopes, and low vegetation; fine silts and sand overlay substrates 3. Low tree canopy cover and lack of medium and large sized trees, many areas less than 50% shade (effective) 4. Low vegetation and recruitment 5. High proportion of fines overlay suitable substrates 6. Development encroachment 7. a) Lack of deep pools and boulders, lack of channel complexity b) Resident fish movement seasonally impaired at SW Oleson and Shattuck c) High proportions of fines and organics overlying the suitable substrates
Reach Summary								
R-1	**Reach 1–Citizen Identified** Lower Vermont extends from the confluence of Vermont and Fanno Creeks, U/S to a tributary approximately 900' D/S of SW 45th Ave. The lower 200' of this reach (Bauman Park) is outside the current study area.		✓			✓	1. Erosion, flooding, impervious surfaces, 7 acres, 34 houses near 3859 SW Canby St. (C. Ensign) [T2] 2. Erosion, animal fecal waste and limited vegetation in Gabriel Park. [T2]	
R-1	**Reach 1**– Lower Vermont extends from the confluence of Vermont and Fanno Creeks, U/S to a tributary approximately 900' D/S of SW 45th Ave. The lower 200' of this reach (Bauman Park) is outside the current study area.		✓	✓	✓	✓	1. Low macroinvertebrate production [T2] 2. High volume of sediments [T2] 3. Riparian habitat/connection varies throughout reach, though several areas are poor [T2] 4. Poor channel condition and lack of spawning and rearing habitat for fish a) Limited residence area for fish, between Oleson Rd and Shattuck 0.4 RM and between Shattuck and Vermont at 52nd 0.5 RM [T2] b) Riffle area low and questionable quality, high proportion of fine sediment and organics cover riffle substrate [T2] c) Fish passage barrier at driveway culverts and roadway [T2] 5. All other issues listed under 'Subbasin-Wide'[T2]	1. High proportion of fines that overlay suitable substrates 2. Road crossings, development, cleared stream banks, and landscaping practices 3. Data Gap 4. a) Undercut banks are rare (8%), boulders are rare, and wood volume is low b) Steep slopes along creek

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
1-1	Mainstem at SW Oleson Rd		✓	✓	✓		1. The 36 in culvert (61 ft long) at SW Oleson Rd is expected to surcharge under the 10-year design storm [T2] 2. Culvert at SW Oleson Rd impedes fish passage particularly during low summer flows [T2] 3. Stream connectivity is disrupted [T2] 4. Limited residence area for fish between SW Oleson Rd and SW Shattuck Rd (only 0.4 rivermiles) [T2] 5. High imperviousness, TSS, and TP [T2]	1. Impacts due to culvert design
1-2	Mainstem at SW Terri Ct		✓	✓	✓		1. The 72” X 42” box culvert (108 ft long – fish barrier) is expected to surcharge under the 10-year storm and Roadway flooding expected during 25-year storm [T2]	
1-3	Mainstem at SW 63rd Ave		✓				1. The 54 in culvert (70 ft long) is expected to surcharge under the 10-year storm [T2]	
1-4	SW Shattuck Rd		✓	✓	✓	✓	2. SW Shattuck culvert impedes fish passage [T2] 2. Stream connectivity is disrupted [T2] 3. Limited residence area for fish between SW Oleson Rd and SW Shattuck Rd (only 0.4 rivermiles) [T2] 3. High imperviousness, TSS, and TP [T2]	
1-5	Mainstem at SW 55th Dr		✓			✓	1. The 48 in culvert (65 ft long) is expected to surcharge under the 10-year storm and Roadway flooding expected during 100-year storm [T2] 2. High imperviousness, TSS, and TP [West Vermont] [T2]	
1-6	SW Vermont and 52nd		✓	✓	✓	✓	1. Potentially deficient pipe within existing sanitary system –**DATA GAP** [T2] 2. Poor riparian habitat connection [T2] 3. Limited residence area for fish between SW Vermont and SW 52nd (only 0.5 rivermiles) [T2] 4. The 175 ft culvert at SW Vermont and the 200 ft storm pipe at SW 52nd completely block fish passage [T2]	3. Development, roadcrossings, cleared stream banks, and landscaping practices
1-7	Near SW 46th Ave Model tributary 05366		✓	✓	✓		1. The 24 in culvert (365 ft long) is expected to surcharge under the 10-year storm and roadway flooding expected during 100-year storm [T2] 2. Confluence of tributary to main stem – abundance and volume of wood severely low, key pieces of wood are rare [T2]	1. Residential development predominates, low vegetation cover in most areas
	Reach 2 – Upper Vermont begins at a tributary approximately 900’ D/S from SW 45th Ave, and extends U/S to the headwaters of Vermont Creek that drains Gabriel Park, along Caldwell St, near 36th Ave. North Fork originates near SW Vermont Ave and 37th South Fork originates near the Garden Home/Multnomah Rd intersection and enters mainstem Vermont Creek 100’ below SW 45th Ave		✓	✓	✓	✓	1. Two culverts within the City are expected to have roadway flooding based on hydraulic modeling results (refer to site specific information listed below [T2] 2. Banks are actively eroding [T2] 3. Significant amount of silt overlay riffle and pool habitat, pools are shallow [T2] 4. Wood volume is low, key pieces are rare, channel complexity is low, and the instream habitat is considered poor 5. Limited flows in the summer months in the North and South Forks [T2] 6. The riparian corridor along North Fork Vermont Creek is narrow’ the riparian canopy is fragmented at 45th which crosses over Vermont Creek and South Fork Vermont Creek [T2] 7. All other issues listed under ‘Subbasin-Wide’ [T2]	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
2-1	Mainstem at 45th Modeled node 3515		✓	✓	✓		1. High Bacteria – High concentrations of the non-point source linked to off-leash area in Park [T2] 2. Narrow corridor, some fragmentation especially at 45th Ave [T2] 3. The 15 in culvert (20 ft long) is expected to surcharge under the 2-year storm and roadway flooding expected during 100-year storm [T2] 4. The 36 in culvert (90 ft long) disconnects upper mainstem and South Fork Vermont Creek from lower Vermont Creek [T2] 5. The riparian canopy is fragmented most dramatically at SW 45th [T2] 6. High imperviousness, TSS, and TP [T2] 7. Lack of channel complexity, deep pools and LWD [T2]	
2-2	Gabriel Park Tributary model node 3215_1300		✓	✓	✓		1. The 12 in culvert (50 ft long) at Gabriel Park is expected to surcharge under the 2-year storm and roadway flooding is expected during a 10-year storm [T2] 2. Riparian conditions compromised in the Park [T2] 3. Wood volume is low and key pieces are rare in the tributary to headwaters that drains Gabriel Park [T2]	2. Foot trails impact riparian areas 3. Residential development predominates in many of the surrounding areas
2-3	Headwaters tributary near Multnomah Blvd			✓	✓		1. The riparian canopy diminishes and the creek runs under an apartment complex and parking lot [T2] 2. Headwater reach is likely inaccessible to fish [T2]	
2-4	Headwaters near SW 34th Mainstem model node 200		✓		✓		1. The 8 in culvert (70 ft long) is expected to surcharge under the 2-year storm and roadway flooding expected during 100-year storm [T2] 2. Limited flows in summer months [T2]	

Vermont Creek Subwatershed – Opportunities

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
	Subbasin-Wide							
1	Throughout the Subbasin	✓	✓	✓	✓	✓	1. The lack of development is an opportunity to keep imperviousness low [T2] 2. Use outlets for information that currently exist (Website, SWNI, SW Watershed Center) [T2] 3. Encourage “Dump no waste” storm drain curb marker program [T2] 4. Support and foster new groups such as Friends of Vermont Creek [T2] 5. Support/Coordinate with completion of the City’s update to its Environmental Land Use Planning Program including the Bureau of Planning’s work to update the City’s existing environmental zones and codes [T2] 6. Support/Encourage/Facilitate restoration of riparian areas along streams in the watershed [T2] 7. Educate citizens about the importance of healthy, small intermittent and headwater streams and watersheds [T2]	
2	**Citizen Identified**	✓	✓				Gabriel Commons: 3865 SW Canby is a 34-unit Condominium complex with the desire to manage our stormwater. We are interested in grants. [T2]	
	Reach Summary							
R-1	**Reach 1**– Lower Vermont extends from the confluence of Vermont and Fanno Creeks, U/S to a tributary approximately 900’ D/S of SW 45th Ave. The lower 200’ of this reach (Bauman Park) is outside the current study area.		✓	✓	✓	✓	1. Opportunities to reduce velocities by floodplain and meander restoration [T2] 2. Good riparian habitat and canopy cover [T2] 3. Biological communities residing in this reach include resident sculpin, wood ducks, coyotes, and a peregrine falcon was sighted by ODFW [T2] 4. Protect vegetative cover for velocity control [T2] 5. Opportunity to protect intact floodplains and unconstrained channel functions [T2] 6. Potentially adequate habitat and refugia for cutthroat trout may be a potential target species 7. Resident fish likely use the beaver ponds for rearing and refuge [T2] 8. Canopy cover is relatively good, with crown cover 50% near Fanno Confluence and 90-100% at the confluence in Bauman Park [T2]	
1-1	Below Shattuck Rd crossing						1. Opportunity to protect high quality fish habitat within the corridor [T2]	
R-2	**Reach 2** – Upper Vermont begins at a tributary approximately 900’ D/S from SW 45th Ave, and extends U/S to the headwaters of Vermont Creek that drains Gabriel Park, along Caldwell St, near 36th Ave. North Fork originates near SW Vermont Ave and 37th South Fork originates near the Garden Home/Multnomah Rd intersection and enters mainstem Vermont Creek 100’ below SW 45th Ave		✓	✓	✓	✓	1. Conifers and hardwoods are present, corridor is relatively intact [T2] 2. This reach provides important refuge during storm flows and during spring rearing (Hab p. 24) [T2] 3. Floodplain connections appear intact in lower portion above 49th Ave. and in portions of Gabriel Park. Flood flows periodically top bank. [T2] 4. Gabriel Park and other areas above the park – protect green space and open spaces [T2] 5. Much of riparian habitat is good [T2] 6. All other issues listed under ‘Subbasin-Wide’ [T2]	
2-1	Headwaters draining Gabriel Park						1. Opportunity to protect the presence of wood in stream – 16.3/ 100 m [T2] 2. Opportunity to protect good riparian habitat [T2] 3. Opportunity to protect floodplain above SW 49th and in Gabriel Park – flood flows periodically top bank [T2]	1. Large woody debris is found in channel and considered moderately good at 16.3 pieces per 100 m 2. Corridor is relatively intact but is narrow; large conifers and hardwoods are present

Woods Creek Subwatershed – Problems

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
	Subbasin-Wide							
1	Throughout the Subbasin	✓	✓	✓	✓	✓	1. Water Quality monitoring results indicated impaired water quality. Potential sources include: a. High TSS [T1] b. High bacteria [T1] c. High nutrients and TP potentially [T1] d. High BOD [T1] 2. Lack of Wood due to Silt deposition degrades channel substrate [T2] 3. Lack of shade [T1] 4. Lack of access to spawning and rearing habitat for fish due to poor stream connectivity [T2] 5. Riffle habitat is generally lacking [T2] 6. Silt and organics degrade instream habitat [T2]	1. a) Sediment loading and transport from upland urban areas and erodible banks b) Sewage, illegal sanitary connections, dumping, failing septic systems, and animal wastes c) Landscape practices, soil erosion, and sewage d) High TP and TSS loading throughout 2. Low vegetative cover along portions of the creek and some upland areas, and development 3. Low tree canopy cover and lack of medium and large sized trees, except near headwater reaches 4. Roadway infrastructures, urban development, and channelization
Reach Summary								
R-1	**Reach 1– Citizen Identified** Begins near the confluence of Fanno Creek and ends before the SW Multnomah Rd crossing Most of Reach 1 is outside the City boundary		✓				1. Surface water runoff and underground springs uphill from SW 56th, drains over private property downhill into Woods Creek. SW 54th above Multnomah Blvd. [T1] 2. Stormwater flows down 59th across Garden Home Rd into a small ditch and then to a downhill stream into Woods Creek. Both sides of Garden Home Rd. have culverts. The south culvert is about 12" and the north culvert is only 5-6" [T2] 3. The unimproved roads do not have drains. Runoff fills the foundation area with large amounts of water in some homes. The area needs a sump dump that drains this water into the street, near 54th and Garden Home. [T2]	
R-1	**Reach 1–** Begins near the confluence of Fanno Creek and ends before the SW Multnomah Rd crossing Most of Reach 1 is outside the City boundary		✓	✓	✓	✓	1. Fourteen culverts are expected to surcharge under the 2-year storm [T2] 2. Twenty-five culverts are expected to surcharge under the 10-year storm, four of which are expected to have roadway flooding [T2] 3. Poor channel condition and lack of spawning and rearing habitat for fish due to: a) Potential fish barrier [T2] b) Lack of potential refugia [T2] c) Silt and organics predominate in substrate [T2] 4. All other issues listed under 'Basin-Wide'	3. a) Initial dam at the beginning of the reach b) Lack of wood, no boulders, no undercut banks, and no secondary channels
	Site Specific							
1-1	Portland Golf Club, near confluence of Fanno Creek – outside of the City Boundary		✓	✓	✓		1. Culvert is a fish barrier [T2]	
1-2	SW Oleson Rd – near Hideaway		✓	✓	✓		1. Culvert likely impairs connectivity [T2] 2. Narrow and fragmented riparian corridor [T2]	2. Homes abut the stream bank and the stream banks have been cleared
1-3	Oleson Rd to 65th near the City Boundary			✓	✓		1. Disconnected floodplains [T2] 2. Fish Ladder [T2]	1. Channelization and urban development near the confluence with Fanno Creek, and forest clearing (from Oleson Rd downstream) Oleson Rd impairs stream connectivity
1-4	SW 60th Ave			✓	✓	✓	1. Roadway likely impairs connectivity [T2]	
1-5	SW Custer and SW 55th Ave		✓				1. Two culverts at 8 and 18 in, 17 and 68 ft long, are expected to surcharge under the 2-year storm; the 68 ft long culvert is expected to have roadway flooding under the 100-year storm [T2]	
1-6	SW Multnomah near SW 58th Tributary 10180		✓				1. Two 12 in culverts (102 and 55 ft long) are expected to surcharge under the 2-year storm, the 102 ft long culvert is expected to have roadway flooding under the 100-year storm [T2]	
1-7	SW Garden Home near SW 60th Tributary 10180		✓				1. Two 12 in culverts (60 an d95 ft long) are expected to surcharge under the 10-year storm and have roadway flooding under the 100-year storm [T2]	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
R-2	**Reach 2 –** Begins below SW Multnomah Rd crossing and ends U/S of the SW Taylors Ferry Rd crossing		✓	✓	✓	✓	1. One culvert within the City is expected to surcharge under the 2-year storm; three culverts expected to surcharge under the 10-year storm [T2] 2. Nine stormpipes are expected to surcharge under the 2-year storm, six stormpipes are expected to surcharge under the 10-year storm [T2] 3. There are many culvert crossings in this reach that are passage barriers [T2] 4. The channel is constrained by terraces and hillslopes within a broad valley [T2] 5. Lack of wood [T2] 6. Pool area us relatively low and generally of poor quality [T2] 7. All other issues listed under 'Basin-Wide'	4. Development 5. Large wood appears to be transient and provides very little structural complexity 6. Fine sediments overlaying substrate
	Site Specific							
2-1	SW Multnomah Blvd - Upstream from April Hill Park		✓		✓		1. Fish passage potentially impaired [T2] 2. Stream connectivity is impaired [T2] 3. The 48 in (96 ft long) culvert is expected to surcharge under the 2-year design storm and have roadway flooding under the 10-year design storm [T2]	
2-2	SW Garden Home Rd		✓	✓	✓		1. Fish passage impaired- length of culvert is 170 ft [T2] 2. Stream connectivity is impaired [T2] 3. The 48 in (170 ft long) culvert is expected to surcharge under the 2-year design storm [T2] 4. The 15 in (72 ft long) culvert on a tributary near Garden Home Rd is expected to surcharge under the 2-year storm [T2] 5. The 12 in culvert (90 ft long) on a tributary near SW Garden Home is expected to surcharge under the 10-year storm [T2] 6. The 12 in culvert (100 ft long) on a nearby tributary is expected to surcharge under the 10-year storm [T2]	
2-3	SW 45th Ave		✓	✓	✓		1. Completely blocks resident fish movement into Woods Memorial Park (long culvert with 2-3 ft drop at the D/S end [T2] 2. Stream connectivity is impaired [T2] 3. The 36 in (325 ft long) culvert is expected to surcharge during the 2-year design storm [T2]	
2-4	SW Taylor's Ferry Rd		✓	✓	✓		1. Fish passage impaired – length of culvert is 170 ft [T2] 2. The 30 in (170 ft long) culvert is expected to surcharge during the 10-year design storm [T2] 3. The 12 in culvert (75 ft long) on a nearby tributary is expected to surcharge under the 10-year storm [T2]	
2-5	Near I-5 Crossing		✓	✓	✓		1. The 30 in culvert (260 ft long) is expected to surcharge under the 10-year storm [T2] 2. Culvert is a fish barrier at 260 ft long [T2]	
2-6	Near SW 49th Ave Tributary 07840		✓				1. Two culverts at 8 and 10 in which are 130 and 100 ft long, are expected to surcharge under 2-year storm [T2]	
2-7	SW 51st Ave Tributary 07840		✓				1. The 10 in culvert (20 ft long) is expected to surcharge under the 10-year storm and have roadway flooding under the 25-year storm [T2] 2. The 8 in culvert (80 ft long) is expected to surcharge under the 2-year and have roadway flooding under the 100-year storm [T2] 3. The 12 in culvert (52 ft long) is expected to surcharge under the 10-year storm [T2] 4. The 12 in culvert (30 ft long) is expected to surcharge under the 2-year storm [T2]	
2-8	SW Multnomah Blvd Tributary 07240		✓				1. Three 12 in culverts near SW Multnomah (35, 30 and 12 ft long) are expected to surcharge under the 10-, 2- and 2-year storms, respectively. [T2]	
2-9	SW Garden Home Tributary 06870		✓				1. The 12 in culvert (16 ft long) is expected to surcharge under the 10-year storm and have roadway flooding under the 100-year storm [T2]	
2-10	Driveway to garage near Tributary 05510		✓				1. The 6 in culvert (61 ft long) is expected to surcharge under the 2-year storm [T2]	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
2-11	SW 45th and SW Dolph St. Tributary 04735		✓				1. Three 12 in culverts (25, 21, and 42 ft long) are expected to surcharge under the 10-year storm and have roadway flooding under the 100-year storm [T2]	
2-12	SW Marigold St. Tributary 04060,		✓				1. The 8 in culvert (240 ft long) is expected to surcharge under the 2-year storm [T2] 2. Five 12 in culverts (25, 213, 200, and 50 ft long) are expected to surcharge under the 10-year storm [T2]	
2-13	Near SW 46th Dr Tributary 04160		✓				1. The 12 in culvert (60 ft long) at SW Brugger St is expected to surcharge under the 10-year storm [T2] 2. The 12 in culvert (25 ft long) is expected to surcharge under the 10-year storm [T2] 3. The 12 in culvert (40 ft long) is expected to surcharge under the 2-year storm [T2]	
2-14	East of SW 42nd Tributary 02775E		✓				1. The 10 in culvert (170 ft long) is expected to surcharge under the 10-year storm [T2]	
2-15	SW Woody Parkway Tributary 02775W		✓				1. The 12 in culvert (63 ft long) is expected to surcharge under the 10-year storm [T2]	

Woods Creek Subwatershed – Opportunities

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
	Basin-Wide							
1	Throughout the Subbasin		✓	✓	✓	✓	1. Numerous seeps and springs exist throughout the basin and provide for protection opportunities [T1] 2. Most riparian areas are considered good [T2] 3. Shade cover is 90-100% throughout much of the basin due to the high vegetation cover along much of the creek [T2] 4. Use outlets for information that currently exist (Website, SWNI, SW Watershed Center) [T2] 5. Encourage “Dump no waste” storm curb marker program [T2] 6. Support Friends of Woods Creek Park and programs for homeowners such as Naturescaping for Clean Rivers [T2] 7. Opportunity to protect streambanks are stable, indicating properly functioning conditions [T2]	
	Reach Summary							
R-1	**Reach 1**– Begins near the confluence of Fanno Creek and ends before the SW Multnomah Rd crossing Most of Reach 1 is outside the City boundary		✓	✓	✓	✓	1. The floodplains are intact and appear to be functioning; wetlands may be present (Hab. p. 16) [T2] 2. Large conifers and deciduous trees exist within this reach [T2] 3. Opportunity for protection of wildlife and riparian habitat – dammed pool, alcoves, backwater pools, and beaver ponds [T2] 4. All other issues listed under ‘Subbasin Wide”	
1-1	Near the Oregon Episcopal School			✓	✓	✓	1. Decent riparian conditions exist as well as numerous springs, seeps, and wetland habitat [T2]	
1-2	Near April Hills Park		✓	✓	✓		1. Open spaces provide opportunity for restoration [T2]	
R-2	**Reach 2 –** Begins below SW Multnomah Rd crossing and ends U/S of the SW Taylors Ferry Rd crossing		✓	✓	✓	✓	1. The floodplains are wider and intact in upper Woods Creek – headwaters (W3) at tributary confluences and lower portion between Multnomah Blvd. and Garden Home Rd. [T2] 2. Mature second growth mixed conifer forest exists within this reach and the riparian habitat in the headwaters of this reach is considered very good [T2] 3. Seeps and hyporheic flows appear intact and protected except at road embankments [T2] 4. Macroinvertebrate production has a high protection value; the riffle habitat supports epifaunal production (Hab. p. 19) [T2] 5. All other issues listed under ‘Subbasin Wide”	
2-1	Corridor between SW Multnomah and SW Garden Home Rd						1. Floodplain is intact - homes are set back outside the immediate stream corridor [T2]	
2-2	Headwaters						1. There is high vegetation cover along the creek [T2]	

North Ash Creek Subwatershed – Problems

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
	Subbasin-Wide							
1	Throughout the Subbasin	✓	✓	✓	✓	✓	1. Water Quality monitoring results indicated impaired water quality: a) Increased sediment loading and transport – **DATA GAP** [T1] b) Lack of shade in the middle and upper portions of the reach many areas with less than 50% – 75% shade cover [T1] c) High bacteria [T1] d) High nutrients potentially **DATA GAP [**T1] 2. Corridor is fragmented, riparian corridor is narrow, not extended beyond 10-20 m, Eroding banks within the middle reach area indicating 90-100% erosion (N. Ash ODFW Survey Map 1) [T2] 3. Pools are significantly aggrading with fines [T2] 4. Lack of large wood, abundance and volume low due [T2] 5. Lack of access to spawning and rearing habitat for fish: a) Completely blocked fish migrations [T2] b) Resident fish barrier [T2] c) Minimal floodplain connections [T2] 6. More staff hours are needed to coordinate BES revegetation cost shares on small private properties. Incentive requests exceed available resources for grants and revegetation cost shares [T2]	1. a) Upland urban area runoff and erodible banks – Data Gap b) Lack of vegetative cover c) Sewage, illegal sanitary connections, dumping, failing septic systems, animal wastes 3. Road and residential developments 4. Characteristic of significant sediment deposition; likely during storm flows resulting from conversion from pools to glides; some isolated areas of high bank erosion at 90-100% 5. Residential development, low vegetation coverage along most of stream and in upland areas 6. a) Nearly a quarter of the creek is piped, residential development, low vegetation coverage along most of stream and in upland areas b) Step/log (0.5 m high) spans creek just below Moonshadow Park c) Residential developments and urban landscaping practices
	Reach Summary							
R-1	**Reach 1**– Begins at Metzger Park at the confluence of South Ash Creek, and ends 100 m D/S of the SW Dolph crossing		✓	✓	✓	✓	1. Riparian habitat fluctuates widely from a wide buffer to no buffer [T2] 2. Lack of refugia [T2] 3. Parts of the stream act as a drainage ditch for Taylor's Ferry Rd [T2] 4. All other issues listed under 'Subbasin-Wide'	1. Development encroachment 2. Lack of wood, no tributaries, and no boulders
	Site Specific							
1-1	SW Ash St Model tributary NorthAsh_5430		✓				1. The 12 in culvert (23 ft long) surcharges under the 2-year storm and roadway flooding is expected under the 100-year storm [T2]	
1-2	Along SW 62nd Dr and 62nd Ave Model tributaries NorthAsh_4840 and NorthAsh_5930_1245 tributary		✓				1. The 12 in culvert (75 ft long) near SW Brugger St surcharges under the 10-year storm [T2] 2. The 12 in culvert (50 ft long) at a driveway near SW 62nd Dr surcharges under the 10-year storm [T2] 3. The 10 in culvert (48 ft long) at a driveway to 62nd surcharges under the 2-year storm and roadway flooding is expected under the 25-year storm [T2] 4. The 12 in culvert (70 ft long) at a driveway to 62nd surcharges under the 2-year storm and roadway flooding is expected under the 100-year storm [T2] 5. The 10 in culvert (290 ft long) near 62nd Dr surcharges under the 2-year storm and roadway flooding is expected under the 100-year storm [T2] 6. The 10 in culvert (48 ft long) at a driveway to 62nd Dr surcharges under the 10-year storm [T2]	
1-3	Main stem at SW Orchid Dr and Dolph Ct		✓	✓	✓		1. Fish passage barriers due to length of culverts [T2] 2. The 48 in culvert (172 ft long) at SW Orchid Dr surcharges under the 10-year storm [T2] 3. The 36 in culvert (106 ft long) surcharges under the 2-year storm, and roadway flooding is expected under the 100-year storm (SW Dolph Ct) [T2]	
1-4	SW Orchid St Model tributary NorthAsh_3920		✓				1. The 18 in culvert (130 ft long) near SW Orchid Dr surcharges under the 10-year storm [T2]	
1-5	Mainstem at SW Lancelot Dr			✓	✓		1. Fish passage barrier – 147 ft long [T2] 2. The 22 in culvert (147 ft long) surcharges under the 10-year storm [T2]	
1-6	Near SW 57th Model tributary NorthAsh_3205		✓				1. The 15 in culvert at SW 57th (236 ft long) surcharges under the 2-year storm [T2] 2. The 15 in culvert at SW Lancelot Ln surcharges under the 10-year storm [T2]	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
1-7	Mainstem at SW 55th			✓	✓		1. Fish passage barrier – culvert is 344 feet long [T2]	
R-2	**Reach 2 –** Begins 100 m D/S of the SW Dolph crossing and ends 10 m U/S of the SW 55th crossing		✓	✓	✓	✓	1. The channel is constrained in some areas [T2] 2. The sewer line transverses the channel in several places, many manholes located within the stream channel [T2] 3. Runoff from the streets drain directly into the stream via culverts [T2] 4. All other issues listed under 'Subbasin-Wide'	
	Site Specific							
2-1	Near SW 53rd Ave Model tributary NorthAsh_1645		✓				1. The 12 in culvert (59 ft long) surcharges under the 10-year storm and roadway flooding is expected under the 25-year storm [T2] 2. The 12 in culvert that parallels SW 53 rd (237 ft long) surcharges under the 2-year storm and roadway flooding is expected under the 25-year storm [T2]	
2-2	Model tributaries NorthAsh_1070 and NorthAsh_1355_Baird		✓				1. The 12 in culvert that runs parallel to 52nd (25 ft long) surcharges under the 2-year storm [T2] 2. The 12 in culvert that runs parallel to 52nd (29 ft long) surcharges under the 2-year storm and roadway flooding is expected under the 100-year storm [T2] 3. The 12 in culvert (66 ft long) surcharges under the 2-year storm (unknown driveway to Baird St) [T2] 4. The 12 in culvert (54 ft long) surcharges under the 2-year storm (unknown driveway to Baird St) [T2]	
2-3	Mainstem at SW 52nd		✓				1. The 30" culvert (30 ft long) surcharges under the 10-year storm [T2]	
2-4	Culvert parallel to SW 51st Model tributary NorthAsh_1070		✓				1. The 12 in culvert that runs parallel to 51st (26 ft long) surcharges under the 10-year storm and roadway flooding is expected under the 10-year storm [T2] 2. The 12 in culvert that runs parallel to 51st (228 ft long) surcharges under the 2-year storm and roadway flooding is expected under the 25-year storm [T2]	

North Ash Creek Subwatershed – Opportunities

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources
		Public Involvement	**Hydrology & Infrastructure**	**Physical Habitat**	**Biological Communities**	**Water Quality**		
	Subbasin-Wide							
1	Throughout the Subbasin			✓	✓		1. Wood – large roots wads observing within active channel likely providing roughness and potential residential fish cover [T2] 2. There are some areas of high vegetation cover in the lower reach [T2] 3. Riffles are abundant and of good quality [T2] 4. Some floodplain interaction [T2] 5. Little erosion – 26% of the banks are considered actively eroding [T2] 6. Protect riparian corridor width which is consistently 0-10 m with 58% tree canopy coverage [T2]	
2	Throughout the Subbasin	✓					1. Use outlets for information that currently exist (Website, SWNI, SW Watershed Council) [T2] 2. Encourage “Dump no waste” storm drain curb marker program [T2] 3. Need to foster new stewardship groups for North Ash Creek [T2]	
	Site Specific							
1-1	Riparian corridor between SW 52 and 57th		✓	✓		✓	1. Wooded SFR area provides relatively extensive tree canopy coverage that should be protected [T2]	

South Ash Creek Subwatershed – Problems

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
	Basin-Wide							
1	Throughout the Subbasin		✓	✓	✓	✓	1. Water Quality monitoring results indicate impaired water quality - High Toxins, nutrients, BOD, TSS, and pesticides - **DATA GAP** [T1] 2. Lack of wood; wood abundance/volume is low, key pieces are rare [T2] 3. Lack of shade [T1] 4. Lack of access to spawning and rearing habitat: a) Headwaters pool area is low, summer low flows - 0.01 cfs [T2] b) Poor riparian habitat and connection especially in the headwaters; homes often abut and cross creek, trails parallel creek, and an old pump station abuts the creek in the upper area [T2] 5. Headwaters area > 80% impervious [T1] 6. Fish passage barrier near an unnamed 'park' [T2] 7. Many sewer manholes in the creek channel [T2] 8. The channel is constrained in a few areas by terraces, areas in the lower end are the reach have been channelized [T2]	2. Residential development along much of the creek and in the upland areas 3. Low tree canopy coverage and development encroachment 4. Homes often abut and cross creek, trails parallel creek, and an old pump station abuts the creek in the upper portion of the reach 5. Data Gap 7. Transportation Corridor – I-5 and Barbur Blvd.
	Site Specific							
1-1	Near SW 65th Model tributary SouthAsh_4140		✓				1. The 12 in culvert (45 ft long) near SW 65th surcharges under the 10-year storm [T2]	
1-2	Near SW 64th Ave. Model tributary SouthAsh_3980_64th		✓				1. The 12 in culvert (200 ft long) along SW 64th surcharges under the 2-year storm [T2]	
1-3	Tributary to the main stem near SW 62nd Dr Model tributary SouthAsh_2475		✓				1. The 12 in culvert (180 ft long) at driveway near 62nd Dr. surcharges under the 2-year storm [T2]	
1-4	Mainstem at SW 62nd Dr		✓	✓	✓		1. 100 m long culvert is a fish passage barrier [T2] 2. Exposed sewer pipe 270 m downstream from SW 62nd Ave. [T2]	
1-5	Near SW 61st Ave Model tributary SouthAsh_3980		✓				1. The 24 in culvert (50 ft long) near SW 61st surcharges under the 10-year storm [T2]	
1-6	Mainstem at SW 57th Pl		✓	✓			1. The 18 in culvert (48 ft long) surcharges under the 2-year storm [T2]	
1-7	Main stem at SW 55th near SW Luradel		✓	✓			1. The 18 in culvert (115 ft long) surcharges under the 10-year storm [T2] 2. Impedes fish passage due to length [T2]	
1-8	Unnamed tributary from SW 50th near Alfred St to confluence to mainstem near SW Huddleson St. (downstream from SW 57th) Model tributary SouthAsh_2290		✓				1. The 12 in culvert (60 ft long) along SW 50th surcharges under the 10-year storm 2. The 12 in culvert (120 ft long) near SW Alfred surcharges under the 2-year storm and is expected to have roadway flooding under the 100-year storm 3. The 12 in culvert (448 ft long) along SW Alfred surcharges under the 2-year storm and is expected to have roadway flooding under the 100-year storm 4. The 12 in culvert (213 ft long) near SW 53rd surcharges under the 2-year storm and is expected to have roadway flooding under the 10-year storm 5. The 12 in culvert (82 ft long) near SW 55th surcharges under the 2-year storm and is expected to have roadway flooding under the 10-year storm 6. The 20 in culvert (70 ft long) near SW 57th surcharges under the 10-year storm 7. The 30 in culvert (175 ft long) near SW Huddleson St surcharges under the 10-year storm and is expected to have roadway flooding under the 10-year storm 8. The 24 in culvert (44 ft long) near driveway surcharges under the 10-year storm	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
1-9	Mainstem headwaters above SW 55th and below Barbur Blvd and SW Comus St Model tributary_982		✓	✓	✓		1. Culvert at SW 55th impedes fish migrations 2. The 12 in culvert (240 ft long) along SW Barbur Blvd surcharges under the 10-year storm 3. The 12 in culvert (80 ft long) along SW Barbur Blvd surcharges under the 2-year storm and is expected to have roadway flooding under the 25-year storm 4. The 24 in culvert (66 ft long) along SW Barbur Blvd surcharges under the 10-year storm 5. The 24 in culvert (30 ft long) near SW Comus surcharges under the 2-year storm and is expected to have roadway flooding under the 10-year storm 6. The 24 in culvert (140 ft long) surcharges under the 2-year storm	

South Ash Creek Subwatershed – Opportunities

ID#	**Site Location in the Watershed And ODFW Reach**	**Watershed Attributes**					**Opportunity Description**	**Preliminary Sources**	**Recommendations**
		Public Involvement	**Hydrology & Infrastructure**	**Physical Habitat**	**Biological Communities**	**Water Quality**			
	Basin-Wide								
1	Throughout the Subbasin	✓	✓	✓	✓	✓	1. Wood is present in pools and provides channel roughness [T2] 2. More survey data for fish abundance is needed – **DATA GAP** [T2] 3. Median bacteria concentration levels are below standards – much of the stream is protected by E-zones and P-zones [T2] 4. Riffle area is high and quality is good, cascades common, pools area good quality based on substrate, depth, and complexity – providing critical spawning grounds for resident fish [T2] 5. Good vegetation, crown ratio is relatively full/intact in immediate 30m corridor [T2] 6. Use outlets for information that currently exist (Website, SWNI, SW Watershed Center) [T2] 7. Encourage “Dump no waste” storm drain curb marker program [T2] 8. Encourage and support active stewardship groups - Friends of Dickenson, Crestwood Neighborhood Association and continue to provide support and foster new groups [T2]		
	Site Specific								
1-1	Above SW 55th		✓	✓	✓		1. Potential for restoration/protection in the large open spaces at Dickenson Park and Taylor Woods [T2]		
1-2	Central reach		✓	✓	✓	✓	1. Many areas with 90-100% shade cover [T2]		

Red Rock Creek Subwatershed – Problems

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
	Subbasin-Wide							
1	Throughout the Subbasin	✓	✓	✓	✓	✓	2. Water Quality monitoring results indicated impaired water quality: e) Increased sediment loading and transport – **DATA GAP** [T1] f) Lack of shade in the middle and upper portions of the reach many areas with less than 50% – 75% shade cover [T1] g) High bacteria [T1] h) High nutrients potentially **DATA GAP [**T1] 6. Corridor is fragmented, riparian corridor is narrow, not extended beyond 10-20 m, Eroding banks within the middle reach area indicating 90-100% erosion (N. Ash ODFW Survey Map 1) [T2] 7. Pools are significantly aggrading with fines [T2] 8. Lack of large wood, abundance and volume low due [T2] 9. Lack of access to spawning and rearing habitat for fish: d) Completely blocked fish migrations [T2] e) Resident fish barrier [T2] f) Minimal floodplain connections [T2] 7. More staff hours are needed to coordinate BES revegetation cost shares on small private properties. Incentive requests exceed available resources for grants and revegetation cost shares [T2]	1. a) Upland urban area runoff and erodible banks – Data Gap b) Lack of vegetative cover c) Sewage, illegal sanitary connections, dumping, failing septic systems, animal wastes 4. Road and residential developments 5. Characteristic of significant sediment deposition; likely during storm flows resulting from conversion from pools to glides; some isolated areas of high bank erosion at 90-100% 6. Residential development, low vegetation coverage along most of stream and in upland areas 7. a) Nearly a quarter of the creek is piped, residential development, low vegetation coverage along most of stream and in upland areas b) Step/log (0.5 m high) spans creek just below Moonshadow Park c) Residential developments and urban landscaping practices
	Reach Summary							
R-1	**Reach 1**– Begins at Metzger Park at the confluence of South Ash Creek, and ends 100 m D/S of the SW Dolph crossing		✓	✓	✓	✓	5. Riparian habitat fluctuates widely from a wide buffer to no buffer [T2] 6. Lack of refugia [T2] 7. Parts of the stream act as a drainage ditch for Taylor's Ferry Rd [T2] 8. All other issues listed under 'Subbasin-Wide'	3. Development encroachment 4. Lack of wood, no tributaries, and no boulders
	Site Specific							
1-1	SW Ash St Model tributary NorthAsh_5430		✓				2. The 12 in culvert (23 ft long) surcharges under the 2-year storm and roadway flooding is expected under the 100-year storm [T2]	
1-2	Along SW 62nd Dr and 62nd Ave Model tributaries NorthAsh_4840 and NorthAsh_5930_1245 tributary		✓				7. The 12 in culvert (75 ft long) near SW Brugger St surcharges under the 10-year storm [T2] 8. The 12 in culvert (50 ft long) at a driveway near SW 62nd Dr surcharges under the 10-year storm [T2] 9. The 10 in culvert (48 ft long) at a driveway to 62nd surcharges under the 2-year storm and roadway flooding is expected under the 25-year storm [T2] 10. The 12 in culvert (70 ft long) at a driveway to 62nd surcharges under the 2-year storm and roadway flooding is expected under the 100-year storm [T2] 11. The 10 in culvert (290 ft long) near 62nd Dr surcharges under the 2-year storm and roadway flooding is expected under the 100-year storm [T2] 12. The 10 in culvert (48 ft long) at a driveway to 62nd Dr surcharges under the 10-year storm [T2]	
1-3	Main stem at SW Orchid Dr and Dolph Ct		✓	✓	✓		4. Fish passage barriers due to length of culverts [T2] 5. The 48 in culvert (172 ft long) at SW Orchid Dr surcharges under the 10-year storm [T2] 6. The 36 in culvert (106 ft long) surcharges under the 2-year storm, and roadway flooding is expected under the 100-year storm (SW Dolph Ct) [T2]	
1-4	SW Orchid St Model tributary NorthAsh_3920		✓				2. The 18 in culvert (130 ft long) near SW Orchid Dr surcharges under the 10-year storm [T2]	
1-5	Mainstem at SW Lancelot Dr			✓	✓		3. Fish passage barrier – 147 ft long [T2] 4. The 22 in culvert (147 ft long) surcharges under the 10-year storm [T2]	
1-6	Near SW 57th Model tributary NorthAsh_3205		✓				3. The 15 in culvert at SW 57th (236 ft long) surcharges under the 2-year storm [T2] 4. The 15 in culvert at SW Lancelot Ln surcharges under the 10-year storm [T2]	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
1-7	Mainstem at SW 55th			✓	✓		2. Fish passage barrier – culvert is 344 feet long [T2]	
R-2	**Reach 2 –** Begins 100 m D/S of the SW Dolph crossing and ends 10 m U/S of the SW 55th crossing		✓	✓	✓	✓	5. The channel is constrained in some areas [T2] 6. The sewer line transverses the channel in several places, many manholes located within the stream channel [T2] 7. Runoff from the streets drain directly into the stream via culverts [T2] 8. All other issues listed under 'Subbasin-Wide'	
	Site Specific							
2-1	Near SW 53rd Ave Model tributary NorthAsh_1645		✓				3. The 12 in culvert (59 ft long) surcharges under the 10-year storm and roadway flooding is expected under the 25-year storm [T2] 4. The 12 in culvert that parallels SW 53 rd (237 ft long) surcharges under the 2-year storm and roadway flooding is expected under the 25-year storm [T2]	
2-2	Model tributaries NorthAsh_1070 and NorthAsh_1355_Baird		✓				5. The 12 in culvert that runs parallel to 52nd (25 ft long) surcharges under the 2-year storm [T2] 6. The 12 in culvert that runs parallel to 52nd (29 ft long) surcharges under the 2-year storm and roadway flooding is expected under the 100-year storm [T2] 7. The 12 in culvert (66 ft long) surcharges under the 2-year storm (unknown driveway to Baird St) [T2] 8. The 12 in culvert (54 ft long) surcharges under the 2-year storm (unknown driveway to Baird St) [T2]	
2-3	Mainstem at SW 52nd		✓				2. The 30" culvert (30 ft long) surcharges under the 10-year storm [T2]	
2-4	Culvert parallel to SW 51st Model tributary NorthAsh_1070		✓				3. The 12 in culvert that runs parallel to 51st (26 ft long) surcharges under the 10-year storm and roadway flooding is expected under the 10-year storm [T2] 4. The 12 in culvert that runs parallel to 51st (228 ft long) surcharges under the 2-year storm and roadway flooding is expected under the 25-year storm [T2]	

Red Rock Creek Subwatershed – Opportunities

ID#	**Site Location in the Watershed And ODFW Reach**	**Watershed Attributes**					**Opportunity Description**	**Preliminary Sources**
		Public Involvement	**Hydrology & Infrastructure**	**Physical Habitat**	**Biological Communities**	**Water Quality**		
	Subbasin-Wide							
1	Throughout the Subbasin			✓	✓		7. Wood – large roots wads observing within active channel likely providing roughness and potential residential fish cover [T2] 8. There are some areas of high vegetation cover in the lower reach [T2] 9. Riffles are abundant and of good quality [T2] 10. Some floodplain interaction [T2] 11. Little erosion – 26% of the banks are considered actively eroding [T2] 12. Protect riparian corridor width which is consistently 0-10 m with 58% tree canopy coverage [T2]	
2	Throughout the Subbasin	✓					4. Use outlets for information that currently exist (Website, SWNI, SW Watershed Council) [T2] 5. Encourage “Dump no waste” storm drain curb marker program [T2] 6. Need to foster new stewardship groups for North Ash Creek [T2]	
	Site Specific							
1-1	Riparian corridor between SW 52 and 57th		✓	✓		✓	2. Wooded SFR area provides relatively extensive tree canopy coverage that should be protected [T2]	

CHAPTER 17

Tryon Creek Watershed Problem and Opportunity Tables

INTRODUCTION

These tables compile problems and opportunities identified in the Tryon Creek watershed characterizations. Problems are categories into two broad categories, Tier 1 and Tier 2. Criteria for these two categories are listed below.

Tier 1 problems are:

1. Directly related to water quality.
2. Critical limiting factors identified in the characterization that impair ecological functions in the watershed.
3. Directly related to Endangered Species Act (ESA) listed species.
4. Well-characterized problems and sources with appropriate solutions. Benefits to watershed health are clear.

Tier 2 problems are:

1. Not directly related to critical limiting factors identified in the characterization that impair ecological functions of the watershed.
2. Non-critical culverts e.g., impassable fish culverts that exist upstream of other impassable culverts.
3. Problems ranked low in other studies or plans.
4. Poorly characterized problems and sources. Further analysis, data, and supporting documentation needed.

As Tier 1 problems are addressed some Tier 2 problems may be elevated to Tier 1 problems. For example, if the highway 43 culvert in Tryon Creek is replaced to allow fish passage, the upstream Boones Ferry Road culvert may be elevated from Tier 2 to Tier 1 because it becomes the next major fish barrier.

Opportunities are also divided into two tier categories. Criteria for these two categories are listed below.

Tier 1 Opportunities are:

1. Existing high value resource areas and assets. Particularly areas that will provide a clustering of positive watershed attributes.
2. Opportunities/Assets that help protect existing resource areas, improve Tier 1 problems, and help further objectives identified in the subwatershed and reach e.g., retain low-density residential development.
3. Opportunities that enhance habitat connectivity, particularly in areas that directly improve Tier 1 problems and help further objectives identified in the subwatershed and

reach.

4. All open drainageways, wetlands, seeps, and springs throughout the watershed, particularly in areas not currently protected in environmental zones.
5. Areas of relatively high vegetation cover not currently protected in environmental zones.

Tier 2 Opportunities are:

1. Opportunities/assets that improve Tier 2 problems.
2. Opportunities/assets to enhance habitat connectivity throughout the watershed that indirectly improve Tier 1 problems and further objectives identified in the subwatershed and reach.

Tryon Creek Subwatershed - Problems

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
1	Throughout the Basin	✓	✓	✓	✓	✓	1. Impervious surfaces and loss of trees in upper portions of the watershed increase storm water runoff volume and velocities. These conditions degrade downstream habitat, such as TCSNA. [T1] 2. Most storm pipes less than 12” in diameter are not included in the hydraulic model and are not evaluated in conveyance analysis. DATA GAP [T2] 3. Lack of channel complexity and roughness (wood and boulders) [T1] 4. Marginal habitat conditions - lack of high quality pool areas (deep, complex pools, with low fines), refuge, and instream structure (lack of wood volume and density and high fines) [T1] 5. Eroding banks throughout the watershed due to increased runoff volume from upland areas, lack of upland vegetation, upland imperviousness, and steep slopes [T1] 6. Low macroinvertebrate production [T2] 7. Diminishing bird populations – the Olive Sided Flycatcher and Piliated Woodpecker on the state’s vulnerable list [T2] 8. Degraded floodplains and poor connectivity [T1] 9. Water Quality monitoring results indicated impaired water quality. (a) Summer instream temperatures exceed the water quality standard of 64 degrees F for protection of salmonid rearing. Lack of shading in upper watershed areas is an important contributing factor [T1] (b) E. coli levels exceed water quality standard (406 counts/100 m.) in approximately 20 % of samples [T1]. (c) Instream bacteria concentrations higher in summer than winter and during runoff (rainfall) events [T1]. (d) Poor ranking on the Oregon Water Quality Index (OWQI) due to high levels of nutrients (TP, ammonia+nitrate nitrogen), total solids, and bacteria (fecal coliform) [T1]. (e) High silt and sediment loads and transport from upland urban areas; high phosphorus [T1]. (f) Water quality and habitat in lower reaches, such as TCSNA, is degraded by upstream sources like Interstate 5. Moreover, pollutants have a tendency to increase in concentration and accumulate in lower reaches of the watershed [T1]. 10. Incentive requests from residents exceed available resources for grants and revegetation cost shares [T2] 11. No Eco-businesses certified in the Tryon watershed (Automotive and Landscaping) [T2] 12. Some people perceive that citizen monitoring is not used by agencies [T2] 13. Current maintenance practices, such as street sweeping, may not be timed or frequent enough to remove accumulated pollutants on city streets [T1].	1. Impervious area cover is greater than 40% in Upper Tryon (mainly above I-5), vegetation loss is also the highest at this location due to extensive development. There are two major stormwater outfalls at the I-5 crossing contributing significant levels of various water quality pollutants. The GIS analysis identifies transportation corridors as major sources of pollutants (higher concentration than all other land use types)… 2. DATA GAP 3,4. Lack of wood and boulders 4,5, 9d, 9e. Eroding streambanks especially in Upper TCNA, below I-5, and near SW Maplecrest Dr. Sources include: vegetation/tree removal along the riparian areas, landscaping to the edge of creek, stormwater outfalls discharging into the segment (quick delivery of stormwater), stormwater volumes and velocities resulting from high impervious areas, soil disturbance due to placement of infrastructure, etc. 6. Lack of substratum, toxins, a lack of plant diversity and transportation runoff with degraded water 7. Toxins, predators, invasive plants, and fire suppression 8. High development within floodplain (especially within the I-5/Barbur Blvd Corridor) 9a.Temperature: Low canopy on stream reaches 4 and 5, low summer flows, lack of groundwater recharge, pools within lower TCNA, wide stream channels, low water depths. 9b-e. Elevated bacteria concentration: potential sources: Non-point sources (pets, wildlife) faulty septic systems, potential cross-connections, sanitary system leakage, horses within the park, and 48% TSS contribution from I-5/Barbur Blvd corridor. High nutrients due to the transportation corridor especially I-5/Barbur Blvd, landscape practices, soil erosion, and sewage 13. Coordination with Maintenance Bureau

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
2	**Citizen Identified – near Marshall Cascades**						Erosion control urgently needed in the Marshall Cascades and in the makeshift tributary crossings SW of Maplecrest Dr. in park trails. There are impervious surface area concerns in recent in-fill development near Marshall Park [T2].	
	Reach Summary							
R-1	**Reach 1**– Confluence: Mouth of Tryon Creek to above State St. Culvert. (Not within City Boundary)		✓	✓	✓	✓	1. Degraded floodplains and poor connectivity: incised banks, development, and steep bank slopes [T1] 2. Narrow riparian corridor throughout due to development. Trees are also small and not a significant wood source [T1] 3. Lack of spawning and rearing habitat for fish: a) Lack of instream structure, long deep pools with high deposition, erosive flows scour and transport wood and rock into the Willamette [T1] b) High silt loads cover 100% riffle habitat (at least by 25%) and fill pools (a depositional area), lack of sources of LWD and ability for the creek to retain key pieces [T1] 4. Water Quality Impaired: High nutrients levels from landscaping and agricultural practices; shade at 67% [T1] 5. All other issues listed under 'Basin-Wide' 6. State street culvert is a fish barrier to Coho, Steelhead and Cutthroat most times of the year [T1]	1, 2. Imperviousness 23% (Eng. Services) and locale of highly developed areas 1, 3a. Most land areas > 26% slope All problems potentially related to the following findings listed within the ODFW Summary: Actively eroding banks @ 69% 25% silt/organics content 35% gravel 47% scour pools 20% riffle habitat Valley width index is 20.0
	Site Specific							
1-1	Highway 43 (State St)		✓	✓	✓		1. Culvert is a fish barrier due to its length (i.e., 200 feet long with a formidable slope and jump into the outlet), if this culvert were navigable, 2.6-rivermiles (up to Boones Ferry Rd) of relatively good habitat would become accessible to anadromous and resident fish [T1]	Length, slope, and jump exceed requirements for fish
1-2	Confluence of Tryon Creek with the Willamette River			✓	✓	✓	1. Grasses are dominant riparian vegetation, lack of conifers, hardwoods are small (15-30 cm dbh). Tree canopy cover is 50% from 0-10 m, 0-20% beyond [T1]	
R-2	**Reach 2** –Begins at the Lower Canyon State St. culvert to Nettle Creek confluence		✓	✓	✓	✓	1. More than half of the riffle habitat has 12-25% fines and organics (marginal fish habitat) [T1]. 2. Low wood and no key pieces; recruitment and/or retainment of large pieces is low, flows transport downstream, fine sediments overlay entire stream bed [T1] 3. Narrow floodplain, terraces are isolated and few, stormwater/sewer pipe runs parallel to Tryon Creek, within the immediate riparian corridor and floodplain ~ 325 m [T1] 4. Water quality monitoring station at Boone's Ferry Rd shows exceedances of some water quality standards. High TSS pervasive throughout Middle reaches of Tryon mainstem – a depositional area [T1]. 5. All other issues listed under 'Basin-Wide'. Impervious area is not extensive in the immediate area. However, impervious surfaces in the upper watershed impact this reach.	1, 2. Slopes in uplands generally >26% (GIS slope map) 5. Imperviousness only 8% (Eng. Services) All problems potentially related to the following findings listed within the ODFW Summary: Equal parts fines, gravels, & cobbles Large wood volume is 2.8 m^3/100m 17% riffle habitat(65% are >12% & <25%) Valley width index is 4.3
	Site Specific							
2-1	Tributary to Nettle Creek along SW Timberline Dr		✓				• The 12 in culvert (866 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 100-year storm [T2]	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
R-3	**Reach 3** – Begins at the Nettle Creek confluence and ends at the Arnold Creek tributary junction (near the Boones Ferry culvert)		✓	✓	✓	✓	1. Most banks 80-100% eroding, and streambanks have been channelized throughout [T1] 2. Narrow floodplain, creek is bound by terraces, minimal interactions floodplain/creek. Terraces are bound on both sides of creek, creating a funnel by which flows must overtop before the creek can interact with the riparian corridor and floodplain [T1] 3. T3A only 21% riffles with <21% fines; T3B low riffle area with high % fines (a depositional area); pools fill with sediments [T1] 4. Large wood is present but low in abundance, volume, and no key pieces: density is especially low in the middle of the reach; high flows transport most wood [T1] 5. Fish passage impeded by the Boones Ferry culvert for Coho, Steelhead, and Cutthroat [T1] 6. All other issues listed under 'Basin-Wide'. Impervious area is not extensive in the immediate area. However, impervious surfaces in the upper watershed impact this reach. 7. No Eco-business certified in Tryon watershed [T2]	1,4. Steep slopes in uplands (GIS slope map) 5. The Boones Ferry culvert is considered impassable; it is perched and long All problems potentially related to the following findings listed within the ODFW Summary: Actively eroding banks @ 60% Large wood volume @ 3.2m/100m Equal parts fines, gravels, & cobbles 57% scour pools 29% riffles Valley width index is 9.2
3-1	SW Boones Ferry Rd Model tributary 4840		✓				1. The 18 in culvert (79 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 25-year storm [T2]	
3-2	SW Orchard Hill Rd and Boones Ferry Rd Model tributary 4840		✓				1. Three stormpipes within this tributary are expected to surcharge under the 2-year storm [T2]	
3-3	SW Boones Ferry Rd Model tributary 4840		✓				1. The 21 in culvert (158 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 100-year storm [T2] 2. The 18 in culvert (53 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 2-year storm [T2]	
3-4	SW Boones Ferry Rd near the confluence to the main stem - Model tributary 4840		✓				1. The 24 in culvert (75 feet long) is expected to surcharge under the 2-year storm [T2]	
Reach 4								

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
R-4	**Reach 4** – Upper Tryon Creek, begins at Arnold Creek confluence to Taylor's Ferry Rd (Falling Creek Confluence)		✓	✓	✓	✓	1. Erosive flows scour stream-bed, pushing bars (and bed form) downstream. Impervious areas in the upper watershed contribute to this problem [T1]. 2. Maplecrest Dr to Marshall Park, low wood density; Marshall Park to 18th Pl – low wood count and density [T2] 3. Channel incision immediately below Maplecrest Dr; Poor fish habitat, riffle habitat impaired by fines; riffle habitat impaired by fines, good pool area but most shallow and poor complexity; no information on habitat conditions for above 18th Pl - [T2] **DATA GAP** 4. Pool forming process is not in balance, flows are moving swiftly through this reach - low settleable solids, fines overlay creek bed [T2] 5. Bank erosion is high at 58%, instream structure is lacking [T2] 6. Riparian habitat ranges from fair to poor [T2] 7. Floodplain is disturbed, particularly along NE side of the creek – between Maplecrest Drive to Marshall Park; narrow, floodplain disconnected – T4C; floodplain information lacking above 18th Pl – [T2] **DATA GAP** 8. Recruitment of wood into the creek is low [T2] 9. Lack of large trees and tree canopy cover, numerous areas with <50% shade – may need to evaluate forest type composition and wetland species in the riparian corridor [T2] 10. All other issues listed under 'Basin-Wide' 11. No Eco-business certified in Tryon watershed [T2]	1. No groundwater rechargeand imperviousness 28% (Eng. Services) 2. LWD 3. DATA GAP 4. 5. 6. Homes and landscaping practices encroach on the stream channel in portions of the reach. 7. DATA GAP 8. No old trees within the surrounding area 9. Shade 85%
	Site Specific							
4-1	Mainstem at SW Lancaster Rd		✓	✓	✓	✓	1. The 48 in culvert (42 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 2-year storm [T2] 2. Fish Barrier 3. Bank erosion 4. High imperviousness	
4-2	Mainstem at SW 18th Pl Jensen Natural Area (Portland Parks)		✓				1. The 72 in culvert (48 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 25-year storm [T2] 2. Fish Barrier 3. Bank Erosion 4. Invasive plants (Japanese Knotweed, English Hawthorne, Holly, Clematis)	
4-3	Mainstem at SW Boones Ferry Rd		✓				1. The 60 in culvert (180 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 2-year storm [T2] 2. Fish Barrier due to its length	
4-4	Model tributary 2057 along SW Dolph Ct		✓				1. The 18 in culvert (215 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 10-year storm [T2]	
4-5	Model tributary 2057 near SW Marigold St		✓				1. The 24 in culvert (132 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 25-year storm [T2]	
4-6	Model tributary 2057 near SW 23rd St		✓				1. The 30 in culvert (114 feet long) is expected to surcharge under the 2-year storm [T2]	
4-7	Model tributary 2057 near SW 18th St		✓				1. The 24 in culvert (85 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 100-year storm [T2]	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
4-8	Model tributary 1528 near SW Huber St		✓				1. The 12 in culvert (259 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 2-year storm [T2] 2. The 18 in culvert (177 feet long) is expected to surcharge under the 2-year storm [T2] 3. The 18 in culvert (265 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 100-year storm [T2]	
4-9	Model tributary 1528 near SW Lancaster Pl		✓				1. The 24 in culvert (95 feet long) is expected to surcharge under the 2-year storm [T2]	
4-10	Model tributary 2404 near SW Maplecrest Dr		✓				1. The 24 in culvert (40 feet long) is expected to surcharge under the 2-year storm [T2]	
4-11	Foley-Baumer Natural Area (Portland Parks)		✓	✓		✓	1. Downcutting and sedimentation in stream [T2] 2. Invasive plants (Ivy, Japanese Knotweed, Reed Canary grass, Clematis, Blackberry) [T2]	
4-12	Marshall Park (Portland Parks) SW 18th			✓	✓		1. Invasive plants (mainly Ivy) 2. Trail alignment cause erosion 3. Off-leash dog walking causes erosion	
R-5	**Reach 5** – Headwaters above Taylor's Ferry Rd (Falling Creek) and Carson St		✓	✓	✓	✓	1. Five areas identified as having potentially erodible open channel [T2] 2. Lack of tree canopy and narrow riparian zones does not buffer stream channels [T2] 3. Connectivity: highly fragmented but islands exist between Carson St and Dolph St [T2] 4. No information on floodplain interactions – **DATA GAP** 5. All other issues listed under 'Basin-Wide' 6. No Eco-business certified in Tryon watershed	1-3. Steep slopes and little vegetation cover (GIS Maps) 2. Imperviousness 46% (Eng. Services) 4. DATA GAP
	Site Specific							
5-1	Mainstem along SW Carson		✓	✓			1. The 24 in culvert (43 feet long) is expected to surcharge under the 2-year storm [T2] 2. The 42 in culvert (27 feet long) is expected to have roadway flooding under the 2-year storm [T2]	
5-2	Mainstem along SW Spring Garden St		✓	✓			1. The 24 in culvert (35 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 100-year storm [T2] 2. The 24 in culvert (65 feet long) is expected to surcharge under the 2-year storm [T2]	
5-3	Mainstem at SW Dolph Ct		✓	✓	✓		1. The 36 in culvert (280 feet long) is expected to surcharge under the 2-year storm [T2]	
5-4	Tributary to Tryon Main at SW 33rd and Marigold St (Tryon Headwaters Natural Area)		✓	✓	✓	✓	1. Stream cuts through private property and is degraded before entering Portland Parks property [T2] 2. Wetland area is of low value [T2]	
5-5	Tryon Mainstem along SW 26th immediately downstream of I-5	✓	✓	✓	✓	✓	1. Confluence of various stormwater sources (piped main stem, I-5 runoff, unnamed drainage ditch) create private property problems (erosion), high flows and severely lowered water quality [T1] 2. The 48 in culvert (139 feet long) is have roadway flooding under the 100-year storm [T2] 1. The 48 in culvert (66 feet long) is expected to surcharge under the 2-year storm and have roadway flooding under the 100-year storm [T2] 2. High imperviousness, TSS, TP [T1] 3. The 139 foot long culvert is a fish barrier [T2]	

Tryon Creek Subwatershed - Opportunities

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources	Recommendations (Placeholder)
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality			
1	Throughout the Subbasin	✓	✓	✓	✓	✓	1. Hydrologic/Hydraulic Opportunities include [T1]: a) Flow augmentation in summer for intermittent streams in reaches 4 and 5 b) Riparian groundwater levels (to maintain riparian functions, biological communities, and fauna) c) Channel configurations (meanders and morphology) d) Springs, seeps, and hyporheic areas greatest in T3B 2. Add "Tryon Creek Watershed" signs "Tryon Creek Watersheds" at creek crossings for Watershed Awareness [T2] 3. Encourage "Dump no waste" storm drain curb marker program [T2] 4. Support active stewardship groups – continue to provide support and foster new groups (Friends of Arnold Creek, Tryon Creek Watershed Council, Friends of Tryon Creek State Park, and Portland Parks Natural Areas) [T1] 5. Support Friends of TCSP in their efforts their efforts to eradicate non-Native plants [T1] 6. Overall, Tryon Creek provides habitat from the Confluence with the Willamette up to the Marshall Cascades. Retrofitting two impassable culverts would open up much habitat for anadromous fish [T1]. 7. Opportunity to coordinate and collaborate with Watershed Council [T1] 8. Opportunity to coordinate and collaborate with Active neighborhoods [T1] 9. Opportunity to work with individual property owners to enhance streamside habitat [T2]. 10. Support/Coordinate with completion of the City's update to its Environmental Land Use Planning Program including the Bureau of Planning's work to update the City's existing environmental zones and codes [T1] 11. Support/Encourage/Facilitate restoration of riparian areas along streams in the watershed [T1] 12. Educate citizens about the importance of healthy, small intermittent and headwater streams and watersheds [T1] 13. Land acquisition [T2] a) Open areas within the corridors of the reaches 4 and 5 b) Tree canopy intact near Marshall Park c) Water quality facilities near transportation outfalls - Detention pond between Barbur Blvd and I-5. d) Recharge areas in reaches 4 and 5 e) Sparse development within corridor f) Low density areas g) Intact channels - corridor is greater than 100 ft wide from Marshall Park to 18th Pl h) Add easements below I-5 in order to widen it out, thereby removing imperviousness	1. a. Detention facilities? b. groundwater recharge techniques? c. Logs, gabions, or weirs can be used to redirect streamflow and to collect sediment and create meanders, thereby lengthening the stream channel d. Need for protection/restoration on site specific basis 2,3. Goal 2 -Public outreach strategies are to be developed to inform citizens about pollutants they can minimize through behavioral change. 4. Goal 7 -Stewardship – Maintain long-term community-wide commitment to improve and sustain overall watershed health. 5. Some streamside areas are lined with blackberries 6. Access above key culverts would improve habitat in terms of deep pools, complex pools, good riffle habitat, and instream structure 7-9 Coordination to combine efforts for overall watershed health 13. Placeholder, specific locations to come out of characterization process.	- There is an opportunity to develop a correlation between imperviousness and high velocity areas to determine the relationship between the two parameters.
	Reach Summary								
R-1	**Reach 1–** Confluence: Mouth of Tryon Creek to above State St. Culvert. (Not within City Boundary)		✓	✓	✓	✓	1. Opportunity to improve street ditch maintenance practices in the upland areas [T1] 2. Opportunity to create off-channel habitat on the Metro owned land at the mouth of Tryon. BES and Lake Oswego can work together to restore the riparian area at the Tryon confluence as well [T2]. 3. All other issues listed under 'Basin-Wide'	2. Work with the City of Lake Oswego to develop a plan to restore riparian areas on publicly owned lands near the mouth of Tryon Creek, specifically for off-channel habitat.	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources	Recommendations (Placeholder)
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality			
R-2	Reach 2 –Begins at the Lower Canyon State St. culvert to Nettle Creek confluence		✓	✓	✓	✓	1. Specific habitat opportunities within this reach are at Beaver ponds that likely detain stormwater, attenuate stream flow and create areas of hyporheic flow [T2] 2. Opportunity to protect riparian habitat in general within TCSNA– support Friends of TCSP restoration activities, expand E-zones [T1] 3. Wood present but densities are low in the lower canyon including lower TCSNA [T1] 4. Opportunity for enhancing floodplain functions with potential sources of LWD within TCSNA [T1] 5. Opportunity to consolidate alluvial materials and reduce velocities through in-channel planting, channel flow redirection, and velocity reduction techniques [T1] 6. Opportunity to create off-channel and slack water habitats near stream (high (flashy) stormflows flush eggs fry, juveniles, and adults from system) [T1] 7. Nettle Creek is a barrier free tributary, winter refugia assessment is opportunity DATA GAP 8. Pool area and quality are good, deep pools are present, gravels good, but with high fines [T1]. 9. All other issues listed under 'Basin-Wide'	2. Riparian width is greater than 200 ft and is continuous, includes large trees 3. The floodplain is narrow but surveys show Creek interacts with floodplain more than typical urban streams 4. Opportunity to protect existing tree canopy, which is composed of some large trees (50-90 dbh).	1. Enforce e-zone regulations, and revegetate stream banks 2. Support Friends of TCSP in their efforts their efforts to eradicate non-Native plants
R-3	Reach 3 – Begins at the Nettle Creek confluence and ends at the Arnold Creek tributary junction (above the Boones Ferry culvert)		✓	✓	✓	✓	1. Assist with the acquisition of the Englewood Property (an open area that provides the opportunity to protect seeps, springs, and hyporheic functions) [T1] 2. Beaver ponds likely detain stormwater, attenuate stream flow and create areas of hyporheic flow [T1] 3. Red Fox Creek, Palatine Hill and Park Creek are barrier-free tributaries [T1] 4. Opportunity to protect vegetation. Key pieces of wood present in-stream and intact tree cover provides long-term source of large wood [T1] 5. All other issues listed under 'Basin-Wide'		
R-4	Reach 4 – Upper Tryon Creek, begins at Arnold Creek confluence to Taylor's Ferry Rd (Falling Creek)		✓	✓	✓	✓	1. Support Portland Parks efforts to eradicate invasive and non-Native plants, relocate trails away from springs in Marshall and Foley-Baumer Parks. [T1] 2. Opportunity for public involvement at 17th and Taylor's Ferry (TCWC) for swale project [T1] 3. Opportunity to protect in-stream habitat. pool area is desirable, deep pools are present, beaver ponds are present, good riffle gravels, EDT indicates preservation and enhancement of TCSNA will enhance fish productivity [T1] 4. Opportunity to increase habitat accessible to fish by opening up key culverts. In-stream habitat includes deep pools, complex pools, good riffle habitat, and instream structures [T1] 5. Tributary at TCSNA and Marshall Park provides significant floodplain zone [T2] 6. All other issues listed under 'Basin-Wide' 7. Quail Creek corridor is designated "high priority" by Tryon Creek Watershed Council for stewardship activities [T1] 8. Opportunity to encourage private land owners to use Naturescaping techniques, through theTryon Creek Watershed Council [T1] 9. Opportunity to partner with Portland Parks at Foley-Baumer Natural Area to stabilize streambanks and remove invasive vegetation [T1] 10. Opportunity to partner with Portland Parks at Jensen Natural Area to remove invasives and plant natives in riparian and upland areas. [T1] 11. Opportunity to partner with Portland Parks at Marshall Park which needs the master plan, signs, trail realignment and invasive plant removal. [T1]		2. Early Action Listed

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources	Recommendations (Placeholder)
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality			
R-5	Reach 5 – Headwaters above Taylor's Ferry Rd (Falling Creek) and Carson St		✓	✓	✓	✓	1. Detention pond between Barbur Blvd and I-5. [T1] 2. Encourage Revegetation Cost Share and SOLV in the fragmented areas between Carson St and Dolph Ct [T1] 3. Open up culverts at I-5 and Barbur Blvd for deep pools, complex pools, good riffle habitat and instream structure [T2] 4. Add easements below I-5 in order to widen it out, thereby removing imperviousness [T1] 5. All other issues listed under 'Basin-Wide' 6. Opportunity to partner with Portland Parks Natural Area program at Tryon Creek Headwaters site for Wetland Enhancement, stream alignment, and erosion issues, providing in-stream wood and outreach to neighbors [T1] 7. Aquire property to treat, detain, and infiltrate I-5 runoff. [T1]		

Arnold Creek Subwatershed - Problems

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
	Basin-Wide							
1	Throughout the Subbasin	✓	✓	✓	✓	✓	1. Water Quality monitoring results indicated impaired water quality a) High TSS [T2] b) Increased summer temperature from lack of shade [T1] c) High nutrients [T2] 2. Eroding banks throughout the basin [T1] 3. Diminish potential for floodplain interactions 4. Poor channel condition and lack of spawning and rearing habitat for fish: a) Habitat considered suboptimal, Lack of channel complexity due to channel undercutting and low wood [T2] b) Riffle habitat embedded with fines due to local and upstream bank erosion and steep slopes 5. Lack of Shade – **DATA GAP** [T1] 6. Lack of wood, low wood volume and densities [T2] 7. Lack of access to spawning and rearing habitat (see reach wide discussions) [T2] 8. Incentive requests from the public exceed available resources for grants and revegetation cost shares [T2]	1. a) Increased sediment loading from upland urban areas and erodible banks b) concentrated lack of vegetation in middle and lower portions of this reach c) Landscape practices, soil erosion and sewage. 2. .Increased runoff volume from upland areas, steep slopes, low vegetation, moderate root density, and a preponderance of sand and silt in stream channel. 3. Narrow floodplains and steep slopes 4. a) there is an absence of complex pools limiting quality of fish bearing habitat b) Local and upstream bank erosion and steep slopes 5. Low tree canopy cover and lack of medium and large sized trees except near headwater reaches 6. Residential development and low vegetation cover
	Reach Summary							
R-1	**Reach 1**– Begins at the confluenc of Tryon Main stem and ends just upstream from a tributary confluence on private land (just east of SW 31st)		✓	✓	✓	✓	1. Narrow riparian corridor in a few areas [T2] 2. Poor channel condition and lack of spawning and rearing habitat for fish: a) Numerous incised channels [T2] b) Lack of channel complexity due to channel undercutting [T2] c) Habitat considered suboptimal, there is an absence of complex pools limiting quality of fish bearing habitat [T2] d) Riffle habitat embedded with fines due to local and upstream bank erosion and steep slopes [T2] e) Cascades are present at the upper end of reach at the 16th Pl culvert [T2] 3. All other issues listed under 'Basin-Wide'	1. Proximity of SW Arnold Rd 2. d) Local and upstream bank erosion and steep slopes
	Site Specific							
1-1	Mainstem along Arnold Rd 1056 SW Arnold Rd Culvert 11005 SW 16th Pl Culvert 1824 SW Arnold Rd Culvert		✓	✓	✓		1. The 48 in culvert (79 ft long) at SW 16th is expected to surcharge under the 2-year storm and have roadway flooding under the 10-year storm [T2] 2. The culverts near SW 11th and at SW 16th are fish barriers because of velocity and they are perched [T2] 3. The 48 in culvert (43 ft long) along Arnold Rd near SW 11th is expected to surcharge under the 10-year storm and have roadway flooding under the 25-year storm [T2] 4. The 48 in culvert (39 ft long) culvert along Arnold Rd is expected to surcharge under the 2-year storm [T2] 5. Arnold cascades are seasonally impassable [T2]	
1-2	10921 SW Lancaster Rd		✓	✓	✓		1. Fish passage barrier (length, perched) [T2] 2. The 48 in culvert (150 ft long) is expected to surcharge under the 10-year storm and have roadway flooding under the 10-year storm [T2]	
1-3	Tributary to Arnold Mainstem Model tributary Arnold_1128 Confluence is just downstream from SW 31st on private land		✓	✓		✓	1. Trails are slick, erosion, illegal dumping, and sewer line road need revegetation near the West Portland Park Natural Area at SW 39th and Pomona and the Kerr Site at SW 35th and SW Stephenson [T2] 2. The 18 in culvert (45 ft long) along Icarus Loop Dr is expected to surcharge during the 2-year storm and have roadway flooding during the 100-year storm [T2] 3. The 22 in culvert (45 ft long) along Icarus Loop Dr is expected to surcharge under the 10-year storm and have roadway flooding during the 25-year storm [T2] 4. The 20 in culvert (60 ft long) along SW Walking Woods Dr is expected to surcharge under the 2-year storm and have roadway flooding under the 100-year storm [T2]	

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
1-4	Tributary to Arnold Mainstem Model tributary Arnold_1116 Confluence is just downstream from SW 31st on private land		✓	✓	✓		1. The 18 in culvert (20 ft long) is expected to surcharge under the 10-year storm and have roadway flooding under the 10-year storm [T2] 2. The 24 in culvert (120 ft long) near SW 35th is expected to surcharge under the 10-year storm [T2] 3. The culvert near SW 35th is a fish barrier due to its length [T2] 4. The 18 in culvert (85 ft long) at SW 33rd is expected to surcharge under the 2-year storm and have roadway flooding under the 2-year storm [T2]	
R-2	Above SW 31st - Headwaters							

Arnold Creek Subwatershed – Opportunities

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunities Description	Preliminary Sources	References
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality			
	Basin-Wide								
1	Throughout the Subbasin	✓	✓	✓	✓	✓	1. Some boulders are present in the basin which may provide critical cover and refuge during high flows, good riffle-pool sequence, good pool area [T2] 2. Lower 1/3 of Arnold Creek likely provides refuge and additional habitat to rearing fish Need signs at creek crossings for Watershed Awareness [T2] 3. Encourage "Dump no waste" storm drain curb marker program [T2] 4. Support stewardship active stewardship groups – continue to provide support for the Friends of Arnold Creekand Maricara Natural Area Volunteers [T2]		
	Reach Summary								
R-1	**Reach 1**– Begins at the confluence of Tryon Mainstem and ends just upstream of a tributary confluence on private land (just east of SW 31st)		✓	✓	✓	✓	1. High riparian quality, widths greater than 100 (Hab p. 16). [T2] 2. Good floodplain interactions at the confluence [T2]		
	Site Specific								
1-1	Mainstem from Lancaster Rd to 31st Ave		✓	✓	✓	✓	1. Several flats interspersed with steep hillsides provide for good floodplains and connections [T2] 2. Shade is 90-100% [T1] 3. High potential for revegetation and landowner education and educational tours (TCWC) [T1]. 4. Opportunity to partner with Portland Parks at Maricara Natural Area for replacement of eroding trail systems invasive plant removal and wetland enhancement [T2].		
R-2	**Reach 2** - Begins at 31st Ave and ends at 35th Ave			✓	✓	✓	1. Riparian canopy is mixed but mostly intact (Hab p. 18) [T1] 2. High potential for ivy removal and involvement with proposed development plans (TCWC) [T2] 3. Opportunity to partner with Portland Parks at the Kerr Site for enhancement projects [T1]		

Falling Creek Subwatershed – Problems

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Problem Description	Preliminary Sources
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality		
	Basin-Wide							
1	Throughout the Subbasin	✓	✓	✓	✓	✓	1. Narrow floodplains and riparian coverage is fragmented [T2] 2. Lack of detailed information on channel conditions and habitat structure - **DATA GAP** [T2] 3. A large number of apartments close to the stream corridor [T2] 4. Taylors Ferry Rd and SW 35th Dr parallel the stream at distances between 100 and 300 feet. [T2] 5. A significant portion of the stream channel is buried (culvert) under Jackson Middle School play fields [T1] 6. Lack of shade [T1] 7. Poor channel condition and lack of spawning and rearing habitat for fish: a) Lack of significant refugia to resident fish [T2] b) No tributaries converge with Falling Creek [T2] 8. Water Quality monitoring results indicated impaired water quality a) Increased sediment loading and transport [T1] b) High bacteria during summer and rainfall events; [T1] c) High nutrient levels [T1]	1. Residential development, subsequent lack of shade throughout 2. Data Gap 3. Runoff from I-5 Corridor 4. a) Watershed is largely SFR, MFR and shallow conduits exist along most of the main stem b) sewage, illegal septic systems, animal wastes c) High development and imperviousness along the I-5 Corridor
	Citizen Identified							
2	Upper Falling Creek						1. Upper Falling Creek is channelized with steep, non-vegetated banks [T2].	
	Site Specific							
1-1	Near I-5 and Barbur Blvd crossings Model tributary 2300		✓				1. Three 36 in culverts (250 ft, 120 ft, and 294 ft long) are expected to surcharge under the 10-year storm [T2]	
1-2	SW 35th Dr Culverts and embankment		✓	✓	✓		1. Significantly disrupts the riparian area [T2] 2. Connectivity and resident fish passage ends at this culvert [T2] 3. Two 24 in culverts (630 ft and 387 ft long) are expected to surcharge and have roadway flooding under the 2-year storm [T2]	
1-3	SW Hubert St.		✓				1. The 36 in culvert (80 ft long) at SW Hubert St is expected to surcharge under the 2-year storm and have roadway flooding under the 25-year storm [T2]	
1-4	Jackson Middle School		✓	✓	✓		1. Fish Barrier – stormpipe is very long 1300' [T2] 2. Loss of Habitat Connectivity [T2]	
1-5	Along SW Pomona St and near Comus St		✓				1. The 24 in culvert (20 ft long) is expected to surcharge under the 2-year storm and roadway flooding is expected under the 2-year storm [T2] 2. The 24 in culvert (40 ft long) is expected to surcharge under the 2-year storm and roadway flooding is expected under the 2-year storm [T2] 3. The 36 in culvert (20 ft long) along SW 39th Ave is expected to have roadway flooding under the 25-year storm [T2]	
1-6	Along SW 47th Ave Along SW Pasadena St		✓				1. Two 15 in culverts (each 285 ft long) are expected to surcharge under the 10-year and 2-year storm events, respectively [T2]. 2. The 15 in culvert (285 ft long) on SW 47th is expected to surcharge under the 2-year storm event and roadway flooding under the 2-year storm event [T2] 3. The 18 in culvert (299 ft long) on SW Comus Pl is expected to surcharge under the 2-year storm event and roadway flooding is expected under the 100-year event [T2]. 4. The 15 in culvert (420 ft long) is expected to surcharge under the 2-year storm and roadway flooding is expected under the 2-year storm [T2] 5. The 18 in culvert (295 ft long) is expected to surcharge under the 2-year storm and roadway flooding is expected under the 25-year storm [T2]	

Falling Creek Subwatershed – Opportunities

ID#	Site Location in the Watershed And ODFW Reach	Watershed Attributes					Opportunity Description	Preliminary Sources	Reference
		Public Involvement	Hydrology & Infrastructure	Physical Habitat	Biological Communities	Water Quality			
	Basin-Wide								
1	Throughout the Subbasin			✓	✓		1. Provide access above key culverts – to open up habitat in terms of deep pools, complex pools, good riffle habitat, and instream structure [T2] 2. Needs signs at creek crossing for Watershed Awareness [T2] 3. Encourage "Dump no waste" storm drain curb marker program [T2]		
1-1	Huber St to the headwaters above Jackson Middle School	✓					1. Opportunity to support stewardship projects with staff and students at Jackson Middle School and private landowners [T2] 2. Daylighting Falling Creek through Jackson Middle School open space is a "high priority – great opportunity for grant funding and partnerships" (TCWC) [T2] 3. High priority rating by TCWC for community revegetation projects [T2]		

CHAPTER 18

Watershed Goals and Objectives

INTRODUCTION

The *Framework for Integrated Management of Watershed Health* outlines scientific principles and four watershed health goals: hydrology, habitat, biological communities, and water quality. Three additional goals were added for the Fanno and Tryon watersheds: infrastructure, public involvement, and consistency with other plans, policies, and regulations.

Objectives were developed for each goal to address Tier 1 problems and opportunities identified in the watershed characterizations and summarized earlier. Tier 1 problems and opportunities are directly linked to Endangered Specie Act (ESA) listed species or critical limiting factors that impair ecological functions and watershed health. A rationale is provided for each objective.

Objectives are specific outcomes in watershed functions and conditions that will help achieve those goals. Specifically, watershed objectives specify desired changes in an ecological condition (e.g., reduce summer stream temperatures). Generally, several objectives must be met to achieve a given watershed goal.

WATERSHED GOALS AND OBJECTIVES

Hydrology Goal

Move toward normative[1] flow conditions to protect and improve watershed and stream health, channel functions, and public health and safety.

Objectives

HYD1 - Restore stream flows to a normative hydrograph to protect in-stream habitat, minimize channel erosion and limit impacts on water quality.

> *Rationale: High flows can degrade stream channels by eroding banks, scouring, and channel incision. Reducing peak flows fosters stable stream banks, protects in-stream complexity, and reduces channel incision. Volume control can greatly increase flood control, especially in closed basins; help recharge aquifers and maintain stream baseflow; minimize stream channel erosion and habitat loss; and protect water quality by reducing loadings.*

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[1] A normative flow regime provides characteristics of flow magnitude, frequency, duration and timing essential to support diverse and productive salmonids and other flow-dependent resources.

Physical Habitat Goal

Protect, enhance and restore aquatic and terrestrial habitat conditions to support key ecological functions and improved productivity, diversity, capacity and distribution of native fish and wildlife populations and biological communities.

Objectives

HAB1 - Improve spawning and rearing habitats for native fish communities.

> *Rationale: Deposition of sediment from erosion on stream substrate degrades aquatic habitat. Reducing bank and channel erosion can reduce the deposition of sediment over salmon spawning stream substrate.*

HAB2 - Increase stream channel complexity to improve bank form habitats, protect and stabilize stream banks, provide areas for wood and substrate (e.g., fine sediment) to accumulate and settle (e.g., deep pools), and aide channel building processes, such as pool riffle formation, flood flow attenuation, etc.

> *Rationale: Channel complexity provides critical rearing and refuge habitat benefiting all native aquatic communities.*

HAB3 - Protect existing natural areas to help retain existing natural watershed functions and critical habitat.

> *Rationale: Remaining natural areas provide natural watershed functions and critical habitat. Further degradation of these remaining areas could critically undermine overall habitat restoration efforts.*

HAB4 - Protect and restore riparian and floodplain condition and connectivity to help restore normative flow regimes and aquatic and terrestrial habitat conditions.

> *Rationale: Floodplain interactions provide wood, gravel, organic matter and off-channel habitat to streams. Restoring floodplains improves aquatic habitat. Improving riparian areas improves both aquatic and terrestrial habitat. Wide, contiguous, and vegetated riparian buffers provide critical organic matter to streams and habitat for a variety of species*

HAB5 - Remove significant fish passage barriers (physical and hydraulic) to improve stream connectivity and potential fish population productivity.

> *Rationale: Fish barriers, such as long perched culverts, prevent fish migration within a stream system. Removing these barriers makes additional aquatic habitat available to fish. Increasing the distribution of fish in a stream system can enhance the resilience of the species.*

Water Quality Goal

Protect and improve surface water and groundwater quality to protect public health and support native fish and wildlife populations and biological communities.

Objectives

WQ1- Reduce summer in-stream temperatures to improve surface water quality.

> *Rationale: Cooler water is necessary for the health of aquatic communities and to support salmonid rearing and spawning.*

WQ2 - Reduce in-stream bacteria concentrations to improve surface water quality.

> *Rationale: Reducing in-stream bacteria concentrations helps protect public health.*

WQ3 - Reduce in-stream pollutant concentrations to levels that do not threaten aquatic life or human health.

> *Rationale: Stormwater runoff can contain a variety of pollutants, including heavy metals, nutrients, and sediment. Reducing loads of these pollutants from various known/suspected sources such as transportation corridors and spills will improve aquatic habitat.*

WQ4 - Reduce total suspended solids (TSS) to improve in-stream water quality.

> *Rationale: Suspended sediment in streams impacts water quality and can be deposited on channel substrate, both of which degrade aquatic habitat. Reducing sediment loads helps to improve aquatic habitat.*

WQ5 - Reduce phosphorus concentrations in stormwater.

> *Rationale: High phosphorus concentrations spur algal growth, resulting in reduce concentrations of DO.*

WQ6 – Meet dissolved oxygen standard.

> *Rationale: Maintaining an adequate dissolved oxygen level in streams is critical for native fish populations.*

Biological Communities Goal

Protect, enhance and restore native aquatic and terrestrial species and biological communities to improve and maintain biodiversity in Portland’s watersheds.

Objectives

BC1 - Restore healthy, self-sustaining populations of all native fish communities.

> *Rationale: Fish need clean and cool streams with large woody debris, off channel habitat, and sediment free gravel substrate for spawning and rearing. Improving these and other habitat conditions will help increase native fish populations, and benefit other aquatic species.*

BC2 - Increase macroinvertebrate abundance and production.

> *Rationale: More study is needed. However, macroinvertebrate production is connected to all processes occurring in the aquatic - terrestrial continuum. By improving riparian vegetation (e.g., overhanging vegetation), getting marine-derived nutrients back into the system, and improving water quality such as reduction in fine sediment and toxins the overall habitat conditions for macroinvertebrates will improve.*

Infrastructure Goal

Provide adequate sanitary and stormwater infrastructure to protect public health and safety while preserving natural watershed functions.

Objectives

INF1 - Restore infrastructure such that all storm drainage facilities within the closed conduit system area designed to pass a 10-yr storm without surcharge and provide conveyance of the 100-yr storm meeting health and safety requirements.

> *Rationale: Public stormwater facilities protect human health and safety, as well as protect public and private properties from catastrophic damages.*

INF2 - Remove physical and hydraulic barriers for fish passage. Physical barriers include culverts with downstream invert elevations that are 12” above residual pools, lengths greater than 100’ and/or with gradients >0.5%. Hydraulic barriers include lack of flow depth and flow velocities greater than 2 fps.

> *Rationale: Culverts and in some cases storm drainpipes impact the ability of fish to access spawning and rearing habitats and to migrate throughout the system.*

Public Involvement, Education, and Stewardship Goal

Maintain long-term community-wide commitment to improve and sustain watershed health.

Objectives

PI1 - Establish strategies for promoting and carrying out community stewardship projects and programs to improve watershed health.

> *Rationale: The strategy will identify City services to be provided, establish targeted opportunities for stewardship activities, and identify partnerships and funding opportunities for implementation of community and City initiated projects.*

PI2 - Raise community awareness by educating citizens about the impacts that their actions have on watershed health.

> *Rationale: People living in the subwatershed affect watershed health everyday by the choices they make. Public outreach strategies should be geared towards educating citizens about pollutant sources of concern to evoke behavioral changes to reduce non-point source pollutants and restore natural functions to the subwatershed.*

PI3 – Foster citizen involvement in the development and implementation of watershed plans, programs, and projects.

Consistency with other Plans, Policies, and Regulations Goal

Meet watershed goals and objectives, and achieve consistency with applicable plans, policies, and regulations.

CP1 - Establish strategies and actions for coordination with agencies and organizations within and external to BES to ensure that projects, programs, and plans are compatible, and that watershed plan goals and objectives are met.

> *Rationale: The actions of many different agencies affect the health of the watershed. Through coordination and collaboration with other agencies, watershed staff can help to ensure that these agencies' projects, programs, and plans incorporate goals and objectives to improve watershed health.*

CP2 - Establish strategies, projects, and programs that meet and exceed regulatory requirements.

> *Rationale: Watershed Plan strategies, projects, and programs should meet the requirements of existing regulations designed to improve the health of the watershed. These regulatory requirements should be seen as a minimum. Furthermore, regulatory requirements do not always recognize the limiting factors unique to each watershed and subwatershed. Therefore, actions to improve watershed health will both comply with and often exceed regulatory requirements.*

CHAPTER 19

Fanno Creek Watershed Summary Table: Goals, Objectives, Conditions, Targets and Actions

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INTRODUCTION

The Fanno Creek Summary Table summarizes watershed conditions for specific environmental indicators, provides preliminary targets for each indicator, and describes programs, actions, and implementation targets to improve conditions and achieve progress toward watershed goals and objectives. This table will be refined over the next few years as additional data and analysis become available and actions and programs are implemented.

Below is a brief description of each variable (column) in the summary table.

Goals and Objectives

Goal

Watershed Goals represent the primary domains of the natural environment on which the City's watershed management process is based, and for which the *Framework for Integrated Management of Watershed Health* establishes four citywide goals. These goals include hydrology, physical habitat, water quality, and biological communities. Three additional goals were added for the Fanno and Tryon watersheds: infrastructure, public involvement, and consistency with other plans, policies, and regulations.

See the Introduction and Chapter 18 Watershed Objectives of this document for more information.

Key Attribute

A key attribute is a watershed health attribute that is either maintaining existing watershed functions or is limiting watershed functions or a species' ability to survive and carry out its life stages. A key attribute is generally identified as one that is most degraded from historical or reference condition or close to reference condition. A key attribute is usually defined by several indicators (see below).

Objective

An objective is a specific outcome in watershed functions and conditions that will help achieve watershed goals. Specifically, a watershed objective specifies desired changes in an ecological condition (e.g., reduce summer stream temperatures). Generally, several objectives must be met to achieve a given watershed goal.

For more information on objectives, see Chapter 18 Watershed Objectives of this document.

Indicator

Indicators were selected following development of the watershed objectives. Because of the complexity of ecosystems, it is not possible to measure the condition, or changes in, every component of the system. The indicator addresses this issue by representing a readily measurable attribute that captures the condition and dynamics of broader, more complex and less readily measurable attributes of ecosystem health. Measurable indicators enable the City to monitor and evaluate progress toward meeting watershed health objectives and goals and regulatory requirements. Generally, several indicators were selected for each watershed objective and key attribute.

Geographic Area

The geographic area is the spatial extent to which the condition is present. A more detailed description of the location and extent of the conditions is described for each indicator under "current condition" in the table.

Conditions (Characterizations)

Reference Condition

The reference or historical condition describes the conditions for proper or suitable ecosystem function, regardless of urban development or other anthropogenic (i.e., human-caused) constraints.

Current Condition

A current conditions description is provided for each indicator. Conditions are described at three scales: stream reach, subwatershed, and watershed. The scale depends on available data, type of analytical tools used, and the type of indicator. For example, water quality data are collected at only a few locations in Tryon Creek, and the sources of water quality problems often originate from a variety of sources throughout the watershed. Therefore, stream temperature is an indicator that applies at the watershed scale. Aquatic habitat indicators, however, such as channel form and stream complexity are described at the stream reach scale.

See Part 2 Characterization chapters of this document for more detailed information on watershed conditions.

Potential Causes

A brief description of potential causes of current conditions for each indicator is provided. Causes were identified in a number of ways, including monitoring, modeling, information available for point source discharge permits, and peer-reviewed research and scientific literature on source investigation and causes of urban problems.

See Part 2 Characterization chapters of this document for more detailed information of the causes of watershed conditions.

Uncertainties re: Causes

A brief description of the uncertantanties regarding potential causes of current conditions for each indicator is provided. Uncertainties associated with the analysis of complex interactions between environmental and human systems are inevitable. Uncertainties may be due to data gaps, insufficient analytical tools, lack of scientific study, or simply the fact that watershed systems are complex beyond our current ability to fully understand them.

Targets, Benchmarks, and Actions

Desired Future Condition

The desired future condition, or "target" condition, is provided for each indicator. Descriptions vary for each indicator reflecting the unique physical and biological conditions of the watershed. Descriptions reflect the state of the watershed that will ultimately be necessary for the City to achieve the watershed health goals and objectives. Descriptions were generally not established at reference conditions levels. Instead, they take into account major physical, social or even economic constraints that are prevalent within an urban environment.

Programs and Actions

This general description of the types of programs and actions needed to improve the conditions of each indicator. For more information on specific actions, see Chapters 21 and 22 Strategies and Actions of this document.

Implementation Targets

Implementation targets are 5-10 targets for implanting programs and actions to improve watershed health indicators and make progress toward watershed goals and objectives. These targets provide measures to report on and gauge progress.

Goals and Objectives					Conditions (Characterization)				Targets and Actions		
Goal	**Key Attribute**	**Objective**	**Indicator**	**Geographic Area**	**Reference Condition**	**Current Condition**	**Potential Causes**	**Uncertainties re: Causes**	**Desired Future Condition**	**Programs and Actions**	**Implementation Targets (5-10 years)**
Hydrology	**Stream Hydrograph**	Restore stream flows to a normative hydrograph to protect in-stream habitat, minimize channel erosion and limit impacts on water quality.	Base Flow (cubic feet/sec)	Watershed wide	Likely higher than current conditions throughout, especially in summer.	**Fanno**: Fanno Creek monitoring at SW 56th (2000-01): Winter base flow ~ 5 CFS, summer base flow is <1 cfs.	High impervious cover due to development, particularly along and south of Beaverton Hillsdale Highway	No specific monitoring data for tributaries	Stabilize and increase summer base flow	1) Develop and implement stormwater retofit projects 2) Work with BDS to apply stormwater mgmt manual to existing development 3) Make recommendations to stormwater mgmt manual 4) Protect existing natural resources	Difficult to determine due to variability. Monitor base flow. Model potential actions.
			Peak Flow (cubic feet/sec)	Watershed wide	Generally, ~3X less than current conditions (USGS)	Measured flow: Fanno Creek at SW 56th (2000-01): Winter peak flow 30-160 CFS, summer peak flow is 20-80 cfs. Modeled flow: **Fanno** 2-yr is 167 cfs and 10-yr is 347 cfs. **Pendleton** 2-yr is 23.8 cfs and 10-yr is 41.7 cfs. **Vermont** 2-yr is 59.0 cfs and 10-yr is 100.0 cfs. **Woods** 2-yr is 73.0 cfs and 10-yr is 129.0 cfs **N. Ash** 2-yr is 44.0 cfs and 10-yr is 83.0 cfs. **S. Ash** 2-yr is 31.4 cfs and 10-yr is 54.0 cfs. **Red Rock** 2-yr is 116.4 cfs and 10-yr is 171.8 cfs.		No specific monitoring data for tributaries	Trend towards historic conditions of lower peak flows	1) Stormwater retrofit projects 2) Work with BDS to apply stormwater mgmt manual to existing development 3) Land acquisition 4) Protect existing natural resources 5) Projects to enhance floodplain connection 6) Improve native riparian and upland vegetation 7) Strengthen stormwater mgmt manual to further reduce EIA.	Model based on 5-year EIA year target and other projects
			Runoff Flow Volume (million gallons/day - MGD)	Watershed wide	Lower than current conditions	Modeled Flow Volume (million gallons): **Fanno**: 2-yr is 28.95 and 10-yr is 493.9; **Pendleton**: 2-yr is 10.4 and 10-yr is 14.2; **Vermont**: 2-yr is 18.5 and 10-yr is 29.3; **Woods**: 2-yr is 18.9 and 10-yr is 26.5; **N.Ash**: 2-yr is 6.1 and 10-yr is 9.5; **S.Ash**: 2-yr is 5.5 and 10-yr is 8.8; **Red Rock**: 2-yr is 27.4 and 10-yr is 39.0			Reduce runoff volume	1) Develop and implement stormwater retofit projects 2) Work with BDS to apply stormwater mgmt manual to existing development 3) Make recommendations to stormwater mgmt manual 4) Increase stormwater storage/detention capacity 5) Improve native riparian and bank vegetative cover	Model based on 5-year EIA year target and other projects
			Ratio of 10-year predevelopment peak flow to 2-yr existing peak flow	Watershed wide	Ratio of 10-year predevelopment peak flow to 2-yr existing peak flow: 2.5	**Fanno** Mainstem~0.6		No specific data for tributaries	Reduce 2 year existing peak flow to Increase ratio		Establish a relationship between EIA and 2 year peak flow. Model target ratio based on 5-year EIA target and other projects

			Effective impervious area (EIA)	Watershed wide	EIA<10%	Average MIA: **Fanno**: 32% (Beaverton Hillsdale Hwy. Highly impervious area); **Pendleton**=26.6%; **Vermont**=31.5% (SW 45th, SW Vermont, and SW Shattuck are concentration of impervious area) **Woods**= 33.5% (I-5/Barbur, Capitol Hwy. and Mult. Blvd are highly impervious areas); **N. Ash**= 32.5%; **S.Ash**= 38.9% (I-5 and Barbur are highly impervious areas); ; **Red Rock**=38.8% (I-5 and PCC parking lots);			Reduce EIA, focus on transportation and commercial corridors		Establish existing EIA and reduce EIA 2%
			Drainage complexity (ratio of open channel to piped stream length)	Watershed wide	Naturally complex drainage system of open channels. None of basin served by storm sewer	Drainage complexity (open channel/piped): **Fanno mainstem**: 0.44; Tributaries: 0.36	NA		Increase natural drainage complexity (increase ratio of open channel to pipe)	1) Land acquisition 2) Protect existing natural resources 3) Help develop standards to strengthen and apply to drainage reserve code 4) Increase protections where needed to conserve important resources and functional values 5) Stream enhancement (such as daylighting streams).	Stabilize natural drainage complexity at current level (promote bridges and natural bottomed culverts, protect existing drainages)
			Acres of impervious area affected by stromwater projects			Existing development not affected	NA		Increase acres of impervious area affected with stormwater projects.	1) Develop and implement stormwater retofit projects	Projects to treat 15-20 acres of impervious surfaces
	Storm Sewer Infrastructure	Restore infrastructure such that all storm drainage facilities within the closed conduit system area designed to pass a 10-yr storm without surcharge and provide conveyance of the 100-yr storm meeting health and safety requirements.	Number of deficient culverts and storm pipes	see "current conditions"	Number of deficient culverts and storm pipes: NA	# surcharged (12 inch and above in size) **Fanno**: 49 culverts and 9 storm pipes; **Pendleton**: 8 culverts and 4 storm pipes; **Vermont**: 9 culverts and 27 storm pipes; **Woods**: 43 culverts and 19 storm pipes; **N.Ash & S.Ash**: 42 culverts and 32 storm pipes; **Red Rock:** 21 culverts and 36 storm pipes	Increased impervious cover contributing to increased stormwater runoff	Not all pipes or culverts that surcharge are problems	Decrease quantity of deficient pipes	1) Stream enhancement projects (i.e., replace deficient culverts with larger culverts or bridges)	Decrease quantity of deficient pipes (50-100 lineal feet)

		Remove physical and hydraulic barriers for fish passage. Physical barriers include culverts with downstream invert elevations that are 12" above residual pools, lengths >100' and/or with gradients >0.5%. Hydraulic barriers include lack of flow depth and flow velocities > 2 fps.	Number of impassable barriers		No natural fish barriers	**Fanno**: Impassable at Beav-Hills Hwy, SW 30th Dr, and at SW 39th Dr. ; unknown impacts at SW Shattuck Rd. and at SW 43rd Dr. **Pendleton**: Impassable at Beav-Hills Shopping Ctr., seasonally impassable at Shattuck Rd, and unknown impacts at 59th, 54th, 53rd, 52nd, and Fairdale Ct **Vermont**: R1: Seasonally passable at Oleson Rd and Shattuck Rd, completely impassable at Vermont St.; R2: Impassable at 45th Ave and at Multnomah Blvd, unknown impact at Caldew St **Woods**: R1 & R2 impassable at Portland Golf Club, unknown impacts at Oleson Rd and 60th Ave; R3: impassable at 45th Ave and at Taylor's Ferry, unknown impacts at Multnomah Blvd and at Garden Home Rd **N.Ash**: Concrete dam impassable, unknown impacts at Dolph Dr, Orchid Dr, Lancelot Ln, and 55th Ave **S.Ash**: impassable at SW 62nd Ave & at SW Lauradel ; impact unknown at SW 55th Avenue; 4 more culverts with unknown impacts; and cascades/steps may restrict resident fish movement most of year; **Red Rock**: Culverts at Beav-Hills Shopping Ctr., SW 68th Ave and at I-5 are expected to be impassable	NA	Unknown impacts at some culverts	Year-round fish passage, particularly throughout Fanno Creek mainstem and tributaries. Focus on resident cutthroat.	1) Retrofit critical fish passage culverts	Retrofit critical culverts along Fanno mainstem to allow fish passage.
Water Quality	**Stream Temperature**	Reduce summer in-stream temperatures to improve surface water quality.	7 day average of daily maximum temperature	SW 56th	7 day average maximum daily temperature is below 18.0 C; below 13.0 C during spawning and incubation	**Fanno** Monitoring (1998-2002) at SW 56th. Maximum summer period daily temperatures range from 19.7-22.0 C. Average # of days exceeding standard in summer is 44. **Pendleton & Vermont**: no stream specific data **Woods**: Monitoring at Woods Creek at Hideway Park. Maximum summer daily temperatures range from 19.2-19.4 C. Average of 14.2 days exceeding standard in summer. **N.Ash, S.Ash, & Red Rock**: no stream specific data.	Lack of riparian vegetation canopy, due to development and residential landscaping.	No stream specific data for tributaries	7 day average maximum daily temperature is below 18.0 C; below 13.0 C during spawning and incubation	1) Land acquisition 2) Protect existing natural resources 3) Increase protections where needed to conserve important resources and functional values 4) Improve native riparian and bank vegetative cover 5) Stream enhancement (such as daylighting streams).	No net increase

			Stream "effective shade"	see "current condition"	Stream "effective shade">95%	Stream shade cover from ODFW: **Fanno** R1=94% avg., range 61-100%; R2=88% avg. range 39-100%; R3= 86% avg., range 31-100%; R4= 85% avg., range 22-100%; R5=94% avg., range 67-100%; R6= 99% avg., range 89-100 **Pendleton**: no data **Vermont**: R1= 79% avg., range 22-100%; R2= 91% avg., range 47-100% **Woods**: R1= 79% avg., range from 22-100%; R2= 91% avg., range from 58-400 **N.Ash**: R1= 87% avg., range 28-100%; R2= 89% average, range 53-100% **S.Ash**: R1= 47% avg., range 11-100%; R2= 91% avg., range 61-100%; R3= 90% avg., range 35-100% **Red Rock**: tree canopy cover relatively intact			Stream effective shade - average 90-95% basinwide		Establish effective shade and increase by 5%, particularly in R4 and upper watershed. Or, shade range >70% in R4 and upper watershed.
			Stream bank vegetative cover (overhanging vegetation)	see "current condition"	Stream banks covered with native vegetation	**Fanno**: R1-R3: dominated by small, second growth mix of trees. Cover moderate 0-10m, poor 10-30m. R4 and R5: large (>30cm dbh) well established deciduous trees. **Pendleton**: Riparian integrity is fair to good downstream of SW Shattuck Rd and impaired upstream. **Vermont**: Lower Vermont riparian corridor is narrow and fragmented due to development. Best riparian conditions are in upper Vermont, in Gabriel Park. **Woods**: Large, well-established mixed conifers and hardwoods and grasses common including dougas fir, alder, cedar, and willow. Homes abut stream and corridor is narrow in areas and some banks are cleared. Best conditions in upper Woods. **N.Ash**: Dominated by mix of conifer/deciduous trees (second growth). Cover moderate up to 20m but is poor from 20-30 m and beyond. **S.Ash**: Dominated by small, second growth mix of conifer/deciduous trees and grasses, homes and trails often abut creek. Canopy cover high within 30m riparian corridor (63-71%) **Red Rock**: narrow riparian corridor, about 3m buffer width due to development.			Increase native stream bank vegetation throughout		Increase native stream bank vegetation throughout. Target Fanno and Vermont Creeks where bank are highly eroding (20 acres revegetated)

	In-stream Bacteria (E. coli)	Reduce in-stream bacteria concentrations to improve surface water quality.	Bacteria (E. Coli) concentrations per 100 ml. Minimum of 5 samples	At Boones Ferry Rd.	Below 126 organisms per 100 ml. (based on minimum of 5 samples within 30 days)	**Fanno** All year: Based on 30 day geometric mean, averages exceed standard most of the time during summer at 69th, 56th, and about half of time at 39th; winter exceedences are slightly less. **Pendleton**: averages exceed standards about 90% in summer and 75% in winter **Vermont**: averages exceed standards in all samples in summer and 90% in winter **Woods**: averages exceed standards in all samples in summer and 50% in winter **N.Ash**: averages exceed standards in all samples in summer and 90% in winter. **S.Ash**: Based on 30 day geometric mean, averages exceed standards in only 25% of samples in summer and winter. **Red Rock**: no data	Non-point sources (pets, wildlife), faulty septic systems, and sanitary system leakage	Frequency of samplying not great enough to assess	Below 126 organisms per 100 ml. (based on minimum of 5 samples)	1) Outreach and education programs to reduce non-point source pollutants 2) Develop and implement actions to reduce non-stormwater related discharges 3) Develop bacteria management plan (TMDL).	Increase sampling frequency to a level required for analysis (need to indicate specific sampling frequency)
			Bacteria (E. Coli) concentrations per 100 ml. Single sample		Below 406 organisms per 100 ml. (maximum of any single sample	Percentage of samples that exceed standard: **Fanno** Summer (May-Oct.): at 69th and 56th -50%, at 39th -25%. Winter: at 69th, 56th and 39th-25% **Pendleton**: Summer (May-Oct.) -50% Winter -10% **Vermont**: Summer (May-Oct.) -50% Winter -25% **Woods**: Summer (May-Oct.) -50% **N.Ash**: Summer (May-Oct.) -50% Winter -25% Winter -10% **S.Ash**: Summer (May-Oct.) -only 10% Winter -no samples exceed standard. **Red Rock:** no data		No stream specific data for tributaries	Below 406 organisms per 100 ml. (maximum of any single sample		Decrease summer and winter exceedences, no more than 20% of single samples exceeding.
	Dissolved Oxygen (DO)	Meet dissolved oxygen standards	DO		At least 11.0 mg/l (30 day mean minimum)	Data lacking	Increased temperature (see Stream Temperature). Increased nutrient loads which increase oxygen demand	No stream specific data for tributaries	At least 11.0 mg/l (30 day mean minimum)	1) Develop and implement stormwater retrofit projects 2) Work with BDS to apply stormwater mgmt manual to existing development 3) Improve native riparian, bank, and upland vegetative cover 4) Improve O & M practices 5) Treat stormwater runoff, particularly from commercial and transportation corridors.	Achieve TMDL targets for reduction of

	Total Suspended Solids (TSS)	Reduce total suspended solids (TSS) to improve in-stream water quality.	TSS (stormwater discharges)	see "current condition"	Background sources:-no anthropogenic sources of TSS	**Fanno**: Median TSS concentrations at SW 56th. Summer storms: 437 mg/l. All storms: 388 mg/l.	Grid Model indicates commercial, multifamily, and transportation LU's have higher loading rates.	No stream specific data for other subwatersheds	70% reduction from current conditions in TSS in stormwater as required by stormwater management manual	1) Develop and implement stormwater retrofit projects 2) Treat stormwater runoff particularly in commercial & transportation corridors 3) Work with BDS to apply stormwater mgmt manual to existing development 4) Land acquisition 5) Maintain existing zoning 6) Protect existing natural resources 7) Strengthen erosion control manual 8) Increase protections where needed to conserve important resources and functional values 9) Improve native riparian, bank, and upland vegetative cover 10) Improve O and M practices	Reduce TSS in stormwater discharges.
			Erosion control measures	Throughout Watershed	Erosion control: NA	Erosion control manual governs new and redevelopment	Enforcement of erosion control manual		More stringent control and enforcement measures in the City's erosion control manual		Work with BOP and other City Bureaus to further improve erosion control requirments as opportunities arise.
			O&M Activities	Throughout Watershed	O and M activities: NA	Examples of O and M activities: Street sweeping, sediment trap cleaning	Potential Causes: infrequent maintenance, timing, and maintenance practices/protocols		Improved O and M practices and increased activities to reduce TSS in stormwater runoff		Increase frequency and timing of street sweeping on transportation and commercial corridors. Implement projects to trap sediment in stormwater runoff from transportation/commercial corridors
			Feet of streambank vegetated	see "current condition"	Stream banks covered with native vegetation	**Fanno**: R1-R3: dominated by small, second growth mix of trees. Cover moderate 0-10m, poor 10-30m. R4 and R5: large (>30cm dbh) well established deciduous trees. **Pendleton**: Riparian integrity is fair to good downstream of SW Shattuck Rd and impaired upstream. **Vermont**: Lower Vermont riparian corridor is narrow and fragmented due to development. Best riparian conditions are in upper Vermont, in Gabriel Park. **Woods**: Large, well-established mixed conifers and hardwoods and grasses common including douglas fir, alder, cedar, and willow. Homes abut stream and corridor is narrow in areas and some banks are cleared. Best conditions in upper Woods. **N.Ash**: Dominated by mix of conifer/deciduous trees (second growth). Cover moderate up to 20m but is poor from 20-30 m and beyond. **S.Ash**: Dominated by small, second growth mix of conifer/deciduous trees and grasses, homes and trails often abut creek. Canopy cover high within 30m riparian corridor (63-71%) **Red Rock**: narrow riparian corridor, about 3m buffer width due to development.	Development and residential landscaping		Increase native stream bank vegetation throughout		Increase native stream bank vegetation throughout. Target Fanno and Vermont Creeks where bank are highly eroding (20 acres revegetated)

	Other In-stream pollutants	Reduce in-stream pollutant concentrations to levels that do not threaten aquatic life or human health.	Stormwater runoff related pollutants	Throughout Watershed	Toxics: No anthropogenic sources of pollutants	Data lacking	Transportation infrastructure and development and pesticide/herbicide usage	Frequency of sampling not great enough to assess	Reduction of toxic pollutants	1) Treat stormwater runoff, particularly from commercial and transportation corridors 2) Improve O & M practices 3) Outreach and education programs to reduce non-point source pollutants	Increased monitoring, implement stormater retrofits to improve stormwater quality, improved O&M practices
			Percentage of area meeting stormwater manual water quality treatment criteria.	Throughout Watershed	NA: % of area meeting stormwater manual water quality treatment criteria	All new and redevelopment meets stormwater manual criteria, no requirements to retrofit existing development	New and redevelopment must comply with manual. No strategy to retrofit existing development		A strategy to apply stormwater management manual to existing development		
Physical Habitat	**Riparian and Floodplain Conditions**	Protect and restore riparian and floodplain condition and connectivity	Stream bank condition	see "current conditions"	>90% banks stable	% stable banks: **Fanno**: R1= 41%; R2= 45%; R3=45%; R4= 39%; R5=57%; R6=64% **S.Ash**=69%; **N.Ash**=74%; **Woods**: R1= 82%; R2=80% **Vermont**: R1=28%; R2= 6% **Red Rock & Pendleton**: moderately unstable	Riparian area impacted by development and streets.		> 70% stable banks	1) Implement stormwater retrofit projects 2) Apply stormwater manual to existing development 3) Land Acquisition 4) Maintain exsiting zoning 5) Protect existing natural resources 6) Strengthen erosion control manual 7) Develop standards for drainage reserve code 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Improve native upland vegetative cover	Increase native stream bank vegetation throughout. In particular, target Fanno and Vermont Creeks and increase stability to > 50% bank stability. Replicate ODFW survey

			Riparian Width	see "current conditions"	>/250 feet. Continuous corridor of mature native vegetation including red alder, big leaf maple, western red cedar, Douglas fir, vine maple, western wahoo, and salmonberry	**Fanno**: R1-R3: dominated by small, second growth mix of trees. Cover moderate 0-10m, poor 10-30m. R4 and R5: large (>30cm dbh) well established deciduous trees. **Pendleton**: Riparian integrity is fair to good downstream of SW Shattuck Rd and impaired upstream. **Vermont**: Lower Vermont riparian corridor is narrow and fragmented due to development. Best riparian conditions are in upper Vermont, in Gabriel Park. **Woods**: Large, well-established mixed conifers and hardwoods and grasses common including dougas fir, alder, cedar, and willow. Homes abut stream and corridor is narrow in areas and some banks are cleared. Best conditions in upper Woods. **N.Ash**: Dominated by mix of conifer/deciduous trees (second growth). Cover moderate up to 20m but is poor from 20-30 m and beyond. **S.Ash**: Dominated by small, second growth mix of conifer/deciduous trees and grasses, homes and trails often abut creek. Canopy cover high within 30m riparian corridor (63-71%) Red Rock: narrow riparian corridor, about 3m buffer width due to development.			Vegetation zone greater than 2 times bank full width, targeting lower and middle Fanno, and tributaries including Pendleton Cr., lower Vermont Cr. and Red Rock Cr.	1) Land Acquisition 2) Protect existing natural resources 3) Increase protections where needed to conserve important resources and functional values 4) Improve native riparian and bank vegetative cover.	Increase riparian width throughout. Middle Fanno and Upper Fanno, Vermont, and Woods have fair riparian vegetation. Riparian vegetation should be expanded in these areas. Replicate ODFW survey.
			Riparian Fragmentation	see "current conditions"	<2 stream crossings per KM of stream length	Riparian corridor fragmented by roadways, homes, trails, and pipes	Transportation infrastructure and development encroachment.		Minimize roads and trail crossings and reduce their impacts	Evaluate culvert retrofits or replacements or possible suspended foot bridges at specific locations	Minimize roads and trail crossing and their impacts and preserve drainage complexity

			Bank vegetation composition	see "current conditions"	Continuous corridor of mature native vegetation including red alder, big leaf maple, western red cedar, Douglas fir, vine maple, western wahoo, and salmonberry	**Fanno**: R1-R3: dominated by small, second growth mix of trees. Cover moderate 0-10m, poor 10-30m. R4 and R5: large (>30cm dbh) well established deciduous trees. **Pendleton**: Riparian integrity is fair to good downstream of SW Shattuck Rd and impaired upstream. **Vermont**: Lower Vermont riparian corridor is narrow and fragmented due to development. Best riparian conditions are in upper Vermont, in Gabriel Park. **Woods**: Large, well-established mixed conifers and hardwoods and grasses common including dougas fir, alder, cedar, and willow. Homes abut stream and corridor is narrow in areas and some banks are cleared. Best conditions in upper Woods. **N.Ash**: Dominated by mix of conifer/deciduous trees (second growth). Cover moderate up to 20m but is poor from 20-30 m and beyond. **S.Ash**: Dominated by small, second growth mix of conifer/deciduous trees and grasses, homes and trails often abut creek. Canopy cover high within 30m riparian corridor (63-71%) **Red Rock**: narrow riparian corridor, about 3m buffer width due to development.	Riparian area impacted by development and streets.		>90% cover by native vegetation, targeting lower and middle Fanno, and tributaries including Pendleton Cr., lower Vermont Cr. and Red Rock Cr.	1) Land Acquisition 2) Protect existing natural areas 3) Expand e-zones and strengthen protections 4) Improve native riparian and bank vegetative cover.	Increase riparian width throughout. Middle Fanno and Upper Fanno, Vermont, and Woods have fair riparian vegetation. Riparian vegetation should be expanded in these areas. Opportunities in defecient areas should also be targeted. Replicate ODFW survey.
			Stream shade cover	see "current conditions"	Stream "effective shade">95%	Stream shade cover: **Fanno**: R1=94% avg., range 61-100%; R2=88% avg. range 39-100%; R3= 86% avg., range 31-100%; R4= 85% avg., range 22-100%; R5=94% avg., range 67-100%; R6= 99% avg., range 89-100 **Vermont**: R1= 79% avg., range 22-100%; R2= 91% avg., range 47-100% **Woods**: R1= 79% avg., range from 22-100%; R2= 91% avg., range from 58-400 **N.Ash**: R1= 87% avg., range 28-100%; R2= 89% average, range 53-100% **S.Ash**: R1= 47% avg., range 11-100%; R2= 91% avg., range 61-100%; R3= 90% avg., range 35-100% **Red Rock**: tree canopy cover relatively intact			Stream effective shade - average 90-95% basinwide	1) Land Acquisition 2) Protect existing natural resources 3) Increase protections where needed to conserve important resources and functional values 4) Improve native riparian and bank vegetative cover.	Establish effective shade and increase average shade by 5%, particularly in. Or, shade range >70% throughout. Target Fanno R1 and R5, Vermont R2, and other reaches particularly exposed. Replicate ODFW survey

			Number of riparian conifers (30m both sides of stream) >20-in dbh/1000 ft stream	see "current conditions"	More than 300 riparian conifers (30m both sides of stream) greater than 20 in dbh/1000 ft stream length.	**Fanno**: R1 & R4: deciduous dominated (15-30 cm dbh, second growth trees) and shrubs and vines. R2 & R3: Mixed conifer/deciduous (1-15 cm dbh, seedlings, new plantings, and young trees. R5 and R6: Deciduous dominated (30-50 cm dbh, large established trees) and shrubs and vines. **Pendelton**: Riparian integrity considered fair to good downstream of SW Shattuck Rd and impaired upstream of SW Shattuck Rd. Number of conifers > 20 in dbh: **Vermont:** R1=12; R2= 396 **Woods**: R1= 41; R2=229 **N.Ash**: R1= 61; R2= 0 **S.Ash**: R1=98; R2= 0; R3=146 **Red Rock**: Riparian zone intact with mixed deciduous and conifer trees/shrubs			Increase number of riparian conifers throughout.		No net loss. Increase riparian conifers throughout. Middle Fanno and Upper Fanno, Vermont, and Woods have fair riparian vegetation. Riparian vegetation should be expanded in these areas. Opportunities in deficient areas should also be targeted. Replicate ODFW survey. Replicate ODFW survey.
			Number of riparian conifers (30m both sides of stream) >35-in dbh/1000 ft stream	see "current conditions"	More than 200 riparian conifers (30m both sides of stream) >35-in dbh/1000 ft stream	# conifers > 35 in dbh: **Fanno**: R1 & R4: deciduous dominated (15-30 cm dbh, second growth trees) and shrubs and vines. R2 & R3: Mixed conifer/deciduous (1-15 cn dbh, seedlings, new lantings, and young trees. R5 and R6: Deciduous dominated (30-50 cm dbh, large established trees) and shrubs and vines. **Pendelton**: Riparian integrity considered fair to good downstream of SW Shattuck Rd and impaired upstream of SW Shattuck Rd. **Vermont**: R1= 0; R2= 91 **Woods**: R1= 10; R2= 76 **N.Ash**: R1=0; R2= 0 **S.Ash**: R1=12; R2= 0 ; R3= 37 **Red Rock**: Riparian zone intact with mixed deciduous and conifer trees/shrubs			Increase number of riparian conifers throughout.		No net loss. Increase riparian conifers throughout. Middle Fanno and Upper Fanno, Vermont, and Woods have fair riparian vegetation. Riparian vegetation should be expanded in these areas. Opportunities in deficient areas should also be targeted. Replicate ODFW survey.
			Ratio of floodway to stream width (valley width index)	see "current conditions"	VWI>20 in many areas throughout the watershed	VWI index: **Fanno** R1 - R3= 20; R4= 19.5; R5= 10.8; R6= narrow **Pendleton**= no data **Vermont**: R1= 13.0; R2= 10.8 **Woods**: R1=18.5; R2= 7.3 **N.Ash**=7.1; **S.Ash**= 7.4; **Red Rock**= Generally, floodway is confined	High peak flows from upland impervious areas, lack of stable native riparian vegetation.		Enhanced Floodplain Connectivity	1) Implement stormwater retrofit projects 2) Work with BDS to apply stormwater manual to existing development 3) Land Acquisition 4) Maintain existing zoning 5) Protect existing natural resources 6) Increase protections where needed to conserve important resources and functional values 7) Stream enhancement projects, i.e. LWD placement 8) Implement projects to enhance floodplain connection	No net loss of existing floodplain connectivity. Reconnect floodplain where possible as opportunities arise. Fanno R4 and R5 likely prove the greatest existing floodplain functions. Woods Creek and Ash Creek also provide some floodplain interaction. Consider targeting improvements in these areas. Replicate ODFW survey
			Entrenchment ratio (floodprone width/active channel width)		Entrenchment ratio: NA (values >1.0 signify increasing floodplain interaction)	Entrenchment ratio: **Fanno** R1= 1.8; R2= 1.6; R3=1.6; R4= 1.9; R5= 2.0; R6= 3.4; R7= NA **Pendleton**: limited floodplain interactions **Vermont**: R1= 5.7; R2= 2.1 **Wood**s: R1=13.9; R2= 2.3; **N.Ash**=3.5; **S.Ash**= 4; **Red Rock:** limited floodplain interactions					

			Stream gradient (%)		Stream gradient in lower reaches about 1% and up to 5% in upper reaches	Average stream gradient: **Fanno** R1= 0.5%;R2=0.6%; R3=0.6%; R4=1.1%; R5= 1.5%; R6= 4.8% **Pendleton**: 1.8% **Vermont**: R1= 0.6%; R2= 2.4% **Woods**: R1= 0.8%; R2=4.2%; **N.Ash**=6.3%; **S.Ash**=4.5%; **Red Rock**: Upper reach >8% slope	NA		NA (for context only)	NA	NA
	Stream Channel Complexity	Increase stream channel complexity to improve bank form habitats, protect and stabilize stream banks, provide areas for wood and substrate (e.g., fine sediment) to accumulate and settle (e.g., deep pools), and aide channel building processes, such as pool formation.	Large wood (15cm cubed min. size)/100 m stream length	see "current conditions"	>20 pieces of large wood (15 cm cubed min. size)/100 m stream length	# pieces/100m stream: **Fanno**: R1= 1.6 pieces, abundance low R2= 3.4 pieces, large wood relatively absent; R3= data lacking; R4 - R5= wood abundance low. **Pendleton**: Lacking in abundance **Vermont**: R1= 16.3; R2 =4.7 **Woods**: R1= 3.3; R2= 4.3 **N.Ash**: low - avg 3 **S.Ash**: low - avg 2.5 pieces **Red Rock**: Lacking in abundance	Generally, lack of mature native trees to provide sources of large woody debris (LWD)		Increase LWD throughout>10 pieces/100m stream length	1) Implement stormwater retrofit projects 2) Work with BDS to apply stormwater manual to existing development 3) Land Acquisition 4) Maintain existing zoning 5) Protect existing natural resources 6) Increase protections where needed to conserve important resources and functional values 7) Stream enhancement projects, ie. LWD placement 8) Improve native riparian and bank vegetative cover	Increase LWD throughout. Target Fanno reaches R2, R3, and R4 in particular wich provide critical spawning and rearing habitat > 10 pieces/100m stream. Replicate ODFW survey
			Wood volume	see "current conditions"	>30 m cubed of wood /100m stream length	volume (m^3) wood/100m: **Fanno**: R1= 0.9; R2= 0.9; R3= data lacking; R4-R7= wood volume low **Pendleton**: lacking in volume **Vermont:** R1= 7; R2= 1.9 **Woods**: R1=1.7; R2 =4.7 **N.Ash**: 3 **S.Ash**: 1.3 **Red Rock**: lacking in volume			Increase wood volume throughout to > 15 m cubed.		Increase wood volume throughout. Target Fanno reaches R2, R3, and R4 in particular which provide critical spawning and rearing habitat > 15 m cubed/100m stream. Replicate ODFW survey
			Key pieces of wood (>60 cm and 10m long)/100 m stream length	see "current conditions"	>3 key pieces of wood (>60 cm and 10m long)/100 m stream length	# key pieces: **Fanno**: R1= 0; R2= 0; R3: data lacking; R4= key pieces rare, those present found mid-reach in deep pools; R5-R7= key pieces rare **Pendleton**: 0 **Vermont**: 0 **Woods**: R1=0; R2 = 0.1 **N.Ash**: 0 **S.Ash**: 0 **Red Rock**: 0			Increase key pieces throughout to > 2pieces/100 m stream length		Increase key pieces throughout. Target Fanno reaches R2, R3, and R4 in particular which provide critical spawning and rearing habitat > 2 pieces/100m stream. Replicate ODFW survey
			source wood	see "current conditions"	Adequate source of wood, comprised of native conifers and hardwoods	The forest stand structure (size, age, species comp,) does not provide substantive sources of wood to the creek	Refer to attribute above - riparian condition		Adequate source of wood, comprised of native conifers and hardwoods		No net loss. Increase riparian conifers throughout. Middle and Upper Fanno, Vermont, and Woods have fair riparian vegetation. Riparian vegetation should be expanded in these areas. Opportunities in deficient areas should also be targeted. Replicate ODFW survey.
		Improve spawning and rearing habitats for native fish communities	Pool Area (% of total stream area)	see "current conditions"	Pool area>35%	**Fanno**: R1=86%; R2= 53%; R3= no data; R4= 86%; R5= 76%; R6= 42% **Pendleton**: no data **Vermont:** 86% **Woods**: R1= 93%; R2= 26% **N.Ash**: 14% **S.Ash**: 16% **Red Rock**: no data	Overall, lack of large wood combined with the prevalence of higher, flashy storm flows (promoting erosion and sediment deposition) significantly impacts		Maintain pool area>35% throughout	1) Implement stormwater retrofit projects 2) Work with BDS to apply stormwater manual to existing development 3) Land Acquisition 4) Maintain existing zoning 5) Protect existing natural resources 6)	Improve in-stream habitat throughout. Target Fanno reaches R2, R3, and R4 in particular which provide critical spawning and rearing habitat. Replicate ODFW survey

			Pool frequency (channel widths between pools)	see "current conditions"	Pool frequency (channel widths between pools) is 5-8	Channel widths/pool: **Fanno**: R1=11; R2=11.3; R3=9; R4=7.9; R5=18.5; R6=91.7 **Pendleton:** no data **Vermont**: R1=10.3; R2=20.5 **Woods**: R1= 7.8; R2= 17.2 **N.Ash**: R1=10.3; R2 = 33.6 **S.Ash**: R1=6.6; R2=2.4; R3=8.7 **Red Rock:** no data	stream habitat formation and maintenance of good quality spawning and rearing fish habitat, and is likely a prominent factor limiting fish productivity		Maintain pool frequency at 5-8 pools per cahnnel width throughout	Increase protections where needed to conserve important resources and functional values 7) Stream enhancement projects, ie. LWD placement 8) Improve native riparian and bank vegetative cover	Improve in-stream habitat throughout. Target Fanno reaches R2, R3, and R4 in particular which provide critical spawning and rearing habitat. Replicate ODFW survey
			Residual pool depth	see "current conditions"	Average residual pool depth>0.5m	Avg depth (m): **Fanno**: R1= 0.63; R2 and R3= 0.5; R4= 0.61; R5= 0.44; R6= 0.44; **Pendleton**: no data **Vermont:** R1=0.41; R2= 0.22 **Woods**: R1= 0.38; R2 = 0.36 **N.Ash**: 0.28 **S.Ash**: 0.36 **Red Rock**: no data			Retain deep pools > 0.5m throughout		Improve in-stream habitat throughout. Target Fanno reaches R2, R3, and R4 in particular which provide critical spawning and rearing habitat. Replicate ODFW survey
			# Complex pools (pools w/wood complexity>3 pieces)/ 1000m	see "current conditions"	> 2.5 Complex pools (pools w/wood complexity>3 pieces)/1000m	# of complex pools: **Fanno:** R1= 0.6; R2 and R3= 3.8; R4= 4.3; R5= 4.4; R6= 1.6; R7= NA **Pendleton**: no data **Vermont:** R1= 9.0; R2= 5.0 **Woods**: R1= 5.0 ; R2= 3.0 **N.Ash**: 1.4 **S.Ash**: 2.2 **Red Rock**: no data			Increase the number of complex pools to >2 throughout		Improve in-stream habitat throughout. Target Fanno reaches R2, R3, and R4 in particular which provide critical spawning and rearing habitat. Replicate ODFW survey
			Riffle area	see "current conditions"	Riffle area comprised at least 50% of stream	% riffle area: **Fanno**: R1=10%; R2 and R3= 37%; R4=11%; R5=18%; R6= 46%; R7=NA **Pendleton**: no data **Vermont**: R1= 7.0%; R2= 43% **Woods**: R1= 0.3%; R2= 42% **N. Ash**: 37% **S.Ash**: 51% **Red Rock**: no data			Increase riffle are to~ 30-40%	1) Implement stormwater retrofit projects 2) Land Acquisition 3) Protect existing natural resources 4) Increase protections where needed to conserve important resources and functional values	Improve in-stream habitat throughout. Target Fanno reaches R2, R3, and R4 in particular which provide critical spawning and rearing habitat. Replicate ODFW survey
			Riffle gravel area (% of riffle area)	see "current conditions"	>35% of riffle area composed of gravels	% Riffle area composed of gravel: **Fanno**: R1= 31%; R2 and R3= 6%; R4= 43%; R5=63%; R6=35%; **Pendleton**: no data **Vermont:** R1= 27%; R2 = 20% **Woods**: R1=20%; R2= 46% **N.Ash**: 50% **S.Ash**: 21-30% **Red Rock**: no data			Increase riffle habitat throughout to >35%		Improve in-stream habitat throughout. Target Fanno reaches R2, R3, and R4 in particular which provide critical spawning and rearing habitat. Replicate ODFW survey
			Percent fines in riffles	see "current conditions"	<10% fines in riffles	**Fanno**: R1=19%; R2=12%; R3= no data; R4= 9%; R5= 9%; R6= 7%; R7= no data Vermont: R1= 29% ; R2=42% Woods: R1= 50%; R2=11% N.Ash=17%; **S.Ash**=9%; **Red Rock & Pendleton**: no data	Grid Model indicates commercial, multifamily, and transportation LU's have higher loading rates.		Reduce fines throughout to <10% of riffle area with fines>10%	1) Implement stormwater retrofit projects 2) Work with BDS to apply stormwater manual to existing development 3) Land Acquisition 4) Maintain existing zoning 5) Protect existing natural resources 6) Strengthen erosion control manual 7) Develop standards for drainage reserve code 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Improve native upland vegetative cover	Improve in-stream habitat throughout. Target improvements in Fanno reaches R2, R3, and R4 in particular which provide critical spawning and rearing habitat. Replicate ODFW survey
			All in-stream habitat	see "current conditions"	<10% fines in all stream habitat	average % fines: **Fanno**: R1=53%; R2=25%; 34%; R4= 30%; R5=16; R6=13% **Vermont**: R1= 50%; R2= 56% **Woods**: R1= 68%; R2= 24% **N.Ash**: R1=45%; R2=36% **S.Ash**: R1=28%; R2=50%; R3=13% **Red Rock & Pendleton**: no data			Reduce fines throughout to < 10% fines		Improve in-stream habitat throughout. Target improvements in Fanno reaches R2, R3, and R4 in particular which provide critical spawning and rearing habitat. Replicate ODFW survey

	Existing Natural Areas	Protect existing natural areas to help retain existing natural watershed functions and critical habitat.	Large undeveloped parcels (>0.5 acres) adjacent to creek	see "current conditions"	All undeveloped	Acres of public and private open space: **Fanno** 71 acres (3.9% of subwatershed). **Pendleton**: 9.6 acres (4.2% of subwatershed) **Vermont:** 94 acres (12.4% of subwatershed) **Woods**: 45 acres (7.9% of subwatershed) **N.Ash:** 6.1 acres (2.2% of subwatershed) **S.Ash**: 24.5 acres (6.8% of subwatershed). **Red Rock**: 41.3 acres (10% of subwatershed)	Past and current protections, zoning, and acquisition programs.		Improve and expand protections and increased public ownership of areas providing critical watershed functions.	1) Land acquistion 2) Maintain existing zoning 3) Protect existing natural resources 4) Increase protections where needed to conserve important resources and functional values	Work with Parks and other City Bureaus to acquire critical areas as opportunities arise
			Environmental zones		NA	Environmental conservation zones cover 434 acres and protection zones cover 256 acres	TBD		Increase E-zone coverage and strengthen protections		Work with BOP to increase E-zone coverage and strengthen protections as opportunities arise.
	Fish Passage Barriers	Remove significant fish passage barriers (physical and hydraulic) to improve stream connectivity and potential fish population productivity.	Impassable or nearly impassable culverts and other fish barriers	see "current conditions"	no natural (year-round) barriers to fish passage	Fanno Impassable at Beav-Hills Hwy, SW 30th Dr, and at SW 39th Dr. ; unknown impacts at SW Shattuck Rd. and at SW 43rd Dr. **Pendleton** Impassable at Beav-Hills Shopping Ctr., seasonally impassable at Shattuck Rd, and unknown impacts at 59th, 54th, 53rd, 52nd, and Fairdale Ct **Vermont**: R1: Seasonally passable at Oleson Rd and Shattuck Rd, completely impassable at Vermont St.; R2: Impassable at 45th Ave and at Multnomah Blvd, unknown impact at Caldew St **Woods**: R1 & R2 impassable at Portland Golf Club, unknown impacts at Oleson Rd and 60th Ave; R3: impassable at 45th Ave and at Taylor's Ferry, unknown impacts at Multnomah Blvd and at Garden Home Rd **N.Ash**: Concrete dam impassable, unknown impacts at Dolph Dr, Orchid Dr, Lancelot Ln, and 55th Ave **S.Ash**: impassable at SW 62nd Ave & at SW Luradel ; impact unknown at SW 55th Avenue; 4 more culverts with unknown impacts; and cascades/steps may restrict resident fish movement most of year; **Red Rock**: Culverts at Beav-Hills Shopping Ctr., SW 68th Ave and at I-5 are expected to be impassable	NA	Unknown impacts at some culverts	Year-round fish passage at key locations	1) Remove/retrofit critical fish passage culverts	Evaluate Beaverton-Hillsdale shpping center for fish passage opportunities during different flow regimes. Evaluate Shattuck Rd culvert (R3-R4, 45th Ave culvert (R4-R5) and 39th Drive culvert (R5-R6) for fish passage.

Biological Communities	**Native fish communities**	Restore healthy, self-sustaining populations of all native fish communities.	Presence/absence: steelhead	see "current condition"	Steelhead: Self-sustaining population	Anadromous populations no longer present. Resident populations present throughout Upper Fanno watershed	Overall, lack of large wood combined with the prevalence of higher, flashy storm flows (promoting erosion and sediment deposition) and restrictive/impassable culverts significantly impacts stream habitat formation and maintenance of good quality spawning and rearing fish habitat, and is likely a prominent factor limiting fish productivity.		Self-sustaining population	1) Develop and implement stormwater retrofit projects 2) Treat stormwater runoff particularly in commercial & transportation corridors 3) Work with BDS to apply stormwater mgmt manual to existing development 4) Land acquisition 5) Maintain existing zoning 6) Protect existing natural resources 7) Strengthen erosion control manual 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Enhance floodplain connections 11) Retrofit critical fish passage culverts 12) Improve native riparian, bank, and upland vegetative cover 13) Improve O and M practices	Monitor implementation of programs and actions and conduct assessments of conditions and biological communities
			Presence/absence: cutthroat	see "current condition"	Cutthroat: Self-sustaining population	Fanno Observed in middle and upper reaches year round. In upper areas, abundance highest in winter and lowest in fall. Vermont: Cutthroat trout have been noted in lower reach.			Self-sustaining population in middle and upper reaches		
			Presence/absence: coho	see "current condition"	Coho: Self-sustaining population	Coho no longer populate Upper Fanno watershed			Self-sustaining populations of coho salmon		
			Spatial structure: steelhead	see "current condition"	Steelhead spatial structure: Anadromous extended though upper Fanno, resident rainbow trout present through mainstem and major fish-bearing tributary reaches	Anadromous populations no longer present. Resident populations present throughout Upper Fanno watershed			Steelhead spatial structure: Anadromous extended though upper Fanno, resident rainbow trout present through mainstem and major fish-bearing tributary reaches	1) Develop and implement stormwater retrofit projects 2) Treat stormwater runoff particularly in commercial & transportation corridors 3) Work with BDS to apply stormwater mgmt manual to existing development 4) Land acquisition 5) Maintain existing zoning 6) Protect existing natural resources 7) Strengthen erosion control manual 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Enhance floodplain connections 11) Retrofit critical fish passage culverts 12) Improve native riparian, bank, and upland vegetative cover 13) Improve O and M practices	Monitor implementation of programs and actions and conducts assessments of conditions and biological communities
			Spatial structure: cutthroat	see "current condition"	Cutthroat spacial structure: mainstem reach and most tributaries	**Fanno:** Observed in middle and upper reaches year round. In upper areas, abundance highest in winter and lowest in fall. **Vermont:** Cutthroat trout have been noted in lower reach.			Self-sustaining population in middle and upper reaches		
			Spatial structure: coho	see "current condition"	Coho spatial structure: spawned and reared up through the upper headwatere reaches of Fanno.	Coho no longer populate Upper Fanno watershed			Distribution of local populations extends upstream to headwater reaches that support fish-bearing habitats		
			Refer to attribute above - stream channel complexity	see "current conditions" under stream channel complexity	Substantive off-channel habitat	Refer to attribute above - stream channel complexity	Refer to attribute above - stream channel complexity		Refer to attribute above - stream channel complexity		

			Index of Biotic Integrity (IBI) - community richness	see "current condition"	Index of Biotic Integrity (IBI) >=75	**Fanno:** Averages of all seasons. Lower= 41.7; Middle=45.3; Upper=44.9. Upstream of Oleson Rd is severely impaired in summer, fall, and winter **Ash**: Lower= 27.2; Middle= 32.1; Upper = 42.1	Lack of stream channel complexity/ habitat		Improve biotic integrity		
	Macroinvertebrates	Increase macroinvertebrate abundance and production	Benthic Index of Biotic Integrity (B-IBI) :Ephemeroptera, Plecoptera, & Trichoptera abundance	Subwatershed wide	A balanced, integrated adaptive assemblage of benthic organisms having species composition, diversity and functional organization comparable to other natural (reference) habitats in the region: High biological integrity.	no data			B-IBI statistically similar to reference sites	1) Develop and implement stormwater retrofit projects 2) Treat stormwater runoff particularly in commercial & transportation corridors 3) Work with BDS to apply stormwater mgmt manual to existing development 4) Land acquisition 5) Maintain existing zoning 6) Protect existing natural resources 7) Strengthen erosion control manual 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Improve native riparian, bank, and upland vegetative cover 11) Improve O and M practices	Monitor implementation of programs and actions and conducts assessments of conditions and biological communities
Public Involvement, Education, and Stewardship	# of programs to promote community stewardship	Establish strategies for promoting and carrying out community stewardship projects and programs to improve watershed health.	Number of Technical Assistance/Incentive programs for streamside property owners for ecological improvements	Watershed wide	NA	1. Free Plants; 2. Naturescaping for Clean Rivers,; 3. Partnership with SOLV; 4) BES Revegetation Program, 5) Friends of Trees Partnership			Expanded and fully funded programs promoting streamside ecological improvements on private property	Work with watershed services staff and management to expand and fully fund these programs and partnerships	Increase capacity of existing programs
			Number of Technical Assistance/Incentive programs to implement stormwater retrofits on private property	Watershed wide	NA	1. EPA wet weather grants			Well established and funded technical assistance programs to implement stormwater retrofits on private property	Work with watershed services staff and management to expand and fully fund these programs and partnerships	Establish at least one consistently funded technical assistance program.

			Number of participants in programs	Watershed wide	NA				High level of program participation	Work with watershed services staff and management to expand program capacity and increase outreach	Increase number of particpants in Reveg cost share, naturescaping, grants, and SOLV projects
			Number of active friends groups	Watershed wide	NA	1. Fans of Fanno; 2. Friends of Woods Creek Park; 3. Friends of Vermont Creek; 4. Bridlemile Creek Stewards; 5. Dickenson Parks Stewards; 6. Boundary Street Sense of Place Group			Vigrant and active friends groups	Support burgeoning groups and existing groups through collaboration	
	Programs to enhance community awareness of watershed health	Raise community awareness by educating citizens about the impacts that their actions have on watershed health.	Number of programs/incentives available to use less toxic products	Watershed wide	NA						
			Number of program topics	Watershed wide	NA						
			Number of community events/presentations	Watershed wide	NA						
	Citizen involvement in planning, programs, and projects to improve watershed health	Foster citizen involvement in the development and implementation of watershed plans, programs, and projects.	Number of Opportunities / year	NA	NA				Regular opportunities for public involvement in planning and implementation	Open houses, project presentations to community groups, etc.	Monitor the number citizen involvement opportunities and participation.
			Number of Participants / year	NA	NA						

CHAPTER 20

Tryon Creek Watershed Summary Table: Goals, Objectives, Conditions, Targets and Actions

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INTRODUCTION

The Tryon Creek Summary Table summarizes watershed conditions for specific environmental indicators, provides preliminary targets for each indicator, and describes programs, actions, and implementation targets to improve conditions and achieve progress toward watershed goals and objectives. This table will be refined over the next few years as additional data and analysis become available and actions and programs are implemented.

Below is a brief description of each variable (column) in the summary table.

Goals and Objectives

Goal

Watershed Goals represent the primary domains of the natural environment on which the City's watershed management process is based, and for which the *Framework for Integrated Management of Watershed Health* establishes four citywide goals. These goals include hydrology, physical habitat, water quality, and biological communities. Three additional goals were added for the Fanno and Tryon watersheds: infrastructure, public involvement, and consistency with other plans, policies, and regulations.

See the Introduction and Chapter 18 Watershed Objectives of this document for more information.

Key Attribute

A key attribute is a watershed health attribute that is either maintaining existing watershed functions or is limiting watershed functions or a species' ability to survive and carry out its life stages. A key attribute is generally identified as one that is most degraded from historical or reference condition or close to reference condition. A key attribute is usually defined by several indicators (see below).

Objective

An objective is a specific outcome in watershed functions and conditions that will help achieve watershed goals. Specifically, a watershed objective specifies desired changes in an ecological condition (e.g., reduce summer stream temperatures). Generally, several objectives must be met to achieve a given watershed goal.

For more information on objectives, see Chapter 18 Watershed Objectives of this document.

Indicator

Indicators were selected following development of the watershed objectives. Because of the complexity of ecosystems, it is not possible to measure the condition, or changes in, every component of the system. The indicator addresses this issue by representing a readily measurable attribute that captures the condition and dynamics of broader, more complex and less readily measurable attributes of ecosystem health. Measurable indicators enable the City to monitor and evaluate progress toward meeting watershed health objectives and goals and regulatory requirements. Generally, several indicators were selected for each watershed objective and key attribute.

Geographic Area

The geographic area is the spatial extent to which the condition is present. A more detailed description of the location and extent of the conditions is described for each indicator under "current condition" in the table.

Conditions (Characterizations)

Reference Condition

The reference or historical condition describes the conditions for proper or suitable ecosystem function, regardless of urban development or other anthropogenic (i.e., human-caused) constraints.

Current Condition

A current conditions description is provided for each indicator. Conditions are described at three scales: stream reach, subwatershed, and watershed. The scale depends on available data, type of analytical tools used, and the type of indicator. For example, water quality data are collected at only a few locations in Tryon Creek, and the sources of water quality problems often originate from a variety of sources throughout the watershed. Therefore, stream temperature is an indicator that applies at the watershed scale. Aquatic habitat indicators, however, such as channel form and stream complexity are described at the stream reach scale.

See Part 2 Characterization chapters of this document for more detailed information on watershed conditions.

Potential Causes

A brief description of potential causes of current conditions for each indicator is provided. Causes were identified in a number of ways, including monitoring, modeling, information available for point source discharge permits, and peer-reviewed research and scientific literature on source investigation and causes of urban problems.

See Part 2 Characterization chapters of this document for more detailed information of the causes of watershed conditions.

Uncertainties re: Causes

A brief description of the uncertainties regarding potential causes of current conditions for each indicator is provided. Uncertainties associated with the analysis of complex interactions between environmental and human systems are inevitable. Uncertainties may be due to data gaps, insufficient analytical tools, lack of scientific study, or simply the fact that watershed systems are complex beyond our current ability to fully understand them.

Targets, Benchmarks, and Actions

Desired Future Condition

The desired future condition, or "target" condition, is provided for each indicator. Descriptions vary for each indicator reflecting the unique physical and biological conditions of the watershed. Descriptions reflect the state of the watershed that will ultimately be necessary for the City to achieve the watershed health goals and objectives. Descriptions were generally not established at reference conditions levels. Instead, they take into account major physical, social or even economic constraints that are prevalent within an urban environment.

Programs and Actions

This general description of the types of programs and actions needed to improve the conditions of each indicator. For more information on specific actions, see Chapters 21 and 22 Strategies and Actions of this document.

Implementation Targets

Implementation targets are 5-10 targets for implanting programs and actions to improve watershed health indicators and make progress toward watershed goals and objectives. These targets provide measures to report on and gauge progress.

Goals and Objectives					Conditions (Characterization)				Targets and Actions		
Goal	**Key Attribute**	Objective	Indicator	Geographic Area	Reference Condition	Current Condition	Potential Causes	Uncertainties re: Causes	Desire Future Condition	Programs and Actions	Implementation Targets (5-10 years)
Hydrology	**Stream Hydrograph**	Restore stream flows to a normative hydrograph to protect in-stream habitat, minimize channel erosion and limit impacts on water quality.	Base Flow (cubic feet/sec)	Watershed wide	Likely higher than current conditions throughout, especially in summer.	Tryon Creek at Nettle Creek (2001-2002): Winter base flow< 10 CFS, summer base flow is ~1 cfs	High impervious cover due to development in upper subwatershed of Tryon and tributaries	No specific monitoring data for tributaries	Stabilize and increase summer base flow	1) Develop and implement stormwater retrofit projects 2) Work with BDS to apply stormwater mgmt manual to existing development 3) Make recommendations to stormwater mgmt manual 4) Protect existing natural resources	Difficult to determine due to variability. Monitor base flow. Model potential actions.
			Peak Flow (cubic feet/sec)	Watershed wide	Generally, ~3X less than current conditions (USGS)	Tryon Creek at Nettle Creek (2001-2002): Winter peak flows range from 60-120 CFS, summer peak flows < 20 cfs		No specific monitoring data for tributaries	Trend towards historic conditions of lower peak flows	1) Stormwater retrofit projects 2) Apply stormwater mgmt manual to existing development 3) Land acquisition 4) Protect existing natural resources 5) Projects to enhance floodplain connection 6) Improve native riparian and upland vegetation 7) Strengthen stormwater mgmt manual to further reduce EIA.	Model based on 5-year EIA year target and other projects
			Runoff Flow Volume (million gallons/day - MGD)	Watershed wide	Lower than current conditions	Modeled Flow Volume (MGD): **Tryon:** 2-yr is 160.9 and 10-yr is 219.4			Reduce runoff volume	1) Develop and implement stormwater retofit projects 2) Work with BDS to apply stormwater mgmt manual to existing development 3) Make recommendations to stormwater mgmt manual 4) Increase stormwater storage/detention capacity 5) Improve native riparian and bank vegetative cover	Model based on 5-year EIA year target and other projects
			Ratio of 10-year predevelopment peak flow to 2-yr existing peak flow	Watershed wide	Ratio of 10-year predevelopment peak flow to 2-yr existing peak flow: 2.5	Tryon ~0.6		No specific data for tributaries	Reduce 2 year existing peak flow to Increase ratio		Establish a relationship between EIA and 2 year peak flow. Model target ratio based on 5-year EIA target and other projects

			Effective impervious area (EIA)	Watershed wide	EIA<10%	High impervious cover in upper portion of subwatershed. Subwatershed average MIA: **Tryon** = 22.6% (MIA >40% along and above I-5); **Falling** = 37.3% (Area around 35th Ave. and Huber has highest MIA) ; **Arnold**=24%			Reduce EIA, focus on upper portions of Tryon		Establish existing EIA and reduce EIA 2%
			Drainage complexity (ratio of open channel to piped stream length)	Watershed wide	Naturally complex drainage system of open channels. None of basin served by storm sewer	Drainage complexity (open channel/piped): **Tryon watershed: 0.99**	NA		Increase natural drainage complexity (increase ratio of open channel to pipe)	1)Land acquisition 2) Protect existing natural resources 3) Help develop standards to strengthen and apply to drainage reserve code 4) Increase protections where needed to conserve important resources and functional values 5) Stream enhancement (such as daylighting streams).	Stabilize natural drainage complexity at current level (promote bridges and natural bottomed culverts, protect existing drainages)
			Acres of impervious area affected by stormwater projects		None affected	Existing development not affected	NA		Increase acres of impervious area affected with stormwater projects. Focus on upper watershed.	1) Develop and implement stormwater retrofit projects	Projects to encompass 15-20 acres of impervious surfaces
	Storm Sewer Infrastructure	Restore infrastructure such that all storm drainage facilities within the closed conduit system area designed to pass a 10-yr storm without surcharge and provide conveyance of the 100-yr storm meeting health and safety requirements.	Number of deficient culverts and storm pipes	see "current conditions"	Number of deficient culverts and storm pipes: NA	(12 inch and above in size) - PFP identifies 11 culverts along the mainstem and tributaries that are undersized for the 25 year design storm under current conditions and 13 culverts identified as undersized under future conditions (2040). Total: 1067 ft.	Increased impervious cover contributing to increased stormwater runoff	Not all pipes or culverts that surcharge are problems	Decrease quantity of deficient pipes	1) Stream enhancement projects (i.e. replace deficient culverts with larger culverts or bridges)	Decrease quantity of deficient pipes (50-100 lineal feet)

		Remove physical and hydraulic barriers for fish passage. Physical barriers include culverts with downstream invert elevations that are 12" above residual pools, lengths >100' and/or with gradients >0.5%. Hydraulic barriers include lack of flow depth and flow velocities > 2 fps.	Number of impassable barriers		Natural barriers: **Tryon**: Marshall Cascade; **Arnold:** Arnold Falls	**Tryon** State Street culvert (200 ft long) impassable during Fall run, Boones Ferry Road culvert (150 ft long, 12 inch drop, 2% slope) is impassable **Falling** impassable at SW 35th Ave, at Huber St, and at 39th Ave, seasonally impassable at 26th Ave and at Pomona St **Arnold** impassable at 1056 SW Arnold, 11005 SW 16th Pl, 10921 SW Lancaster Rd, and seasonally impassable at 1350 SW Arnold, Arnold Cascades, 1824 SW Arnold, and 11205 SW 35th Ave	NA	Unknown impacts at some culverts	Year-round fish passage, particularly throughout Tryon mainstem	1) Retrofit critical fish passage culverts	Feasibility study of Hwy 43 culvert first and possibly Boones Ferry Rd culvert
Water Quality	**Stream Temperature**	Reduce summer in-stream temperatures to improve surface water quality.	7 day average of daily maximum temperature	Boones Ferry Rd.	7 day average maximum daily temperature is below 18.0 C; below 13.0 C during spawning and incubation	Boones Ferry Rd. monitoring station (1998-2002). Maximum summer period daily temperatures range from 20.0-21.9 C and 7-day average exceeds standard from 27 to 42 days each summer	**Tryon**: **Lack of riparian canopy, particularly in upper Tryon** subwatershed (reaches 4-5), due to development and residential landscaping. **Arnold**: Lower Arnold Creek exhibits high riparian integrity, conditions decline upstream due to residential development	No stream specific data for tributaries	7 day average maximum daily temperature is below 18.0 C; below 13.0 C during spawning and incubation	1) Land acquisition 2) Protect existing natural resources 3) Increase protections where needed to conserve important resources and functional values 4) Improve native riparian and bank vegetative cover.	No net increase
			Stream "effective shade"	see "current condition"	Stream "effective shade">95%	average shade cover from ODFW **Tryon:** R1= 71% avg, range 33-100; R2= 85% avg, range 61-100; R3= 84% avg, range 50-100; R4= 83% avg, range 36-100 **Falling:** riparian coverage poor and fragmented **Arnold:** avg. 88% **,** range 56-100			Stream effective shade - average 90-95% basinwide	1) Improve native riparian and bank vegetative cover	Establish effective shade and increase by 5%, particularly in R4 and upper watershed. Or, shade range I>70% in R4 and upper watershed.
			Stream bank vegetative cover (overhanging vegetation)	see "current condition"	Stream banks covered with native vegetation	**Tryon**: Stream bank vegetation cover good in R2 and R3, moderate to poor in R1, R4, and R5. Non-natives present throughout. **Falling**: poor riparian integrity, much of stream banks heavily landscaped and homes abut creek banks. **Arnold**: riparian vegetation conditions are poor in middle and upper portions due to residential landscaping.		Falling Creek has not been surveyed thoroughly	Increase native stream bank vegetation throughout	1) Improve native riparian and bank vegetative cover	Increase native stream bank vegetation throughout. Target R3, R4 and upper watershed where bank are highly eroding (20 acres?)
	In-stream Bacteria (E. coli)	Reduce in-stream bacteria concentrations to improve surface water quality.	Bacteria (E. Coli) concentrations per 100 ml. Minimum of 5 samples	At Boones Ferry Rd.	Below 126 organisms per 100 ml. (based on minimum of 5 samples within 30 days)	Frequency of sampling not great enough to assess	Non-point sources (pets, wildlife), faulty septic systems, and sanitary system leakage	Frequency of sampling not great enough to assess	Below 126 organisms per 100 ml. (based on minimum of 5 samples)	1) Outreach and education programs to reduce non-point source pollutants 2) Develop and implement actions to reduce non-stormwater related discharges	Increase sampling frequency to a level required for analysis

			Bacteria (E. Coli) concentrations per 100 ml. Single sample	At Boones Ferry Rd.	Below 406 organisms per 100 ml. (maximum of any single sample	At Boones Ferry Rd, % of samples>406 organisms/100ml Summer =23%; Fall/Winter/Spring=16%		No stream specific data for tributaries	All below 406 organisms per 100 ml. (maximum of any single sample	Develop bacteria management plan (Willamette TMDL)	Decrease summer and winter exceedences, no more than 15% of single samples exceeding.
	Dissolved Oxygen (DO)	Meet dissolved oxygen standards	DO	At Boones Ferry Rd.	At least 11.0 mg/l (30 day mean minimum)	Boones Ferry Rd. monitoring station (11 grab samples taken from 1997-2002): DO concentration averages 10mg/l May through June, met during rest of year	Increased temperature (see Stream Temperature). Increased nutrient loads which increase oxygen demand	No stream specific data for tributaries	At least 11.0 mg/l (30 day mean minimum)	1) Develop and implement stormwater retrofit projects 2) Work with BDS to apply stormwater mgmt manual to existing development 3) Improve native riparian,bank , and upland vegetative cover 4) Improve O & M practices 5) Treat stormwater runoff, particularly from commercial and transportation corridors.	
	Total Suspended Solids (TSS)	Reduce total suspended solids (TSS) to improve in-stream water quality.	TSS (stormwater discharges)	see "current condition"	Background sources:-no anthropogenic sources of TSS	**Tryon** Silt and sediment accumulate in the lower reaches; **Arnold** Silt and sediment accumulates in deposition areas, such as pools.	Grid Model indicates commercial, multifamily, and transportation LU's have higher loading rates.		70% reduction from current conditions in TSS in stormwater discharges as required by stormwater management manual	1) Develop and implement stormwater retrofit projects 2) Treat stormwater runoff particularly in commercial & transportation corridors 3) Work with BDS to apply stormwater mgmt manual to existing development 4) Land acquisition 5) Maintain existing zoning 6) Protect existing natural resources 7) Strengthen erosion control manual 8) Increase protections where needed to conserve important resources and functional values 9) Improve native riparian, bank, and upland vegetative cover 10) Improve O and M practices	Reduce TSS in stormwater discharges
			Erosion control measures	Throughout Watershed	Erosion control: NA	Erosion control manual governs new and redevelopment	Enforcement of erosion control manual		More stringent control and enforcement measures in the City's erosion control manual	1) Strengthen erosion control manual	Work with BOP and other City Bureaus to further improve erosion control requirements as opportunities arise.

			O&M Activities	Throughout Watershed	O and M activities: NA	Examples of O and M activities: Street sweeping, sediment trap cleaning	Potential Causes: infrequent maintenance, timing, and maintenance practices/protocols		Improved O and M practices and increased activities to reduce TSS in stormwater runoff	1) Improve O and M practices	Increase frequency and timing of street sweeping on transportation corridors in upper watershed. Implement projects to trap sediment in stormwater runoff from transportation/commercial corridors
			Feet of streambank vegetated	see "current condition"	Stream banks covered with native vegetation	**Tryon**: Stream bank vegetation cover good in R2 and R3, moderate to poor in R1, R4, and R5. Non-natives present throughout. **Falling**: poor riparian integrity, much of stream banks heavily landscaped and homes abut creek banks. **Arnold**: riparian vegetation conditions are poor in middle and upper portions due to residential landscaping.	Development and residential landscaping		Increase native bank vegetation coverage throughout	1) Improve native riparian, bank, and upland vegetative	Increase native stream bank vegetation throughout. Target R3, R4 and upper watershed where bank are highly eroding (20 acres?)
	Other In-stream pollutants	Reduce in-stream pollutant concentrations to levels that do not threaten aquatic life or human health.	Stormwater runoff related pollutants	Throughout Watershed	Toxics: No anthropogenic sources of pollutants	Data lacking	Transportation infrastructure and development and pesticide/herbicide usage	Frequency of samplying not great enough to assess	Reduction of toxic pollutants	1) Treat stormwater runoff, particularly from commercial and transportation corridors 2) Improve O & M practices 3) Outreach and education programs to reduce non-point source pollutants	Increased monitoring
			Percentage of area meeting stormwater manual water quality treatment criteria.	Throughout Watershed	NA	All new and redevelopment meets stormwater manual criteria, no requirements to retrofit existing development	New and redevelopment must comply with manual. No strategy to retrofit existing development		Strategy to apply stormwater management manual to existing development		

Physical Habitat	**Riparian and Floodplain Conditions**	Protect and restore riparian and floodplain condition and connectivity	Stream bank condition	see "current conditions"	>90% banks stable	% Stable banks: **Tryon** R1=31%; R2=64%; R3=34%; R4=42% **Falling** generally moderately unstable **Arnol**d 21%	**Tryon**: TCSNA protected. Upper subwatershed fragmented due to residential development, transportation, non-native landscaping. **Falling**: exhibits poor riparian connectivity due to residential development **Arnold**: Lower Arnold Creek exhibits high riparian integrity, conditions decline upstream due to residential development.	Falling Creek has not been surveyed thoroughly	>90% stable banks	1) Implement stormwater retrofit projects 2) Apply stormwater manual to existing development 3) Land Acquisition 4) Maintain existing zoning 5) Protect existing natural resources 6) Strengthen erosion control manual 7) Develop standards for drainage reserve code 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Improve native upland vegetative cover	Increase bank stability throughout. In particular, increase % of R3 and R4 stable banks to >50%. Replicate ODFW survey.
			Riparian Width	see "current conditions"	>/250 feet. Continuous corridor of mature native vegetation including red alder, big leaf maple, western red cedar, Douglas fir, vine maple, western wahoo, and salmonberry	**Tryon** R2-R4A, riparian widths average 200 ft or more, tree canopy cover high, well-established second growth forest. Narrow riparian corridors in R1 and much of upper subwatershed (R4); **Falling**: <100 feet width riparian coverage, vegetative cover from residential yards **Arnold**: greater than 100' except in areas where Arnold Rd, houses and backyards are very close			Continuous corridor of mature native vegetation up to 300 ft where possible or 4X bank full width. Consistent with Ep and Ec zones.	1) Land Acquisition 2) Protect existing natural resources 3) Increase protections where needed to conserve important resources and functional values 4) Improve native riparian and bank vegetative cover.	Increase riparian width throughout. R4 and upper watershed are particularly degraded - increase vegetated riparian width to 150 ft where possible. Replicate ODFW survey.
			Riparian Fragmentation	see "current conditions"	<2 stream crossings per KM of stream length	**Tryon**: Riparian connectivity good in R2-R3. Connectivity poor in R1, R4, and R5; **Falling & Arnold** : Riparian corridor fragmented by roadways, homes, trails, and pipes	Transportation infrastructure and development encroachment.		Minimize roads and trail crossings and reduce their impacts	Evaluate culvert retrofits or replacements or possible suspended foot bridges at specific locations	Minimize roads and trail crossing and their impacts and preserve drainage complexity.

			Bank vegetation composition	see "current conditions"	Continuous corridor of mature native vegetation including red alder, big leaf maple, western red cedar, Douglas fir, vine maple, western wahoo, and salmonberry	**Tryon** R1-R2 Grasses and forbes are common in understory, canopy provided by second-growth trees, cedar and arbor vita; R3-R4A Dominated by mature deciduous trees and conifers, with maples and douglas fir in lower park and maples and cedars in upper park; R4B-R5 Maple and alder common, and sparse shrubs and grasses **Falling** landscaped yards with non-natives prevalent , some mixed forest of douglas fir and hemlock **Arnold** upland and riparian vegetation is generally less than 60-yrs old; trees mostly deciduous 3-15 cm, and the largest trees are 90+ cm dbh conifers;	**Tryon**: TCSNA protected, however bank vegetation lacking in some areas, causing bank erosion. Upper subwatershed fragmented due to residential development, transportation, non-native landscaping. **Falling**: exhibits poor riparian connectivity due to residential development **Arnold**: Lower Arnold Creek exhibits high riparian integrity, conditions decline upstream due to residential development.	Falling Creek has not been surveyed thoroughly	>90% cover by native vegetation	1) Land Acquisition 2) Protect existing natural resources 3) Increase protections where needed to conserve important resources and functional values 4) Improve native riparian and bank vegetative cover.	Increase native bank vegetation coverage throughout. Stream banks in R3 and R4 are highly unstable and should be targeted in the near term. Replicate ODFW survey.
			Stream shade cover	see "current conditions"	Stream "effective shade">95%	**Tryon** R1= 71% ave, range 33-100%; R2= 85% ave, range 61-100%; R3= 84% ave, range 50-100%; R4= 83% ave, range 36-100% **Falling** riparian coverage poor and fragmented **Arnold** ave. 88% , range 56-100%			Stream effective shade - average 90-95% basinwide (Note: should we use average shade data for indicator, target, and benchmarks	1) Land Acquisition 2) Protect existing natural resources 3) Increase protections where needed to conserve important resources and functional values 4) Improve native riparian and bank vegetative cover.	Establish effective shade and increase average shade by 5%, particularly in R4 and upper watershed. Or, shade range I>70% in R4 and upper watershed.
			Number of riparian conifers (30m both sides of stream) >20-in diameter at breast height (dbh)/1000 ft stream	see "current conditions"	More than 300 riparian conifers (30m both sides of stream) greater than 20 in dbh/1000 ft stream length.	Number of conifers >20" dbh **Tryon** R1= 0; R2 = 61; R3= 152; R4= 37 **Falling** poor riparian integrity **Arnold** 107			Lower and middle Tryon: 225 conifers. Enhance riparian vegetation in upper Tryon and tributaries	1) Land Acquisition 2) Protect existing natural resources 3) Increase protections where needed to conserve important resources and functional values 4) Improve native riparian and bank vegetative cover.	No net loss. Increase riparian conifers throughout. R 4 and upper watershed in particular lack conifers and should be targeted in the near term. Replicate ODFW survey.
			Number of riparian conifers (30m both sides of stream) >35-in dbh/1000 ft stream	see "current conditions"	More than 200 riparian conifers (30m both sides of stream) >35-in dbh/1000 ft stream	# conifers >35" dbh **Tryon** R1= 0; R2 = 0; R3= 15; R4= 0; **Falling** poor riparian integrity **Arnold** 30			Lower and Middle Tryon: 150 conifers. Enhance riparian vegetation in upper Tryon and tributaries	1) Land Acquisition 2) Protect existing natural resources 3) Increase protections where needed to conserve important resources and functional values 4) Improve native riparian and bank vegetative cover.	No net loss. Increase riparian conifers throughout. R 4 and upper watershed in particular lack conifers and should be targeted in the near term. Replicate ODFW survey.

			Ratio of floodway to stream width (valley width index)	see "current conditions"	Ratio of floodway to stream width (VWI)>2.5 in TCSNA and portions of Falling and Arnold	Valley width index: **Tryon** R1= 20; R2=4.3; R3A=7.8; R3B=10.6; R4A=5.0; R4B=10.5; R4C=8.0 **Falling** floodway confined generally **Arnold** R1A =5.0; R1B =11.5; R1C=3.0; R1D=8.3	High peak flows from upland impervious areas, lack of stable native riparian vegetation.	Falling Creek has not been surveyed thoroughly	Enhance Floodplain Connectivity	1) Implement stormwater retrofit projects 2) Apply stormwater manual to existing development 3) Land Acquisition 4) Maintain existing zoning 5) Protect existing natural resources 6) Increase protections where needed to conserve important resources and functional values 7) Stream enhancement projects, i.e. LWD placement 8) Implement projects to enhance floodplain connection	No net loss of existing floodplain connectivity. Reconnect floodplain where possible as opportunities arise. R3, R4, and Arnold 1B provide the best opportunities in the near term (X feet of floodplain reconnected?). Replicate ODFW survey
			Entrenchment ratio (floodprone width/active channel width)		Entrenchment ratio: NA (values >1.0 signify increasing floodplain interaction)	Entrenchment ratio: **Tryon** R1= 1.5; R2=1.2; R3A=1.3; R3B=1.4; R4A=1.4; R4B=1.4; R4C=1.4 **Falling** limited floodplain interaction **Arnold** R1A & R1B =1.5; R1C &1D= N/A					
			Stream gradient (%)		**Tryon**: Downstream of Boones Ferry Rd is generally below 2%, upper basin averages 2.3-3.1%; **Arnold & Falling**: low to moderately steep stream gradient	Average gradient: **Tryon** R1= 1.5; R2=1.2; R3A=1.3; R3B=1.4; R4A=1.4; R4B=1.4; R4C=1.4 **Falling** 3.4% **Arnold** R1A= 3.1%; R1B= 3.8%; R1C= 4.5%; R1D= 1.1%; R1E= 1.9%; R1F= 3.7%	NA	Falling Creek has not been surveyed thoroughly	NA (context only)	NA	NA
	Stream Channel Complexity	Increase stream channel complexity to improve bank form habitats, protect and stabilize stream banks, provide areas for wood and substrate (e.g., fine sediment) to accumulate and settle (e.g., deep pools), and aide channel building processes, such as pool formation.	Large wood (15cm cubed min. size)/100 m stream length	see "current conditions"	>20 pieces of large wood (15 cm cubed min. size)/100 m stream length	#Pieces/100m stream **Tryon** R1= 4.5; R2= 42.3; R3A= 53.6; R3B= 34.0 R3C= 6.4 ;R4A= 17.8 R4B= 2.7; R4C: 6.4 **Falling** lacking in woody debris **Arnold** R1A= 6.8 ; R1B= 4.6; R1C= 1.4 ; R1D= 5.5; R1E= 11.4	The forest stand structure (size, age and condition) does not presently provide substantive sources of wood to the creeks. Past logging also contributes to the problem. **Tryon**: There is a high potential for long-term recruitment. Older forest in R2, younger forest in middle and upper reaches. Sources of wood recruitment severely lacking in upper subwatershed (R4-R5). **Falling**: exhibits poor riparian connectivity due to residential development.		Increase LWD throughout>20 pieces/100m stream length	1) Implement stormwater retrofit projects 2) Apply stormwater manual to existing development 3) Land Acquisition 4) Maintain existing zoning 5) Protect existing natural resources 6) Increase protections where needed to conserve important resources and functional values 7) Stream enhancement projects, i.e. LWD placement 8) Improve native riparian and bank vegetative cover	Increase LWD throughout. Target: R1, R3C, R4B, R4C and upper watershed > 10 pieces/100m stream. Replicate ODFW survey
			Wood volume	see "current conditions"	>30 m cubed of wood /100m stream length	Wood volume m^3/100m stream:. **Tryon** R1=5.06; R2= 1.40; R3A= 1.74; R3B=0.95; R3C=0.94; R4A=3.82; R4B: 0.39; R4C=3.47 **Falling** lacking in woody debris **Arnold** R1A=3.93; R1B=1.31; R1C=0.28; R1D=1.08; R1E=0.99			Increase wood volume throughout to > 20 m cubed.	1) Stream enhancement projects, i.e. LWD placement 2) Improve native riparian and bank vegetative cover	Increase wood volume throughout. Target in the near term: R1, R3, and R4B > 30 m cubed. Replicate ODFW survey

			Key pieces of wood (>60 cm and 10m long)/100 m stream length	see "current conditions"	>3 key pieces of wood (>60 cm and 10m long)/100 m stream length	# key pieces: **Tryon** R1=0; R2=0; R3A=0.91; R3B=0; R3C=0; R4=0; R4B=0; R4C=0 **Falling** lacking in woody debris **Arnold** 0	**Arnold**: Lower Arnold Creek exhibits high riparian integrity, conditions decline upstream due to residential development.		Increase key pieces throughout to >3 pieces/100 m stream length	1) Stream enhancement projects, i.e. LWD placement 2) Improve native riparian and bank vegetative cover	Increase key pieces throughout. Itarget in near term: R1, R3 and 4A > 1 key piece/1000 m. Replicate ODFW survey.
			source wood	see "current conditions"	Adequate source of wood, comprised of native conifers and hardwoods	The forest stand structure (size, age, species comp,) does not provide substantive sources of wood to the creek	Refer to attribute above - riparian condition		Adequate source of wood, comprised of native conifers and hardwoods	1) Protect existing natural resources 2) Increase protections where needed to conserve important resources and functional values 3) Stream enhancement projects, i.e. LWD placement 4) Improve native riparian and bank vegetative cover	No net loss of native riparian conifers and hardwoods. Increase riparian conifers throughout. R4 and upper watershed in particular lack conifers and should be targeted in the near term. Replicate ODFW survey.
		Improve spawning and rearing habitats for native fish communities	Pool Area (% of total stream area)	see "current conditions"	Pool area>35%	**Tryon** R1= 55%; R2=76%; R3= 65%; R4= 30% **Falling** no data **Arnold** 25%	Overall, lack of large wood combined with the prevalence of higher, flashy storm flows (promoting erosion and sediment deposition) significantly impacts stream habitat formation and maintenance of good quality spawning and rearing fish habitat, and is likely a prominent factor limiting fish productivity	Falling Creek has not been surveyed thoroughly	Maintain pool area>35% throughout	1) Implement stormwater retrofit projects 2) Apply stormwater manual to existing development 3) Land Acquisition 4) Maintain existing zoning 5) Protect existing natural resources 6) Increase protections where needed to conserve important resources and functional values 7) Stream enhancement projects, ie. LWD placement 8) Improve native riparian and bank vegetative cover	Improve in-stream habitat throughout. Target R4 and other areas lacking pool area throughout lower and middle Tryon
			Pool frequency (channel widths between pools)	see "current conditions"	Pool frequency (channel widths between pools) is 5-8	Channel width/pool: **Tryon** R1=4.8; R2=4.7; R3= 7.1; R4= 9.3 **Arnold** 18 **Falling** no data			Maintain pool frequency at 5-8 pools per channel width throughout	1) Protect existing natural resources 2) Increase protections where needed to conserve important resources and functional values 3) Stream enhancement projects, i.e. LWD placement 4) Improve native riparian and bank vegetative cover	Improve in-stream habitat throughout. Target R1, R2, and R4

			Residual pool depth	see "current conditions"	Average residual pool depth>0.5m	Average Residual pool depth (m): **Tryon** R1=0.64; R2= 0.59; R3=0.62; R 4= 0.46. Pools are generally of marginal quality. Most deep pools in lower and middle subwatershed. Lacking in R4A-4C (above Boones Ferry). **Arnold** 0.38 **Falling** pools are deep compared to creek depth			Retain deep pools > 0.5m throughout	1) Protect existing natural resources 2) Increase protections where needed to conserve important resources and functional values 3) Stream enhancement projects, i.e. LWD placement 4) Improve native riparian and bank vegetative cove	Increase average residual pool depth to >0.5m in R4A-R4C. Replicate ODFW survey
			# Complex pools (pools w/wood complexity>3 pieces)/ 1000m	see "current conditions"	> 2.5 Complex pools (pools w/wood complexity>3 pieces)/1000m	# complex pools/1000m average: **Tryon** R1=0; R2=6.8; R3A=13.5; R 3B= 7.6; R3C= 0; R 4A= 2.1 R4B=0; R4C=0 **Arnold & Falling** 0			Increase the number of complex pools to >2 throughout	1) Protect existing natural resources 2) Increase protections where needed to conserve important resources and functional values 3) Stream enhancement projects, i.e. LWD placement 4) Improve native riparian and bank vegetative cover	Increase the number of complex pools to > 2/1000m stream length, particularly in R3B and R3C. Replicate ODFW survey.
			Riffle area	see "current conditions"	Riffle area comprised at least 50% of stream	Stream area comprising of at least 50% riffles: **Tryon** moderately low, degraded by fines throughout. R1= 20%; R2= 17%; R3= 29%; R4= 17% **Falling** no data **Arnold** 50%			Increase riffle are to~ 40-50%	1) Implement stormwater retrofit projects 2) Land Acquisition 3) Protect existing natural resources 4) Increase protections where needed to conserve important resources and functional values	Increase riffle area throughout. Replicate ODFW survey.
			Riffle gravel area (% of riffle area)	see "current conditions"	>35% of riffle area composed of gravels	% gravel in riffles: **Tryon** R1=21%: R2=30%; R3=47%; R4= 42% **Falling** no data **Arnold** R1A, R1C and Cascades >35% riffle area composed of gravels; R1B, R1D and R1E 60-90% of the riffle areas are composed of >35% gravels			Retain >35% riffle area composed of gravel substrate	1) Protect existing natural resources 2) Increase protections where needed to conserve important resources and functional values 3) Stream enhancement projects, i.e. LWD placement 4) Improve native riparian and bank vegetative cover	Increase riffle gravel area to >35% in R1 and R2. Replicate ODFW survey.
			Percent fines in riffles	see "current conditions"	<10% fines in riffles	% fines: **Tryon** R1-R3=27%-31%; R4= 21% **Falling** no data **Arnold** 12-25%	Grid Model indicates commercial, multifamily, and transportation LU's have higher loading rates.	Stream channel and bank erosion also contributed to TSS	Throughout Tryon: <10% of riffle area with fines>10%	1) Implement stormwater retrofit projects 2) Apply stormwater manual to existing development 3) Land Acquisition 4) Maintain existing zoning 5) Protect existing natural resources 6) Strengthen erosion control manual 7) Develop standards for drainage reserve code 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Improve native upland vegetative cover	Reduce fines, particularly in R1, R3B and Arnold 1C to <10% of riffle area with fines>10%. Replicate ODFW survey.

			All in-stream habitat	see "current conditions"	<10% fines in all stream habitat	Average % fines: **Tryon** R1=28%; R2=26%; R3=22%; R4=15% **Falling** no data **Arnold** 17%			Lower and middle Tryon <10% fines	1) Protect existing natural resources 2) Increase protections where needed to conserve important resources and functional values 3) Stream enhancement projects, i.e. LWD placement 4) Improve native riparian and bank vegetative cover	Reduce fines, particularly in R1, R3B and Arnold 1C to <10% in all stream habitat. Replicate ODFW survey.
	Existing Natural Areas	Protect existing natural areas to help retain existing natural watershed functions and critical habitat.	Large undeveloped parcels (>0.5 acres) adjacent to creek	see "current conditions"	All undeveloped	**Tryon** 768 acres of public and private open space (22% of subwatershed) ; **Falling** 27.6 acres of open space (9.8% of subwatershed) **Arnold** 9.5% of subwatershed comprised of open spaces	Past and current protections, zoning, and acquisition programs.		Improve and expand protections and increased public ownership of areas providing critical watershed functions.	1) Land acquistion 2) Maintain existing zoning 3) Protect existing natural resources 4) Increase protections where needed to conserve important resources and functional values	Work with Parks and other City Bureaus to acquire critical areas as opportunities arise
			Environmental zones		NA	Environmental conservation zones cover 446 acres and protection zones cover 551 acres	TBD		Increase E-zone coverage and strengthen protections	1) Land acquistion 2) Maintain existing zoning 3) Protect existing natural resources 4) Increase protections where needed to conserve important resources and functional values	Work with BOP to increase E-zone coverage and strengthen protections as opportunities arise (How much has coverage increased over the last few years? Is there a trend?)
	Fish Passage Barriers	Remove significant fish passage barriers (physical and hydraulic) to improve stream connectivity and potential fish population productivity.	Impassable or nearly impassable culverts and other fish barriers	see "current conditions"	Natural barriers: **Tryon**: Marshall Cascade; **Arnold:** Arnold Falls	**Tryon** State St culvert (200 ft long) prevents fish passage during Fall run, Boones Ferry Rd culvert (150 ft long, 12 inch drop, 2% slope) is impassable **Falling** impassable at SW 35th Ave, at Huber St, and at 39th Ave, seasonally impassable at 26th Ave and at Pomona St **Arnold** impassable at 1056 SW Arnold, 11005 SW 16th Pl, 10921 SW Lancaster Rd, and seasonally impassable at 1350 SW Arnold, Arnold Cascades, 1824 SW Arnold, and 11205 SW 35th Ave	NA	Unknown impacts at some culverts	Year-round fish passage	1) Remove/retrofit critical fish passage culverts	Feasibility study of Hwy 43 culvert first and possibly Boones Ferry Rd. culvert

Biological Communities	**Native fish communities**	Restore healthy, self-sustaining populations of all native fish communities.	Presence/absence: steelhead	see "current condition"	Steelhead: Self-sustaining population	**Tryon** Steelhead observed in lower and middle reaches during 1999-2001 fish survey. Indicates anadromous steelhead pass above State St. culvert and/or resident population persists throughout subwatershed. However, abundance, diversity and distribution limited by habitat conditions **Arnold**: Boones Ferry culvert and Marshall cascades are impassable; no anadromous fish passage. Resident populations may occupy habitats upstream of fish barriers.	Overall, lack of large wood combined with the prevalence of higher, flashy storm flows (promoting erosion and sediment deposition) and restrictive/impassable culverts significantly impacts stream habitat formation and maintenance of good quality spawning and rearing fish habitat, and is likely a prominent factor limiting fish productivity.	Falling Creek has not been surveyed by ODFW	Self-sustaining population	1) Develop and implement stormwater retrofit projects 2) Treat stormwater runoff particularly in commercial & transportation corridors 3) Apply stormwater mgmt manual to existing development 4) Land acquisition 5) Maintain existing zoning 6) Protect existing natural resources 7) Strengthen erosion control manual 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Enhance floodplain connections 11) Retrofit critical fish passage culverts 12) Improve native riparian, bank, and upland vegetative cover 13) Improve O and M practices	Monitor implementation of programs and actions and conduct assessments of conditions and biological communities
			Presence/absence: cutthroat	see "current condition"	Cutthroat: Self-sustaining population	**Tryon** Observed in every reach and during every sampled season. However, abundance, diversity, and distribution limited by habitat conditions Boones Ferry culvert and Marshall cascades are impassable; no anadromous fish passage. Resident populations of cutthroat may occupy habitats upstream of fish barriers.			Self-sustaining population	1) Develop and implement stormwater retrofit projects 2) Treat stormwater runoff particularly in commercial & transportation corridors 3) Apply stormwater mgmt manual to existing development 4) Land acquisition 5) Maintain existing zoning 6) Protect existing natural resources 7) Strengthen erosion control manual 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Enhance floodplain connections 11) Retrofit critical fish passage culverts 12) Improve native riparian, bank, and upland vegetative cover 13) Improve O and M practices	Monitor implementation of programs and actions and conduct assessments of conditions and biological communities

			Presence/absence: coho	see "current condition"	Coho: Self-sustaining population	**Tryon** Juvenile coho observed 2001-2002 in spring, summer, and fall in lower subwatershed (R1). R1 functions as off-channel rearing and refuge habitat **Arnold** Boones Ferry culvert and Marshall cascades are impassable; no anadromous fish passage	State street culvert likely most prominent limiting factor affecting distribution - likely excludes fall run fish. Habitat conditions upstream however would provide good spawning and rearing habitat.		Self-sustaining population	Same as above	Monitor implementation of programs and actions and conduct assessments of conditions and biological communities
			Presence/absence: chinook	see "current condition"	Chinook: did not populateTryon Cr	**Tryon** Present in Reach 1 in summer and fall, not spring. Juveniles use Reach 1 year round as off-channel habitat to Willamette mainstem. Likely provides only temporary refuge. **Arnold** Boones Ferry culvert and Marshall cascades are impassable; no anadromous fish passage	Overall, lack of large wood combined with the prevalence of higher, flashy storm flows (promoting erosion and sediment deposition) significantly impacts stream habitat formation and maintenance of good quality spawning and rearing fish habitat, and is likely a prominent factor limiting fish productivity		Will continue to not populate Tryon, lower Tryon will provide rearing and refuge habitat for Willamette Basin Chinook	Same as above	Monitor implementation of programs and actions and conduct assessments of conditions and biological communities
			Spatial structure: steelhead	see "current condition"	Steelhead spatial structure: Up to Marshall Cascades and Arnold Falls	**Tryon** Steelhead observed in lower and middle reaches during 1999-2001 fish survey. Indicates anadromous steelhead pass above State St. culvert and/or resident population persists throughout subwatershed. However, abundance, diversity and distribution limited by habitat conditions.		Falling Creek has not been surveyed by ODFW	Up to Marshall Cascades and Arnold Falls	1) Develop and implement stormwater retrofit projects 2) Treat stormwater runoff particularly in commercial & transportation corridors 3) Apply stormwater mgmt manual to existing development 4) Land acquisition 5) Maintain exisiting zoning 6) Protect existing natural resources 7) Strengthen erosion control manual 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Enhance floodplain connections 11) Retrofit critical fish passge culverts 12) Improve native riparian, bank, and upland vegetative cover 13) Improve O and M practices	Increase access into TCSNA. Monitor implementation of programs and actions and conduct assessments of conditions and biological communities

			Spatial structure: cutthroat	see "current condition"	Cutthroat spacial structure: Up to at least Marshall Cascades on Tryon and to Arnold Falls on Arnold Cr	**Tryon** Observed in every reach and during every sampled season. However, abundance, diversity, and distribution limited by habitat conditions **Arnold** Boones Ferry culvert and Marshall cascades are impassable; no anadromous fish passage			Up to Marshall Cascades and Arnold Falls	Same as above	Increase access into TCSNA. Monitor implementation of programs and actions and conduct assessments of conditions and biological communities
			Spatial structure: coho	see "current condition"	Coho spatial structure: Up to confluence of Tryon and Arnold Creek and possibly up to the Marshall Cascades	**Tryon** Juvenile coho observed 2001-2002 in spring, summer, and fall in lower subwatershed (R1), which functions as off-channel rearing and refuge habitat **Arnold**; No anadromous fish passage into Arnold Cr.			Up to confluence of Tryon and Arnold Creek and possibly up to the Marshall Cascades	Same as above	Increase access into TCSNA. Monitor implementation of programs and actions and conduct assessments of conditions and biological communities
			Spatial Structure: chinook	see "current condition"	Chinook spatial structure: Through Reach 1 of Tryon Creek	**Tryon** Present in R1 in summer and fall, not spring. Juveniles use R1 year round as off-channel habitat to Willamette mainstem. Likely provides only temporary refuge. **Arnold** No anadromous fish passage			Through Reach 1 of Tryon Creek as off-channel habitat to Willamette mainstem	Same as above	Increase access into TCSNA. Monitor implementation of programs and actions and conduct assessments of conditions and biological communities
			Refer to attribute above - stream channel complexity	see "current conditions" under stream channel complexity	Substantive off-channel habitat	Refer to attribute above - stream channel complexity	Refer to attribute above - stream channel complexity		Refer to attribute above - stream channel complexity	Same as above	Increase access into TCSNA. Monitor implementation of programs and actions and conduct assessments of conditions and biological communities
			Index of Biotic Integrity (IBI) - community richness	see "current condition"	Index of Biotic Integrity (IBI) >=75	**Tryon** R1: moderately impaired in Spring/Summer, acceptable in Fall; R2: Severely impaired in Spring/Summer, moderately impaired in Fall R3 & R4: Severely impaired	Lack of stream channel complexity/ habitat		Improve biotic integrity	Same as above	Improve IBI in R1-R3

	Macroinvertebrates	Increase macroinvertebrate abundance and production	Benthic Index of Biotic Integrity (B-IBI) :Ephemeroptera, Plecoptera, & Trichoptera abundance	Subwatershed wide	A balanced, integrated adaptive assemblage of benthic organisms having species composition, diversity and functional organization comparable to other natural (reference) habitats in the region: High biological integrity.	**Tryon** EPT taxa abundance mean =32% and richness = 4 taxa		Falling Creek and Arnold has not been surveyed by ODFW	B-IBI statistically similar to reference sites	1) Develop and implement stormwater retrofit projects 2) Treat stormwater runoff particularly in commercial & transportation corridors 3) Apply stormwater mgmt manual to existing development 4) Land acquisition 5) Maintain existing zoning 6) Protect existing natural resources 7) Strengthen erosion control manual 8) Increase protections where needed to conserve important resources and functional values 9) Stream enhancement projects 10) Improve native riparian, bank, and upland vegetative cover 11) Improve O and M practices	Monitor implementation of programs and actions and conduct assessments of conditions and biological communities
Public Involvement, Education, and Stewardship	# of programs to promote community stewardship	Establish strategies for promoting and carrying out community stewardship projects and programs to improve watershed health.	Number of Technical Assistance/Incentive programs for streamside property owners for ecological improvements	Watershed wide	NA	1. Free Plants; 2. Naturescaping for Clean Rivers,; 3. Partnership with SOLV; 4) BES Revegetation Program, 5) Friends of Trees Partnership			Expanded and fully funded progrtams promoting streamside ecological improvements on private property	Work with watershed services staff and management to expand and fully fund these programs and partnerships	Increase capacity of existing programs
			Number of Technical Assistance/Incentive programs to implement stormwater retrofits on private property	Watershed wide	NA	1. EPA wet weather grants			Well established and funded technical assistance programs to implement stormwater retrofits on private property	Work with watershed services staff and management to expand and fully fund these programs and partnerships	Establish at least one consistently funded technical assistance program.
			Number of participants in programs	Watershed wide	NA				High level of program participation	Work with watershed services staff and management to expand program capacity and increase outreach	Increase number of participants in Reveg cost share, naturescaping, grants, and SOLV projects
			Number of active friends groups	Watershed wide	NA	1. Friends of Tryon Creek State Park			Vigrant and active friends groups	Support burgeoning groups and existing groups through collaboration	

	Programs to enhance community awareness of watershed health	Raise community awareness by educating citizens about the impacts that their actions have on watershed health.	Number of programs/incentives available to use less toxic products	Watershed wide	NA						
			Number of program topics	Watershed wide	NA						
			Number of community events/presentations	Watershed wide	NA						
	Citizen involvement in planning, programs, and projects to improve watershed health	Foster citizen involvement in the development and implementation of watershed plans, programs, and projects.	Number of Opportunities / year	NA	NA				Regular opportunities for public involvement in planning and implementation	Open houses, project presentations to community groups, etc.	Monitor the number citizen involvement opportunities and participation.
			Number of Participants / year	NA	NA						

CHAPTER 21

Fanno Creek Watershed Strategies and Actions

INTRODUCTION

This chapter describes strategies and actions designed to improve conditions of critical watershed attributes and make progress toward meeting watershed objectives and goals outlined in Chapter 19 (Fanno Creek Watershed Summary Table).

KEY FACTORS LIMITING WATERSHED HEALTH

Key limiting environmental factors (i.e. conditions) contributing to changes in ecosystem functions and subsequent decline in both anadromous and resident fish populations in Fanno Creek, described in detail in Chapter 19, include changes to stream flows (hydrology and channel hydraulics), riparian and floodplain condition and functions, water quality (high sediment loading and stream temperatures), fish passage obstructions, and impacts to the amount and quality of aquatic habitat. A summary of these conditions in Fanno Creek is provided below:

Goal Area	Watershed Health Indicator	Watershed Condition
Hydrology	Stream Flows	▪ High-density impervious surface (EIA) throughout the watershed increases peak flows and reduces base flows.
Water Quality	Total Suspended Solids (TSS)	▪ High sediment loads smother spawning habitats (riffle gravels) and fill pools. ▪ Sediment associated pollutants may persist throughout the watershed. ▪ High silt cover reduces areas for macroinvertebrate production.
	Stream Temperature	▪ Elevated summer temperatures stress fish communities resulting in lethal and sub lethal effects.
	Phosphorus	▪ Elevated phosphorus concentrations, measured in some tributaries, contribute to increased algal growth. Algal blooms in the Tualatin River can result in exceedances of state chlorophyll a, pH, and dissolved oxygen standards.
	Pollutants (PAH's, metals, and organics)	▪ Chronic and acute chemical toxicity may result in lethal and / or sub lethal effects to aquatic communities, including macroinvertebrate production.
Physical Habitat	Fish Passage Barriers	▪ Roadways significantly impact fish passage throughout Upper Fanno during times of the year. Key roadways include: Beaverton-Hillsdale Shopping Center; SW Shattuck Rd, SW 59th Ave, SW 45 Ave, SW 43 Ave, SW 39 Ave, and SW 30 Ave. ▪ The severity of passage at these specific locations is being further evaluated using FishXing.
	Riparian and Floodplain Condition and Connectivity	▪ Second growth, deciduous-dominated riparian and floodplain vegetative communities predominate and do not provide large wood pieces or substantive volume of woody debris into the creek. ▪ Lack of native conifers as source woody debris will limit the

		longevity and function of wood in the creek. ▪ Lack of overhanging vegetation along the stream banks destabilizes the creek, and minimizes potential protective cover to fish and wildlife. Lack of mature native trees and shrubs contributes to increased stream temperatures in the summer.
	Key Habitats (spawning and rearing habitats)	▪ Lack of high quality riffles, deep pools, side channels, secondary channels, off-channel, backwater and seasonal wetland habitats limits potential native fish productivity.
	Stream Channel Complexity	▪ Lacking large wood; large and medium sized substrate and overhanging vegetation ▪ Shorter stream length with fewer meanders and simplified channel morphology (channelization).
Biological Communities	Anadromous steelhead and cutthroat, and resident rainbow and cutthroat trout historically populated Fanno Creek. Coho have populated the Tualatin River Basin and Fanno Creek since the late 1800's; Chinook probably did not populate Fanno Creek.	▪ Reticulate sculpin, redside shiner, cutthroat trout and lamprey are most abundant fish communities; Coho and steelhead present since late 1990's (ODFW Fish Distribution Maps, December 2003).

APPROACH TO IMPROVE WATERSHED HEALTH

Development in the watershed has increased stormwater runoff volumes and velocities, both of which degrade stream and riparian conditions. Based on the watershed characterizations and other analysis described in this document, the approach to improve watershed health includes three main elements:

1. Implementation of programs and stormwater retrofit actions in highly developed areas of the watershed (impervious cover exceeds 40%) to manage stormwater runoff from impervious areas on-site. These projects will help reduce stormwater runoff volumes and velocities to protect in-stream habitat and improve water quality by reducing channel erosion and resulting concentrations of total suspended solids (TSS). In addition, efforts will be undertaken to expand and strengthen existing programs, policies, and requirements to reduce effective impervious area (EIA).

   Implementation schedule: projects (1-10 years) and programs (on-going)

2. Implementation of programs and stormwater retrofit actions to improve the quality of stormwater runoff from upper Tryon Creek to protect in-stream habitat and meet total maximum daily load (TMDL) requirements. Actions and programs will initially focus on transportation and commercial corridors, and increasing stream shade cover to cool stream temperatures during summer.

   Implementation schedule: projects (1-10 years) and programs (on-going)

3. Implementation of actions and programmatic and policy measures to protect and improve aquatic and riparian habitat. These include revegetation, stream restoration, protection and policy, operations and maintenance, and stewardship.

   Implementation schedule: projects (1-20 years) and programs (on-going)

CATEGORIES OF ACTIONS AND ENVIRONMENTAL BENEFITS

Stormwater

Stormwater management facilities help decrease the volume and velocity of stormwater runoff and improve stormwater quality. These facilities include eco-roofs, swales, vaults, pervious pavement, planter boxes, and constructed wetlands.

Revegetation

Planting native vegetation in the watershed helps reduce the volume and velocity of stormwater runoff, provides shade helping to cool streams, trap sediment, filter pollutants, provide food and cover for wildlife, and provides woody debris and other organic material to streams.

Aquatic and Riparian Enhancement

Enhancing aquatic and riparian resources help protect and improve aquatic habitat, improve water quality, restore the watersheds natural complexity, and benefit fish and wildlife. Aquatic and riparian enhancement includes restoring and creating channel complexity, natural meanders and off-channel habitat, planting stream banks and riparian areas with native vegetation, and retrofitting culverts to enable fish passage.

Protection and Policy

Protecting features and areas that provide important watershed functions and applying policies to minimize the environmental impact of development and redevelopment are important strategies to improving watershed functions and conditions. These actions, in collaboration with other City bureaus could include: land acquisition, natural resource plan updates, land use and development policies and programs to help prevent or limit development impacts, and stormwater management requirements.

Operations and Maintenance

Operations and Maintenance (O&M) activities include regular maintenance of all stormwater and water quality facilities. Regular maintenance ensures that these facilities provide the stormwater management and water quality benefits that they were designed to provide. Beyond regular O&M activities, this category could include: review of existing street sweeping schedules to maximize water quality benefits, conversion of ditches to swales where possible, and other activities in collaboration with other City bureaus to improve all O&M activities.

Outreach, Stewardship, and Education

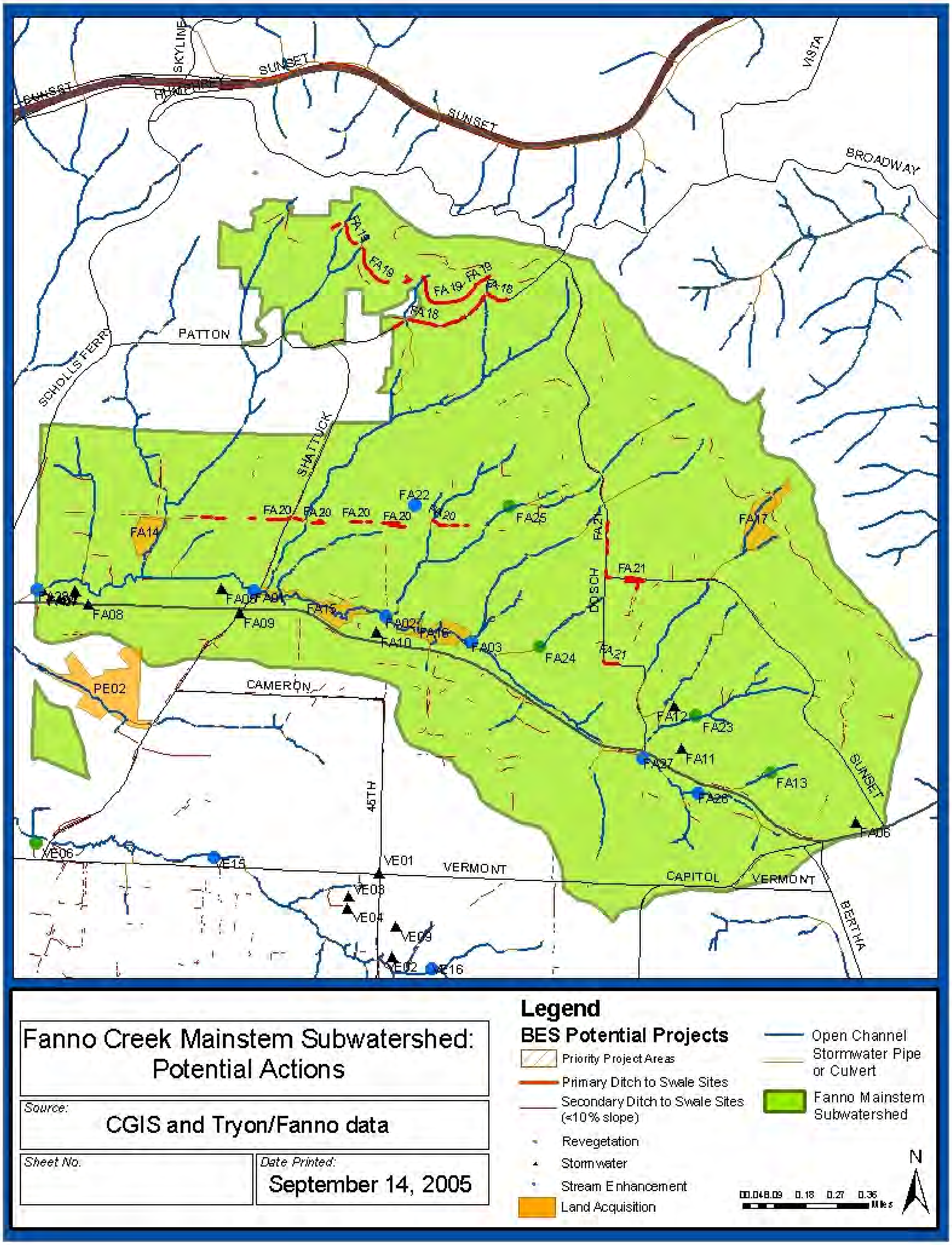
These actions include involving the public in watershed planning and projects, promoting community watershed stewardship activities such as tree planting, providing education materials and programs that promote watershed restoration and help reduce the use of toxics (pesticides, herbicides, hazardous materials, etc.) that degrade water quality and habitat.

WATERSHED SPECIFIC ACTIONS

This section describes potential actions to improve watershed health, by subwatershed. A map depicting potential actions and a brief description of each potential action is provided. These are planning level potential actions only. Additional analysis will be conducted to determine specific solutions at each site. Continuation of the planning and implementation processes will include extensive consultations with the public including property owners and neighborhood associations and collaboration with various community partners.

More potential actions will be identified as research and analysis continues.

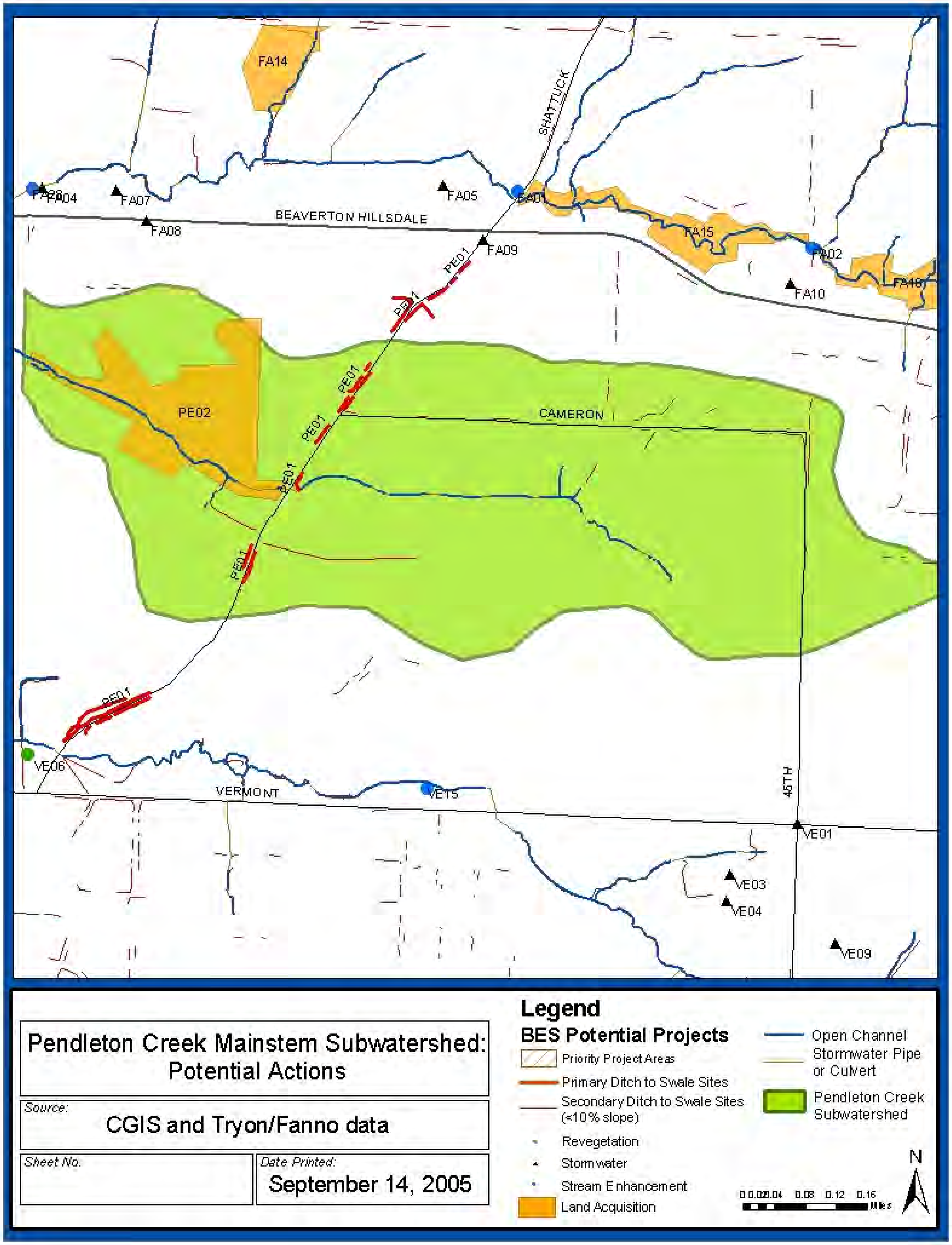
Fanno Creek Mainstem Subwatershed



Action ID	Name	Description
FA01	SW Shattuck Road Culvert	Aquatic restoration: retrofit the culvert to improve fish passage.
FA02	SW 45th Avenue Culvert	Aquatic restoration: retrofit the culvert to improve fish passage.
FA03	SW 39th Culvert	Aquatic restoration: retrofit the culvert to improve fish passage.
FA4	Raleigh Hills Shopping Center	Stormwater: retrofit the shopping center parking lot to reduce runoff and improve water quality.
FA05	Albertson's and Rite Aid Parking Lots	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
FA06	Hillsdale	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
FA07	Raleigh Woods Apartments	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
FA08	Beaverton Hillsdale Highway	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
FA09	Beaverton Hillsdale Highway at Shattuck Road	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
FA10	Beaverton Hillsdale Highway at 45th	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
FA11	Portland Christian Center	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
FA12	Nevah Shalom parking lot swales	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
FA13	Kanan St. property	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
FA14	Fanno Creek Natural Area	Land Acquisition: procure land of high resource value for preservation
FA15	Fanno Reach 4	Land Acquisition: procure land of high resource value for preservation
FA16	Fanno Reach 5	Land Acquisition: procure land of high resource value for preservation
FA17	NE Fanno	Land Acquisition: procure land of high resource value for preservation
FA18	Along SW Patton	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
FA19	Along SW Hewett St	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
FA20	Along SW Hamilton St	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
FA21	Along SW Dosch Rd	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
FA22	Hamilton Park Project	Stream Enhancement: Restructure trail system to

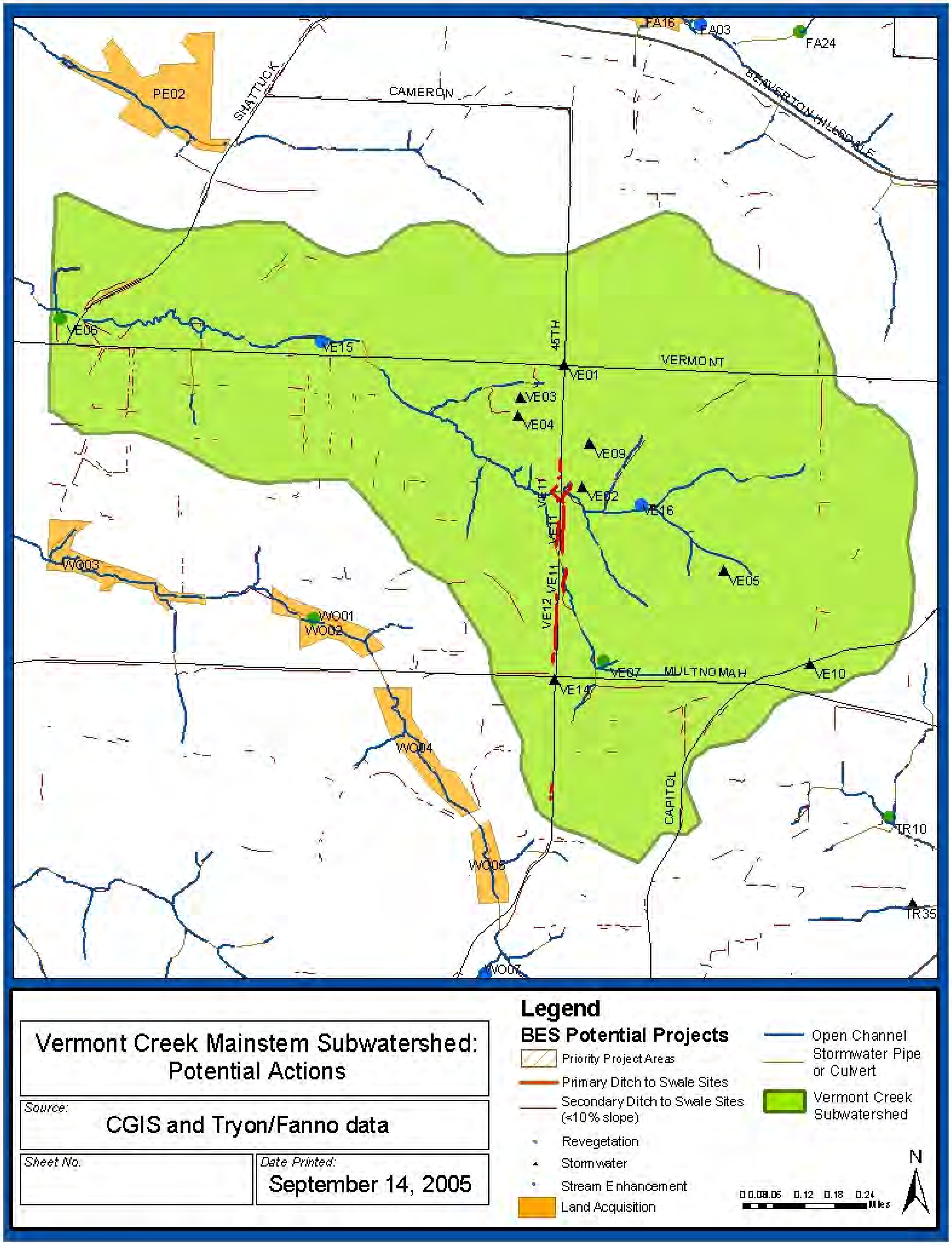
		reduce the in-stream impacts from erosion
FA23	Boundary Street Tributary	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
FA24	Albert Kelly Park	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
FA25	Ivey Creek	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
FA26	Cambridge Village Pump Station	Stream Enhancement:
FA27	SW 30th at Beaverton-Hillsdale Hwy Culvert	Aquatic restoration: retrofit the culvert to improve fish passage.
FA28	SW Beaverton-Hillsdale Hwy Culvert	Aquatic restoration: retrofit the culvert to improve fish passage.

Pendleton Creek Subwatershed



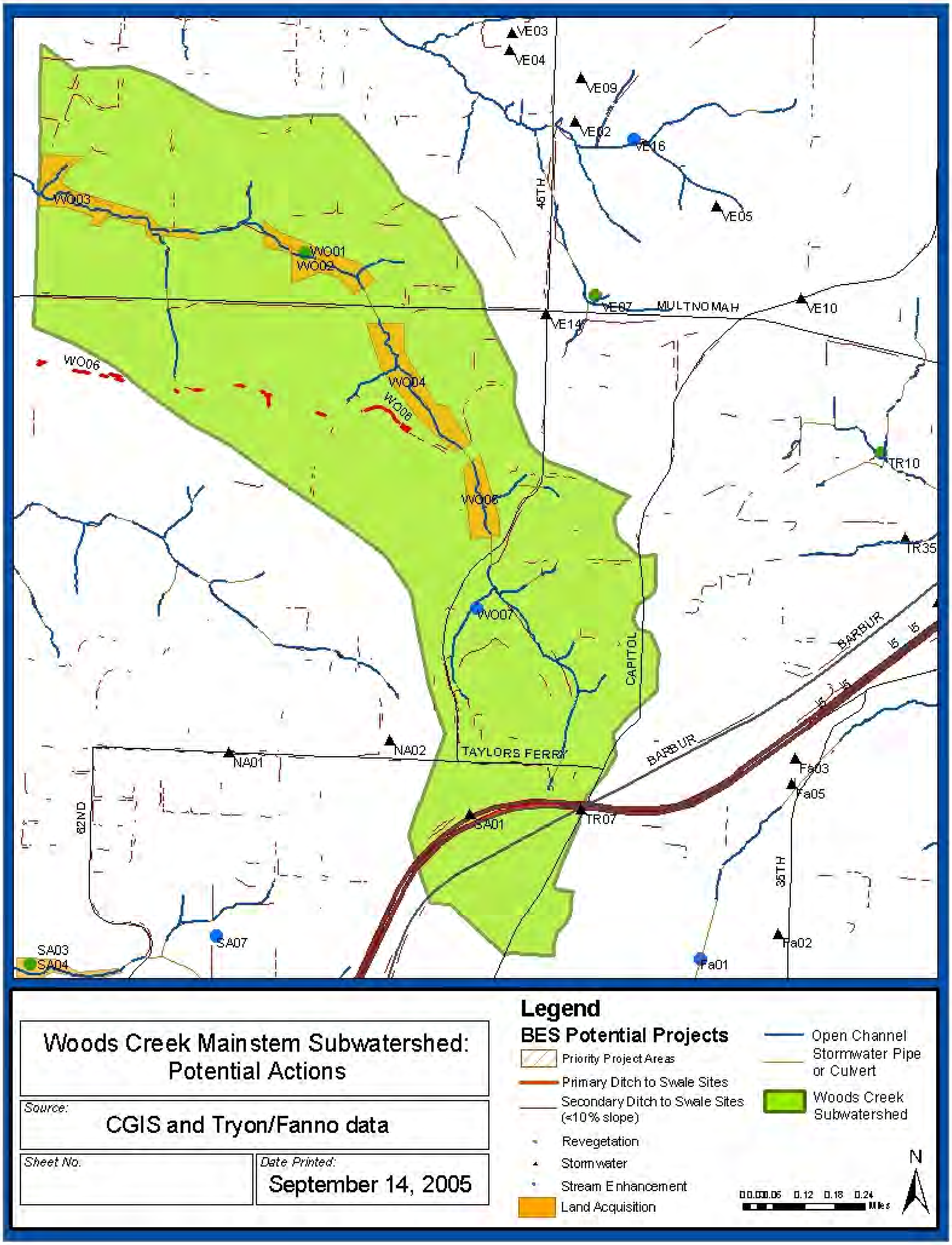
Action ID	**Name**	**Description**
PE01	Shattuck Rd	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
PE02	Pendleton Woods	Land Acquisition: procure land of high resource value for preservation

Vermont Creek Subwatershed



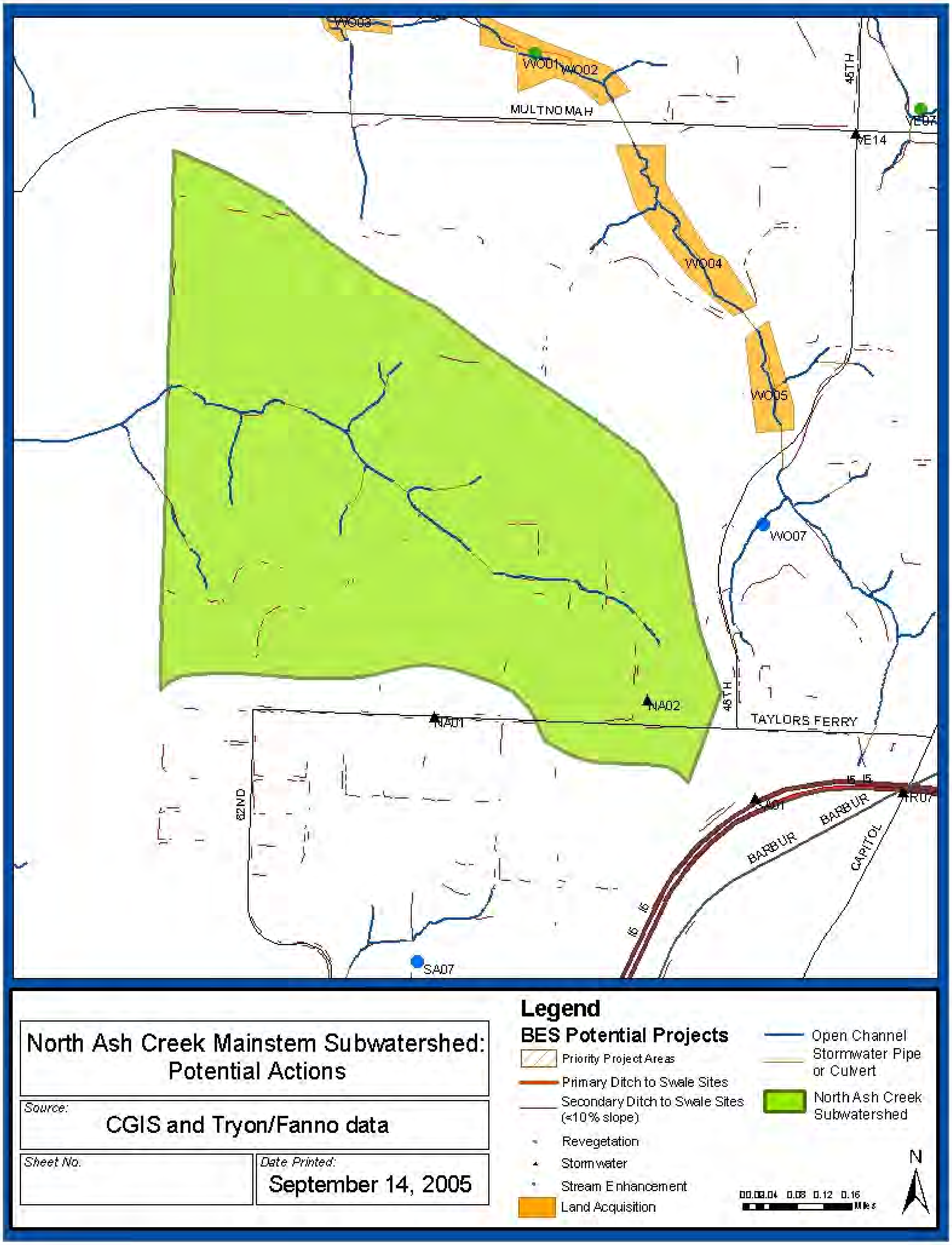
Action ID	**Name**	**Description**
VE01	SW 45th and Vermont parking lots	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
VE02	Gabriel Park Off Leash Area	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
VE03	St. Lukes Lutheran	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
VE04	St. John Fisher	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
VE05	Gabriel Commons	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
VE006	South Alpenrose (Burkland)	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
VE07	Multnomah Post Office	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
VE08	Gabriel Park Trails	Stream Enhancement: Restructure trail system to reduce the in-stream impacts from erosion
VE09	Gabriel Park parking lot	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
VE10	Multnomah Village	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
VE11	45th and Nevada	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
VE12	Along 45th	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
VE13	45th and Garden Home	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
VE14	SW 45th and Multnomah	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.
VE15	Idaho Pump Station	Stream Enhancement:

Woods Creek Subwatershed



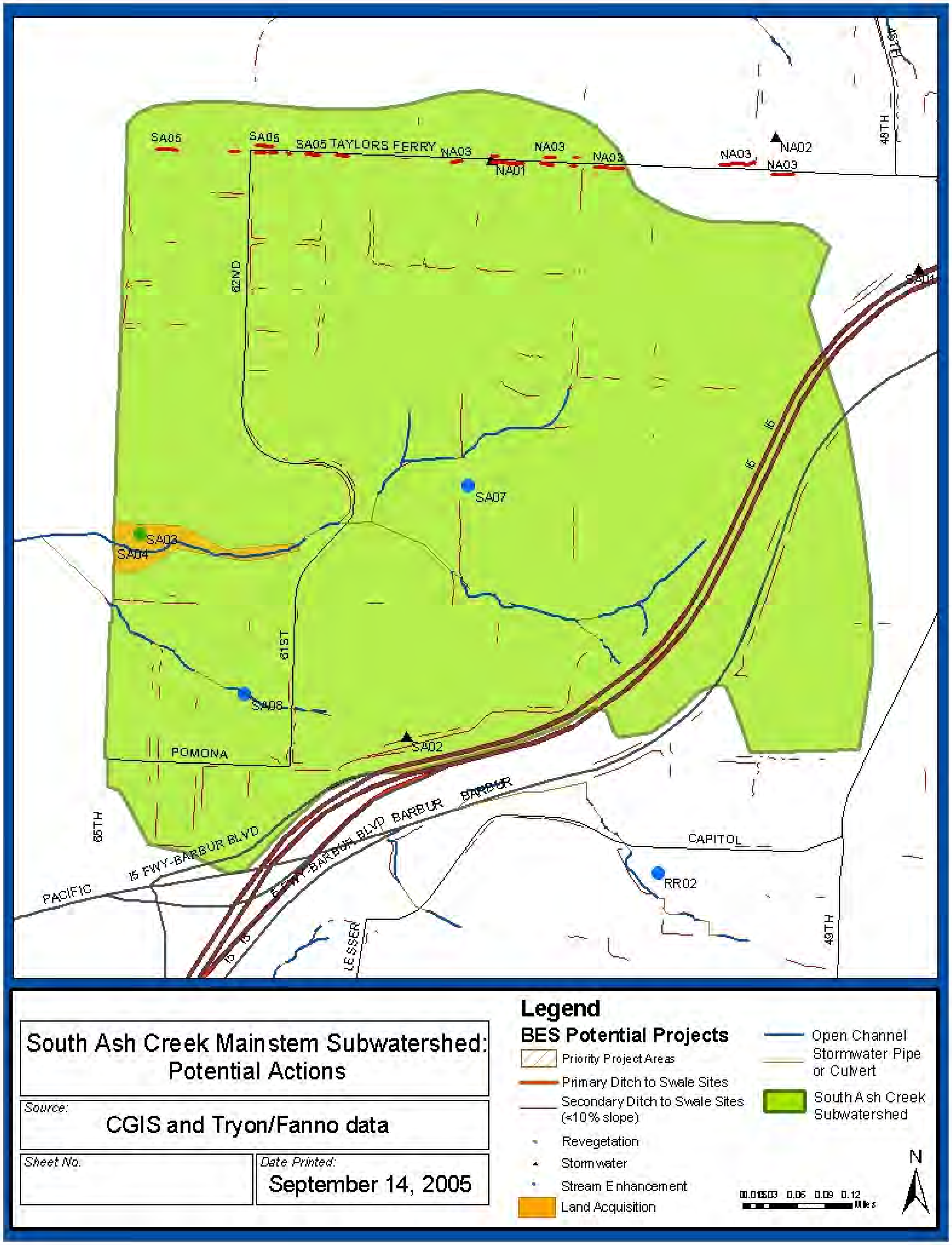
Action ID	Name	Description
WO01	Fogarty	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
WO02	April Hill Park east ext.	Land Acquisition: procure land of high resource value for preservation
WO03	April Hill Park west ext.	Land Acquisition: procure land of high resource value for preservation
WO04	Middle Woods Creek	Land Acquisition: procure land of high resource value for preservation
WO05	Woods Park west ext. (Erosion Control, bridges, reveg)	Land Acquisition: procure land of high resource value for preservation
WO06	Garden Home	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
WO07	Woods Park Trails	Stream Enhancement: Restructure trail system to reduce the in-stream impacts from erosion
WO08	West Portland Town Center	Stormwater: retrofit the parking lots to reduce runoff and improve water quality.

North Ash Creek Subwatershed



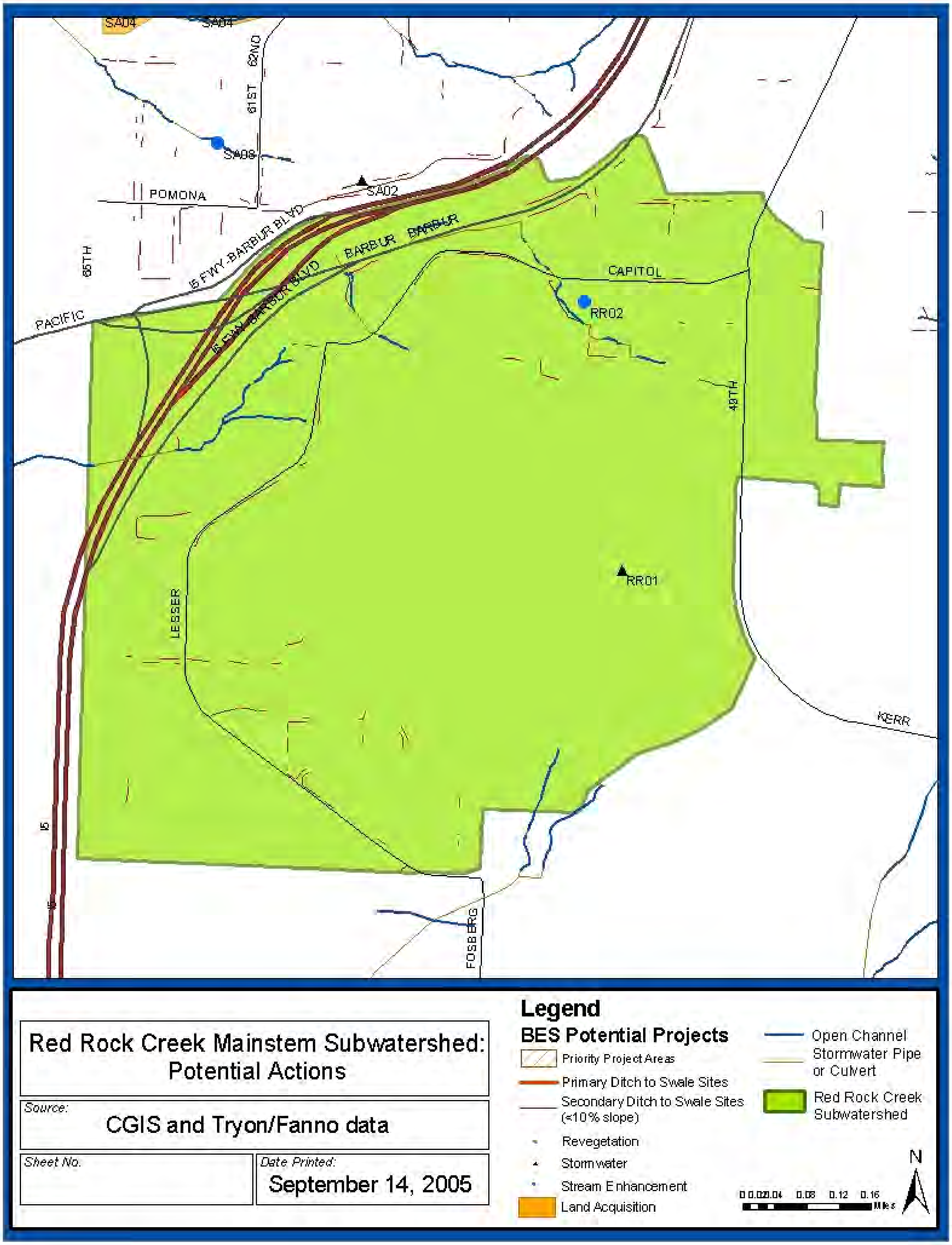
Action ID	Name	Description
NA01	Taylor’s Ferry Vision Plan Site	Stormwater: retrofit the impervious areas to reduce runoff and improve water quality.
NA02	West Portland Commercial Area	Stormwater: retrofit the impervious areas to reduce runoff and improve water quality.
NA03	Taylor’s Ferry Rd East	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety.

South Ash Creek Subwatershed



Action ID	**Name**	**Description**
SA01	S. Ash and Woods Creek	Stormwater: retrofit the impervious areas to reduce runoff and improve water quality.
SA02	I-5 and Barbur at S. Ash outfalls	Stormwater: retrofit the impervious areas to reduce runoff and improve water quality.
SA03	Falk II	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
SA04	S. Ash	Land Acquisition: procure land of high resource value for preservation
SA05	Taylor’s Ferry Rd East	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
SA06	SW 62nd Culvert	Aquatic restoration: retrofit the culvert to improve fish passage.
SA07	Dickinson Park Trails	Stream Enhancement: Restructure trail system to reduce the in-stream impacts from erosion

Red Rock Creek Subwatershed



Red Rock Creek Mainstem Subwatershed: Potential Actions

Source: CGIS and Tryon/Fanno data

Sheet No.

Date Printed: September 14, 2005

Action ID	Name	Description
RR01	PCC parking lots	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
RR02	Capitol Highway (Sylvania Park)	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.

CHAPTER 22

Tryon Creek Watershed Strategies and Actions

INTRODUCTION

This chapter describes strategies and actions designed to improve conditions of critical watershed attributes and make progress toward meeting watershed objectives and goals outlined in Chapter 20 (Tryon Creek Watershed Summary Table).

KEY FACTORS LIMITING WATERSHED HEALTH

Key limiting environmental factors (i.e. conditions) contributing to changes in ecosystem functions and subsequent decline in both anadromous and resident fish populations in Tryon Creek, described in detail in Chapter 20, are summarized in Table 1 below. These factors include: development above Boones Ferry Road has degraded natural functions; impervious surfaces, loss of vegetation, and diminished drainage complexity have increased stormwater runoff volumes and velocities degrading water quality and in-stream habitat, particularly below Boones Ferry Road in Tryon Creek State Natural Area (TCSNA); loss of contiguous riparian vegetation has diminished stream complexity; and culverts limit and in some cases completely prevent fish passage. Only small populations of steelhead, rainbow, cutthroat, and sculpin continue to spawn and rear in Tryon Creek.

Table 1: Key Limiting Factors

Goal Area	Watershed Health Indicator	Watershed Condition
Hydrology	Stream Flows (including base flows and peak flows)	▪ High-density impervious surface (EIA) in upper Tryon and its tributaries has altered the hydrograph, specifically, increasing stormwater run-off, and decrease summer base flows.
Water Quality	Total Suspended Solids (TSS)	▪ High sediment loads smother spawning habitats (riffle gravels) and fill pools. ▪ Sediment associated pollutants prevalent throughout the basin. ▪ High silt cover reduces areas for macroinvertebrate production.
	Stream Temperature	▪ Elevated summer temperatures stress fish communities resulting in lethal and sub lethal effects.
Physical Habitat	Fish Passage Barriers	▪ HWY 43 significantly blocks anadromous fish from accessing Middle Tryon Creek ▪ Boones Ferry Rd. completely blocks anadromous and resident fish from accessing Upper Tryon Creek.
	Riparian and Floodplain Condition and Connectivity	▪ Second growth, even-aged deciduous riparian and floodplain forests in Middle Tryon Creek do not provide large wood pieces and substantive volume of woody debris. ▪ Lack of native conifers as source woody debris will limit the longevity and function of wood forms in the creek. ▪ Lack of overhanging vegetation along the stream banks destabilizes the creek, and minimizes potential protective cover to fish and wildlife. Lack of mature native trees and shrubs in Upper Tryon

		Creek contribute to increased stream temperatures in the summer.
	Key Habitats (spawning and rearing habitats)	▪ Lack of high quality riffles, deep pools, side channels, secondary channels, off-channel and backwater habitats.
	Stream Channel Complexity	▪ Lacking large wood; large and medium sized substrate; overhanging vegetation; undercut banks and terraced banks ▪ Shorter stream length with fewer meanders and simplified channel morphology (channelization).
Biological Communities	Native Fish Communities	▪ Anadromous steelhead and coho salmon, and resident rainbow and cutthroat trout historically populated Tryon Creek – Chinook did not. ▪ Only steelhead, rainbow and cutthroat continue to spawn and rear in Tryon Creek. ▪ Willamette Basin coho, chinook and steelhead continue to use the lower confluence reach as off-channel habitat year-round.

APPROACH TO IMPROVE WATERSHED HEALTH

Development in the upper Tryon Creek watershed has increased stormwater runoff volumes and velocities, both of which degrade stream and riparian conditions in the lower watershed. Based on the watershed characterizations and other analysis described in this document, the approach to improve watershed health includes three main elements:

1. Implementation of programs and stormwater retrofit actions in upper Tryon Creek (impervious cover exceeds 40%) to manage stormwater runoff from impervious areas on-site. These actions will help reduce stormwater runoff volumes and velocities and to protect in-stream habitat below Boones Ferry Road and improve water quality. Expanding and strengthening existing programs, policies, and requirements to reduce effective impervious area (EIA) is also included in this approach.

   Implementation schedule: projects (1-10 years) and programs (on-going)

2. Implementation of programs and stormwater retrofit actions to moderate hydrology and improve the quality of stormwater runoff from upper Tryon Creek, which will have the added benefit of protecting in-stream habitat below Boones Ferry Road. Actions and programs will initially focus on transportation and commercial corridors, and increasing stream shade cover to cool stream temperatures during summer.

   Implementation schedule: projects (1-10 years) and programs (on-going)

3. Implementation of actions and programmatic and policy measures to protect and restore habitat initially below Boones Ferry Road and increase fish access to TCSNA. Breaks in longitudinal stream connectivity, particularly at State Street and Boones Ferry Road culverts, severely impede resident and anadromous fish movement. State Street culvert in Lake Oswego is significant in that it may isolate fish use to lower Tryon Creek for much of the year.

   Implementation schedule: projects (5-20 years) and programs (on-going)

Applying this approach will help improve conditions of key watershed health attributes and contribute to improving watershed health.

CATEGORIES OF ACTIONS AND ENVIRONMENTAL BENEFITS

Stormwater

Stormwater management facilities help decrease the volume and velocity of stormwater runoff and improve stormwater quality. These facilities include eco-roofs, swales, vaults, pervious pavement, planter boxes, and constructed wetlands.

Revegetation

Planting native vegetation in the watershed helps reduce the volume and velocity of stormwater runoff, provides shade helping to cool streams, trap sediment, filter pollutants, provide food and cover for wildlife, and provides woody debris and other organic material to streams.

Aquatic and Riparian Enhancement

Enhancing aquatic and riparian resources help protect and improve aquatic habitat, improve water quality, restore the watersheds natural complexity, and benefit fish and wildlife. Aquatic and riparian enhancement includes restoring and creating channel complexity, natural meanders and off-channel habitat, planting stream banks and riparian areas with native vegetation, and retrofitting culverts to enable fish passage.

Protection and Policy

Protecting features and areas that provide important watershed functions and applying policies to minimize the environmental impact of development and redevelopment are important strategies to improving watershed functions and conditions. These actions, in collaboration with other City bureaus could include: land acquisition, natural resource plan updates, land use and development policies and programs to help prevent or limit development impacts, and stormwater management requirements.

Operations and Maintenance

Operations and Maintenance (O&M) activities include regular maintenance of all stormwater and water quality facilities. Regular maintenance ensures that these facilities provide the stormwater management and water quality benefits that they were designed to provide. Beyond regular O&M activities, this category could include: review of existing street sweeping schedules to maximize water quality benefits, conversion of ditches to swales where possible, and other activities in collaboration with other City bureaus to improve all O&M activities.

Outreach, Stewardship, and Education

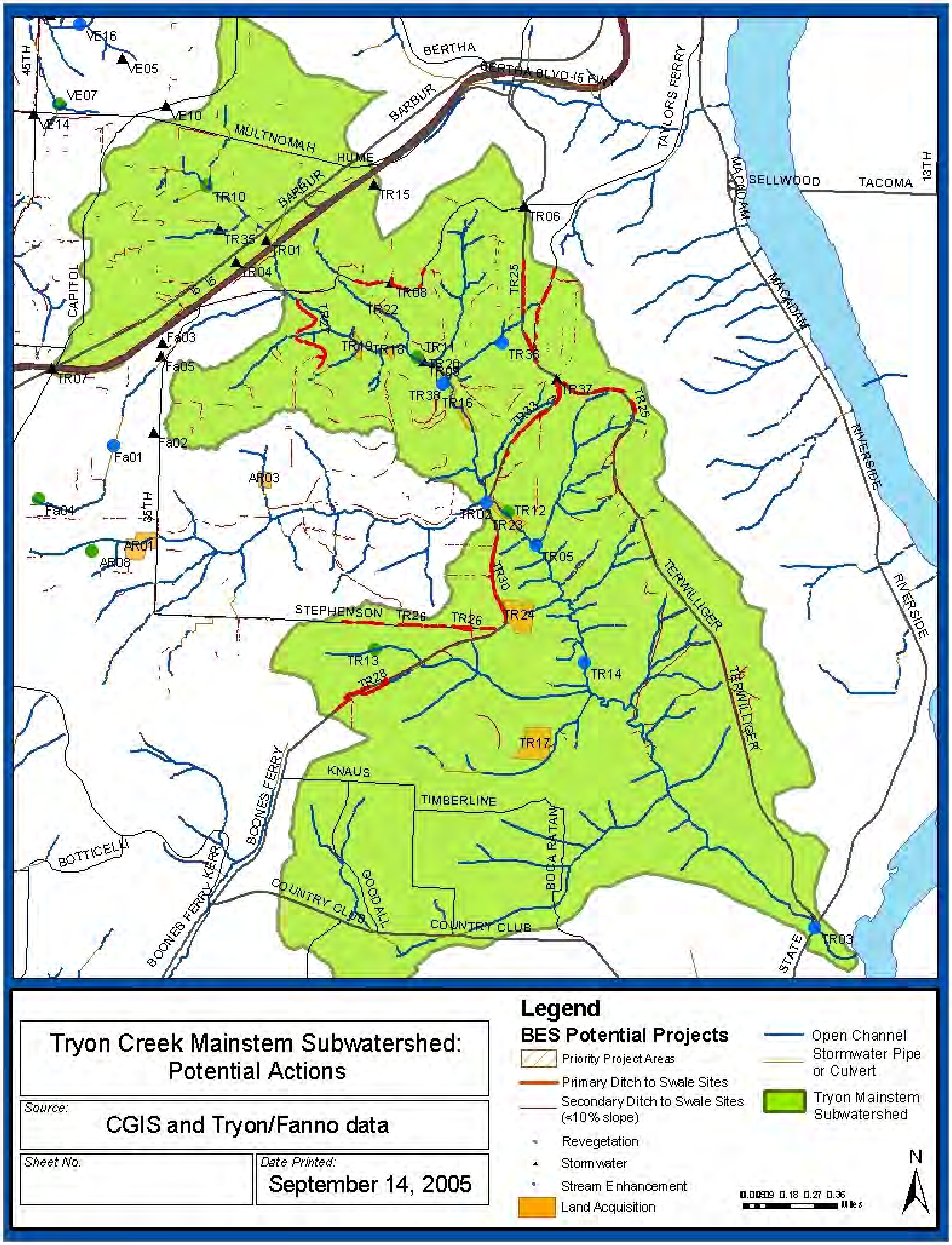
These actions include involving the public in watershed planning and projects, promoting community watershed stewardship activities such as tree planting, providing education materials and programs that promote watershed restoration and help reduce the use of toxics (pesticides, herbicides, hazardous materials, etc.) that degrade water quality and habitat.

WATERSHED SPECIFIC ACTIONS

This section describes potential actions to improve watershed health, by subwatershed. A map depicting potential actions and a brief description of each potential action is provided. These are planning level potential actions only. Additional analysis will be conducted to determine specific solutions at each site. Continuation of the planning and implementation processes will include extensive consultations with the public including property owners and neighborhood associations and collaboration with various community partners.

More potential actions will be identified as research and analysis continues.

Tryon Creek Mainstem Subwatershed



Tryon Creek Mainstem Subwatershed:
Potential Actions

Source:
CGIS and Tryon/Fanno data

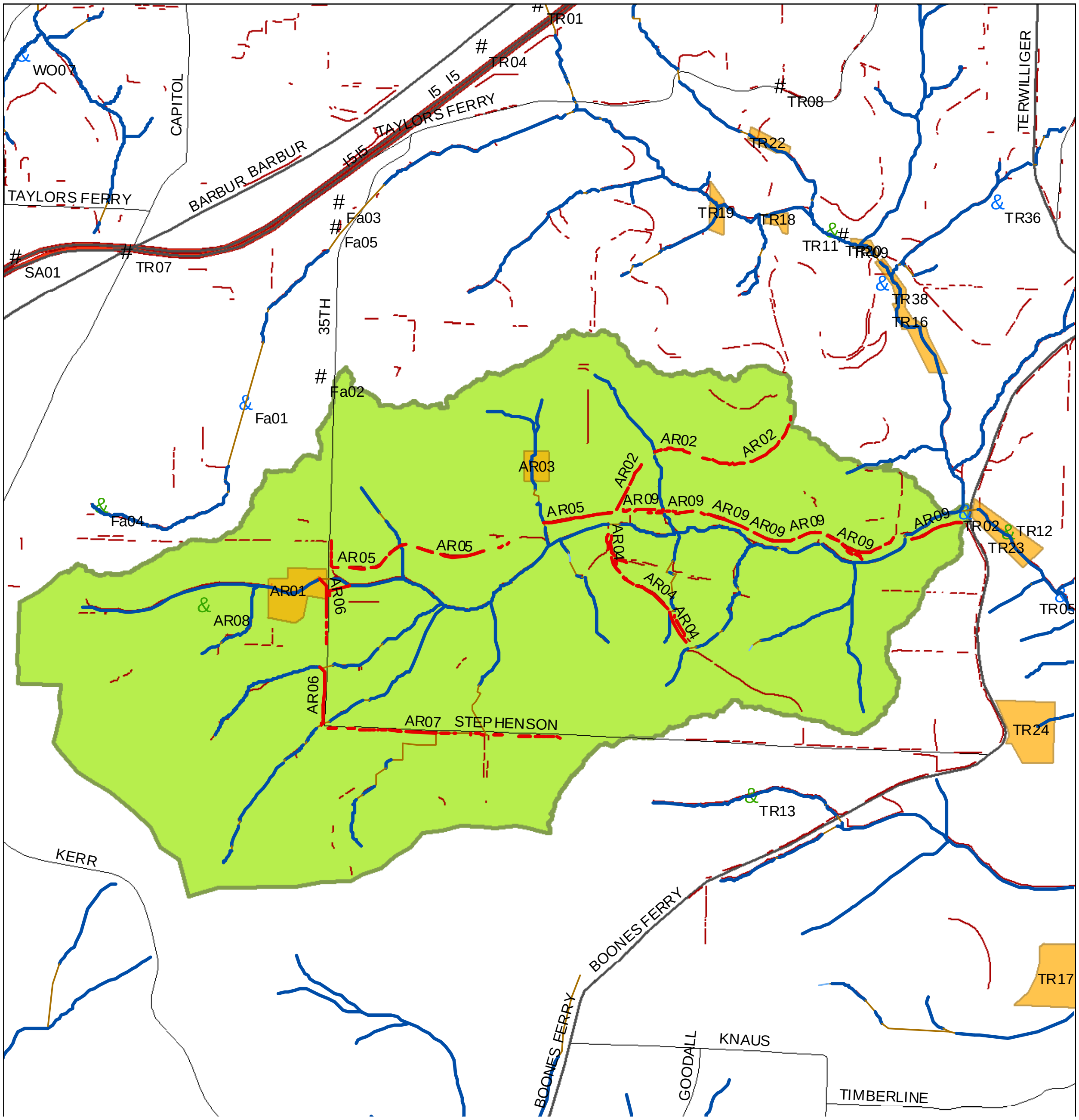
Sheet No.

Date Printed:
September 14, 2005

Action ID	**Name**	**Description**
TR01	I-5 and Barbur Blvd Retrofit	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
TR02	Boones Ferry Rd Culvert	Aquatic restoration: retrofit the culvert to improve fish passage.
TR03	Highway 43 Culvert	Aquatic restoration: retrofit the culvert to improve fish passage.
TR04	Upper Tryon Creek Commercial Area Retrofit	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
TR05	NOAA Tryon Creek Enhancement	Stream Enhancement: Improve aquatic habitat complexity and protect sanitary sewer.
TR06	Burlingame Mall Retrofit	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
TR07	Capitol Hwy West Portland Center Retrofit	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
TR08	17th and Taylor's Ferry Rd	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
TR09	Marshall Park impervious area removal	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
TR10	Windgate	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
TR11	Marshall Park South Basketball Court area	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
TR12	Boones Ferry Rd Crossing	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
TR13	Meadowview	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
TR14	Tryon Creek State Natural Area Stream Restoration	Stream Enhancement: Improve aquatic habitat complexity and protect sanitary sewer.
TR15	Capitol Hill Elementary School	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
TR16	East of Marshall Park	Land Acquisition: procure land of high resource value for preservation
TR17	Englewood	Land Acquisition: procure land of high resource value for preservation
TR18	Extension near stream	Land Acquisition: procure land of high resource value for preservation
TR19	Jensen Foley Connection	Land Acquisition: procure land of high resource value for preservation
TR20	Marshall Park Connection N Maplecrest	Land Acquisition: procure land of high resource value for preservation
TR21	Maricara Park Riparian Extension	

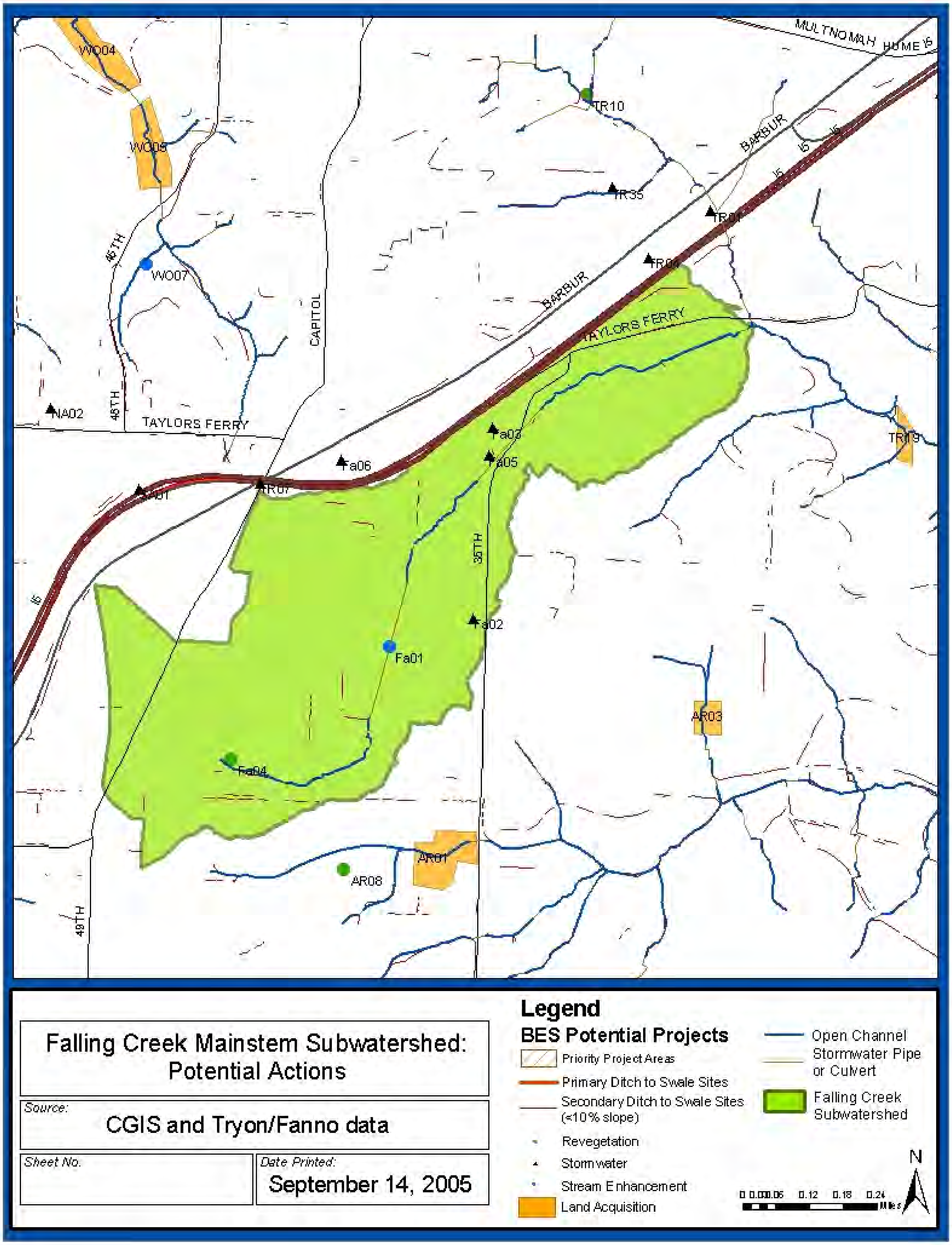
TR22	Marshall Park North Extension	Land Acquisition: procure land of high resource value for preservation
TR23	Tryon Creek State Natural Area Connection	Land Acquisition: procure land of high resource value for preservation
TR24	Tryon Life Farm	Land Acquisition: procure land of high resource value for preservation
TR25	Along Terwilliger	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
TR26	Along Stevenson	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
TR27	Along Lancaster North	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
TR28	Boones Ferry Rd Southwest	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
TR29	Boones Ferry Rd South	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
TR30	Boones Ferry Rd South 2	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
TR31	Boones Ferry Rd North	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
TR32	Boones Ferry Rd Mid Southwest	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
TR33	Boones Ferry Rd Mid	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
TR34	Near 17th on Taylor’s Ferry Rd	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
TR35	Headwaters Project	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
TR36	Plum Pocket Project (SW 6th and Lucille)	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
TR37	Terwilliger and Boones Ferry Rd Intersection	Stormwater: retrofit, as part of PDOT projects, to reduce runoff and improve water quality.
TR38	Marshall Park Trails	Stream Enhancement: retrofit trail system to decrease erosive impacts to stream banks

Arnold Creek Subwatershed



Action ID	**Name**	**Description**
AR01	West Portland Park extension	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
AR02	Lancaster Mid South	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
AR03	Maricara Park Riparian Extension	Land Acquisition: procure land of high resource value for preservation
AR04	Lancaster South	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
AR05	Along Arnold St	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
AR06	Along SW 35th	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
AR07	Along Stevenson	Stormwater: Implement Ditch to Swale retrofits to improve water quality and public safety
AR08	Tryon Creek Metro	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall

Falling Creek Subwatershed



Action ID	**Name**	**Description**
Fa01	Jackson Middle School	Stream Enhancement: Daylight stream for peak flow reduction and habitat restoration.
Fa02	Jackson Middle School	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
Fa03	ODOT Yard	Stormwater: retrofit the impervious parking areas to reduce runoff and improve water quality.
Fa04	Pasadena	Revegetation: plant trees to provide habitat, stabilize soils, and intercept rainfall
Fa05	I-5 outfall and WQ Facility	Stormwater: retrofit the impervious areas to reduce runoff and improve water quality.
Fa06	Barbur Blvd Transit Center	Stormwater: retrofit the impervious areas to reduce runoff and improve water quality.

Tryon/Fanno Creek Watershed Plan

Critical Questions
Date: 3/18/2002

Core Team Critical Questions Work Session (9/14/2001)
Amin Wahab (BES), Micheal Reed (ESA), Tim Kurtz (BES), Steve Hawkins (BES), Mark Liebe (BES), Leonard Gard (SWNI)
Advisory Committee Meeting 10/22/2001

		Who	Corresponding Goal/Objective	Related Workplan Step	question be answered	Notes
Water quantity						
1	What factors alter the hydrograph and volume?	Core Team	1	Step 3,4,5	Y	
2	What effects will these changes have on human health and property?	Core Team	1,5	Step 3,4,5	Y	
3	What benefits?	Core Team	1,5	Step 3,4,5	Y	
4	What adverse effects?	Core Team	1,5	Step 3,4,5	Y	
5	What effects will these changes have on habitat?	Core Team	1,3,4	Step 3,4,5	Y	
6	What benefits?	Core Team	1,3,4	Step 3,4,5	Y	
7	What adverse effects?	Core Team	1,3,4	Step 3,4,5	Y	
8	Where are your major sources of runoff	Core Team	1	Step 3,4,5	Y	
9	How does existing runoff compare to future runoff?	Core Team	1	Step 3,4,5	Y	
10	How does developed vs. undeveloped land respond?	Core Team	1	Step 3,4,5	Y	
11	Where are the critical sources of baseflow?	Core Team	1	Step 3,4,5	Y	based on soils
12	What critical flow conditions occur within the basin that effect channel conditions and physical habitat?	Core Team	1	Step 3,4,5	Y	
13	What types of solutions are available in Southwest to moderate hydrology?	Core Team	1,5	Step 3,4,5	Y	
14	What influence does upland management have (sensitivity analysis) on stream and stormwater conveyance?	Core Team	1,5	Step 3,4,5	Y	
15	What is the overall magnitude of total flow and volume reduction needed throughout the basin?	Core Team	1	Step 3,4,5	Y	
16	Do we have the room needed for this?	Core Team	1,5	Step 3,4,5	Y	
17	What is the optimal mix of on-site, in-stream, and constructed regional facilities to meet objectives?	Core Team	1,5	Step 3,4,5	Y	
18	What are the capacity problems with culverts for flooding, fish passage, maintenance issues?	Core Team	1,5	Step 3,4,5	Y	
19	Where do we have flooding and what is its frequency?	Core Team	1,5	Step 3,4,5	Y	
20	Is that flooding a problem?	Core Team	1,5	Step 3,4,5	Y	
21	What capacity issues occur to cause SSOs? What points of interface exist?	Core Team	5	Step 3,4,5	N	Facilities Plan Issue
22	How will surface water management solutions effect groundwater flow and slope stability?	Core Team	1,5	Step 3,4,5	Y	
23	How should zoning regulations be updated to address water quality/quantity?	SM	1,5	Step 3,4,5	Y	SW Community Plan
24	How should construction standards be updated to address water quality/quantity?	SM	1,5	Step 3,4,5	- to some exte	Recommnedations to OPDR
25	What is the adequate benchmark for this goal?	MG	1,5	Step 3	Y	Velocities, baseflows, capacities
26	What adverse conditions as identified by the plan are not presently possible to correct under this plan due to legal, financial or political constraints?	JG	1,5	Step 7	- to some exte	Adverse conditions are identified in plan
Water quality						
1	What are the major sources of pollutants (TMDL)?	Core Team	2	Step 3,4	Y	TMDL Process
2	What is our total output of pollutants (TMDL, SED)?	Core Team	2	Step 3,4	Y	Land Use/Modeling
3	DO (total settlable volatile solid)	Core Team	2	Step 3,4	Y	
4	Phosphorus	Core Team	2	Step 3,4	Y	Existing Reports
5	Chlor-a	Core Team	2	Step 3,4	Y	Existing Data
6	temp	Core Team	2	Step 3,4	Y	TMDL/Revegetation
7	ammonia	Core Team	2	Step 3,4	NA	
8	What stream reaches are "high-quality"?	Core Team	1,3	Step 3,5	Y	
9	What reaches are severly impacted?	Core Team	1,3	Step 3,5	Y	
10	What aspects of water quality will be addressed (loads vs. fate/transport)	Core Team	2	Step 3,5	Y	
11	How do we correlate pollutant loading (from DEQ) with in-stream water quality?	Core Team	2	Step 3,5	N	DEQ
12	Are our modeling tools adequate for the task?	Core Team	1,2,5	Step3,4,5	Y	

		Who	Corresponding Goal/Objective	Related Workplan Step	question be answered	Notes
13	Is our data adequate to support this detail?	Core Team	1,2,5	Step 3,4,5	Y	TBD
14	What effects do SSOs have on quality? Where do SSOs occur?	Core Team	2,5	Step 4,5	Y - to some e	based on what is known
15	What impact do un-sewered areas have on water quality? Where are they?	Core Team	1,2,5	Step 4,5	Y	based on what is known
16	What are the general sources of bacteria pollutants and what are their importance?	Core Team	1,2,5	Step 4,5	Y	Existing studies
17	What are the moderating effects of groundwater discharge on stream temperatures?	Core Team	3,4	Step 4,5	Y	modeling
18	What are the long-term effectiveness of BMPs?	Core Team	1,2,3,5	Step 8	Y	
19	What BMPs are going to be considered?	Core Team	2	Step 4,5	Y	
20	How do we quantify the BMPs in the MS4 in relationship to the TMDLs?	Core Team	2	Step 4,5,6	Y	
21	What related air quality issues need to be addressed? How do air quality issues impact water quality?	SM	NA	NA	NA	
22	What is the adequate benchmark for this goal?	MG		Step 3	Y	TMDL, WQ Standards, MS4
23	What adverse conditions as identified by the plan are not presently possible to correct under this plan due to legal, financial or political constraints?	JH		Step 7,8		
Habitat						
1	What are the attributes and indicators of the following habitat parameters that are adequate for measuring current limiting factors for biological communities, target species and key ecological functions in the watershed?	Core Team	Goal 3	Step 3,4,5	Y	ESA UHA
	a. Riparian integrity	Core Team	Goal 3	Step 3,4,5	Y	ODFW
	b. Shoreline complexity, bank condition	Core Team	Goal 3	Step 3,4,5	Y	ODFW
	c. Channel substrate	Core Team	Goal 3	Step 3,4,5	Y	ODFW
	d. Off-channel habitat; associated wetlands	Core Team	Goal 3	Step 3,4,5	Y	
	e. Instream habitat	Core Team	Goal 3	Step 3,4,5	Y	
	f. Fish passage	Core Team	Goal 3	Step 3,4,5	Y	ODFW, Surveys, Modeling
2	What is the desired future condition for these parameters that will meet protection, restoration or recovery goals for biological communities, target species and key ecological functions in the watershed?	Core Team	Goal 3	Step 3,4,5	Y	UHA (Desired Future Conditions)
3	What is the adequate benchmark for this goal?	MG	Alt.analysis	3	Y	UHA (Desired Future Conditions)
4	What adverse conditions as identified by the plan are not presently possible to correct under this plan due to legal, financial or political constraints?	JH	Implementation	7,8		TBD
Biological Communities						
1	What are the target species, biological communities or indicator species targeted for protection, restoration or recovery actions in the Tryon and Fanno Creek Watershed Management Plan? (Note: The Tryon and Fanno Watershed Planning core team has determined that ESA listed (and proposed for listing) salmonid species will be the target species focused on in this initial planning effort due to the limited time scope. Additional species, biological communities, and indicator species will be targeted in future planning efforts).	Core Team	Goal 3	Step 3,4,5	Y	ESA UHA
2	What are key life history strategies that need to be protected, restored or enhanced in order to assist in the recovery of listed salmonid populations in the Tryon and Fanno planning area?	Core Team	Goal 3	Step 3,4,5	Y	Different Fanno and Tryon
3	Can the “Viable Salmonid Population” (VSP) parameters of abundance, productivity and spatial structure be adequately addressed in the Plan?	Core Team	Goal 3	Step 3,4,5	Y	UHA/ESA Work Critical
4	What are key species interactions that need to be understood (both negative and positive) to determine appropriate management strategies?	Core Team	Goal 3	Step 3,4,5	Y	Within legal limites
5	Are there appropriate invasive or non-native species control measures that need to be taken in the watershed?	Core Team	Goal 3	Step 3,4,5	Y	Within legal limites
6	What is the adequate benchmark for this goal?	MG	Alt.analysis	3	Y	Within legal limites
7	What adverse conditions as identified by the plan are not presently possible to correct under this plan due to legal, financial or political constraints?	JH	Implementation	7,8	Y	TBD
Public Health and Safety						
1	What public health and safety issues exist?	Core Team	1,2,5	3,4	Y - for surface	TBD - None significant; within jurisdictior
2	What improvements will be made?	Core Team	1,2,5	5,6	Y - for surface	TBD - None significant; within jurisdictior
3	What negative impacts will occur from these activities?	Core Team	5	5,6	NA	
4	What is the adequate benchmark for this goal?	MG	Alt.analysis	3	Y	Conveyance, WQ
5	What adverse conditions as identified by the plan are not presently possible to correct under this plan due to legal, financial or political constraints?	JH	Implementation	7,8	Y	TBD
Public Involvement						

		Who	Corresponding Goal/Objective	Related Workplan Step	question be answered	Notes
1	What changes are the public willing to accept to changes in life style and costs to address the changes needed?	Core Team	Goal 6	Step 6	Y - identified	Open Houses/surveys
2	Are all aspects of public involvement adequately covered in the plan?	Core Team	Goal 6	Step 1,2	Y	
3	Will this plan enhance long-term public stewardship?	Core Team	Goal 7	Step 6,7	Y	TBD
4	What is the adequate benchmark for this goal?	MG	Alt.analysis	Step 6,7	Y	
5	What educational efforts are needed to assure the involved public understands the plan?	JH	Implementation	Step 6	Y	TBD
Monitoring						
1	Are we establishing measurable results of effectiveness of program?	Core Team	goal 8	Step 8	Y	Standards
2	What are the plans measures to success?	Core Team	goal 8	Step 8	Y	Implementation
3	What do we need to be monitoring?	Core Team	goal 8	Step 8		
4	What's the purpose of the monitoring?	Core Team	goal 8	Step 8	Y	
5	Who's responsible for the monitoring?	Core Team	goal 8	Step 8	Y	
6	How long does the monitoring have to go on?	Core Team	goal 8	Step 8	Y	
7	What is the adequate benchmark for this goal?	MG	Alt.analysis	3		
8	How do we monitor for cumulative and interactive effects of the various actions?	JH	Implementation	7,8		
Coordination and consistency with other plans and policies						
1	What are the key coordination links to this watershed plan?	Core Team	goal 9	Step 3	Y	ESA , RR, SWCP
2	What is the adequate benchmark for this goal?	MG	Alt.analysis	Step 3		
3	How is this effort coordinated with Metro's fish and wildlife habitat protection efforts?	JH	Implementation	Step 3		
Stewardship.						
1	Who are the key agents for watershed stewardship?	SM	goal 7	Step 7,8	Y	
2	What measures should be taken to facilitate collaboration among stewardship agents and with governmental agencies?	SM	goal 7	Step 7,8	Y	Project PI Plan
3	What information resources should be made available to agents? In what form?	SM	goal 7	Step 7,8	Y	
4	What education measures best support stewardship?	SM	goal 7	Step 7,8		
5	What factors encourage stewardship?	SM	goal 7	Step 7,8		
6	What are the roles and responsibilities encouraged for citizen stewards?	SM	goal 7	Step 7,8		
7	What are models for successful stewardship? How can they be replicated and improved?	SM	Alt.analysis	Step 3		
8	What is the adequate benchmark for this goal?	MG	Implementation	Step 7,8		
Misc.						
1	What are the iterative loops on modeling/habitat/planning/alternatives assessment?	Core Team	goal 3,4	Steps 3,4	Y	TBD

CITY OF PORTLAND
Portland, Oregon

Final Work Plan

Fanno and Tryon Creek Watershed Plan

Prepared by

City of Portland

August 30, 2001

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Introduction

The City of Portland (City) is launching the Fanno and Tryon Creek Watershed Management Plan project. This Work Plan provides details on the process and tasks planned by the City to develop and implement the Fanno and Tryon Creek Watershed Management Plan. When completed, the Watershed Management Plan will recommend a comprehensive, strategic set of projects and programs to improve water quality, fish and wildlife habitat, and watershed "functions" in the Portland's Fanno and Tryon Creek Watershed.

The Watershed Management Plan will address Clean River Plan priorities, and contribute substantially to the City's Clean Water Act and ESA compliance efforts. The Watershed Management Plan will guide key City programs and projects in the Fanno and Tryon Creek Watershed including water quality and performance monitoring, stormwater BMPs, watershed revegetation, habitat restoration, and infrastructure projects. The Watershed Management Plan will provide a basis for development of the City's operating and capital budget to fund priority actions. The Watershed Management Plan will be submitted to the City Council for endorsement.

The Watershed Management Plan will be founded on sound watershed science. As such, it will address instream flows and water quality, impervious area and stormwater issues, channel hydrology, stability and erosion, pollution prevention, biological communities and fish and habitat restoration, monitoring needs, and education/stewardship opportunities.

The Watershed Management Plan will establish specific goals and objectives, identify and evaluate program/project alternatives, (e.g., combinations of stormwater BMPs, revegetation, habitat enhancements, land acquisition/easements, monitoring, bank stabilization, culvert replacement, floodplain reconnection, education/stewardship, etc.), and provide a prioritized set of short-term and long-term implementation actions to solve or prevent identified problems, and meet watershed goals and objectives.

Effective coordination and collaboration with key City bureaus and Portland's ESA program is required for the success of the Fanno and Tryon Creek watershed management planning process and the plan itself. Consultants will provide technical assistance on specific project tasks.

Background

In July 1999, the City's Bureau of Environmental Services (BES) published the *Public Facilities Plan* (PFP). The PFP is a planning document that uses a watershed approach to evaluate the existing and future conditions and functioning of the City's wastewater and stormwater facilities through the year 2015. "Identification of the stormwater system needs (was) based on a performance evaluation of system hydraulics, water quality, and natural resources" (PFP, p. 3-27). Even though the City does not have specific standards for natural resources, the City "…recognizes that the condition of natural resources within its watersheds directly affects the functionality and performance of both natural streams and man-made stormwater quantity and quality facilities" (PFP, p. 3-25).

The *Fanno Creek Resource Management Plan (RMP) and the Upper Tryon Creek Corridor Assessment (UTCCA)* were completed in 1997/1998 as one of the tasks of the PFP. Because of the numerous projects identified by the PFP, the RMP and the UTCCA, it is recommended that the Fanno and Tryon Creek Watershed Management Plan be developed. The Plan would be a comprehensive action plan for the watershed, which includes Fanno and Tryon Creeks and their tributaries. Skyline West and Cedar Mill Creek are recommended for evaluation through a separate process. The PFP described such a project as basin pre-design. The PFP recommended that:

> *The predesign will evaluate, on a system-wide basis, the appropriate projects necessary to meet federal mandates and improve the conveyance (It) will build on the work that was accomplished in the RMP and UTCCA and as part of this PFP by developing additional field data, enhancing the existing hydraulic model (including water quality modeling), and evaluating upland areas for water quality and quantity improvements (PFP, p. 4-97).*

The need for the Fanno and Tryon Creek Watershed Management Plan also lies in new water quality and ESA regulations and land use planning. The Oregon Department of Environmental Quality (ODEQ) has set the target water quality standards for Fanno and Tryon Creek s and their tributaries. As some water quality standards are not being met in the Tualatin Basin, DEQ has proposed total maximum daily loads (TMDLs) for the following:

1. Total phosphorus
2. Temperature
3. Dissolved Oxygen
4. Bacteria

DEQ has placed Tryon Creek on the 303 (d) list as water quality limited for temperature.

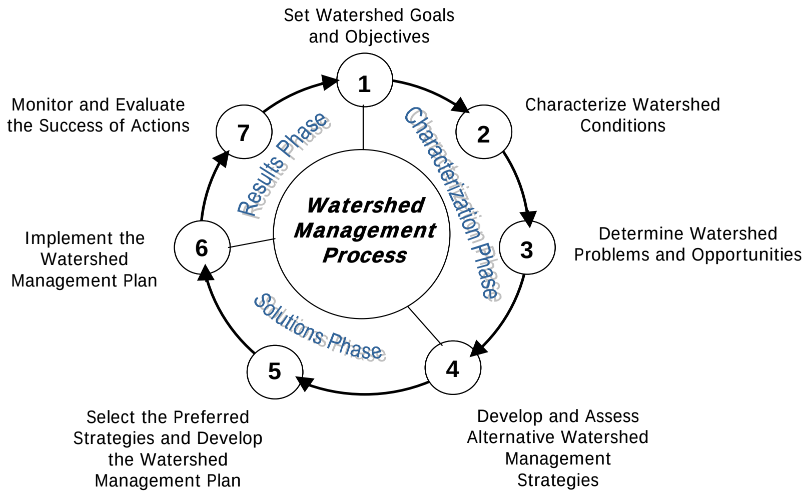
In addition, the City's MS4 permit requires that all pollutants should be removed to the maximum extent practicable. This is taken to mean that the TMDLs and water quality standards shall be met.

Purpose and Process

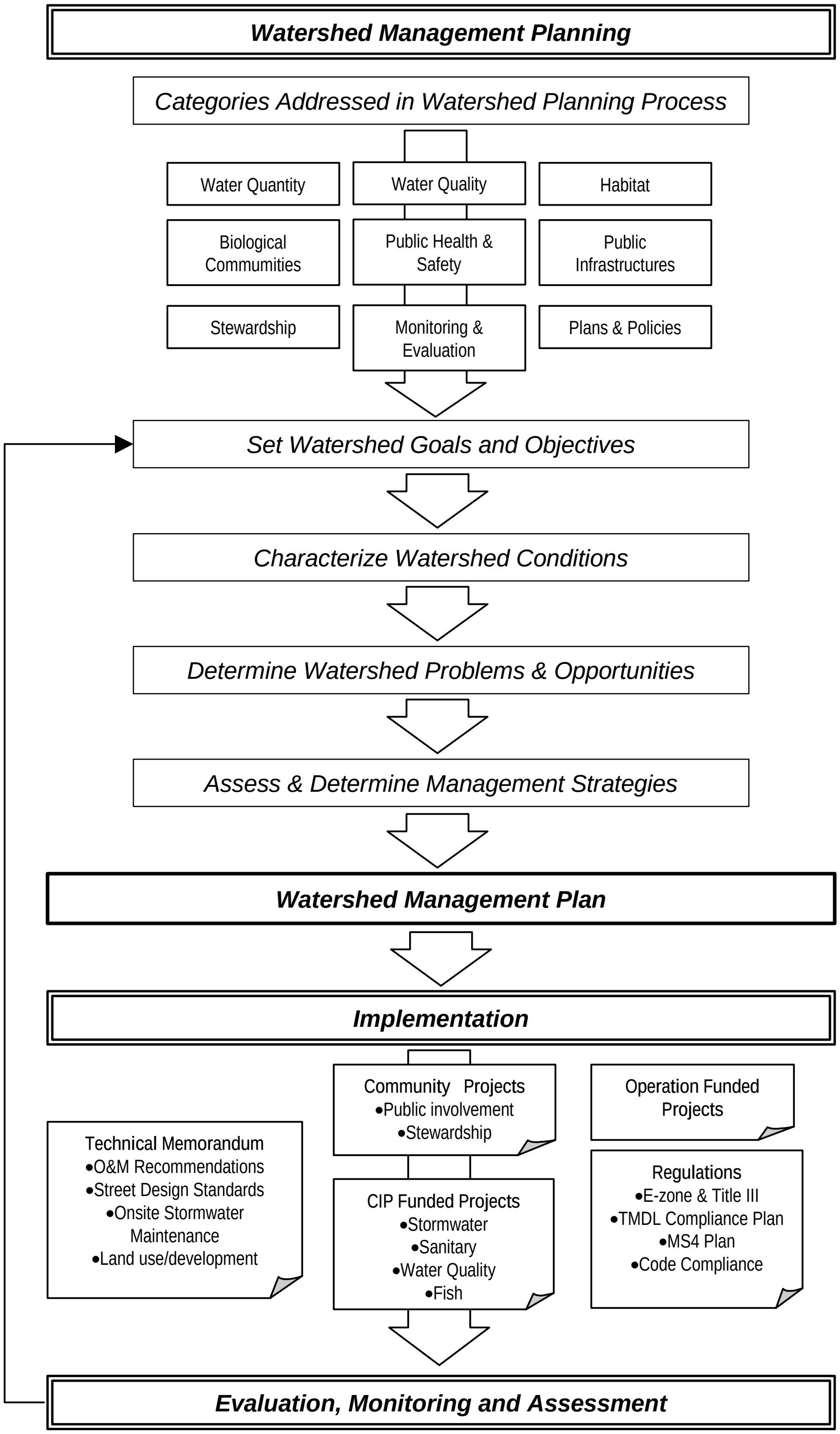
The purpose of the Watershed Management Plan is to complete and augment the work that was started by the Fanno Creek RMP and UTCCA, as recommended by the Public Facilities Plan. The Watershed Management Plan will include the portions of the Fanno and Tryon Creek watersheds that are within Portland's Urban Services Boundary (USB). The Watershed Management Plan will include a comprehensive evaluation of the contributing upland areas, water quality, infrastructure capacity and impact, ESA, land use and land development analysis, including the evaluation of the creeks and creek corridors.

The Watershed Management Plan is expected to result in groups of recommendations, technical memos, projects, procedures and guidelines for O&M, further studies, programs recommendations, and specific water quality achievement guidelines. The Watershed Management Plan will establish milestones and timelines for implementation to achieve specific objectives such water quality goals to meet TMDLs. Development of the Watershed Management Plan is expected to take two years to complete - assuming necessary allocation of resources and expertise during this time.

The following diagram shows the three-phase, seven-step watershed management process that serves as the framework for development of the Fanno and Tryon Creek Watershed Management Plan. The steps represent a sequential assessment and decision-making approach to set watershed goals and objectives, characterize conditions, develop management solutions, and implement actions and assess their success. The circular nature of the process suggests that watershed management involves ongoing adaptive management, and important feedback to ensure that watershed goals and objectives are achieved. This Work Plan provides detailed descriptions of specific work tasks, including deliverables and schedules, that are organized according to this three-phase, seven-step watershed management process.



The three-phase, seven-step watershed management process will consider resources and facilities, and produce key deliverables and outcomes as summarized in the following diagram:



Phase I: Scoping and Characterization

Step 1: Set Watershed Management Goals and Objectives

Task 1.1 Develop Draft Goals and Objectives

- Develop initial draft goals and objectives for the Fanno/Tryon Creek Watershed Management Plan.
- Key component categories to be addressed in the Watershed Management Plan goals and objectives include
  - Water Quantity
  - Water Quality
  - Habitat
  - Biological Communities
  - Public Health and Safety/Infrastructure
  - Public Involvement
  - Stewardship
  - Monitoring and Evaluation
  - Coordination and Consistency with Plans and Policies
- Circulate draft goals and objectives for review by Fanno/Tryon Creek Watershed Core Team, Interbureau Project Advisory Committee, and Project Oversight Committee.
- Develop final draft goals and objectives for the Fanno/Tryon Creek Watershed Management Plan, and distribute to external stakeholders (see Task 1.5).

Deliverable: *Draft List of Goals and Objectives*

Subtask 1.1.1 Determine Links to, and Consistency with Other Internal and External Planning Efforts

- Determine how this watershed management planning is, or will be linked to other internal and external planning efforts, such as:
  - City standards, policies, goals, and objectives
  - City’s River Renaissance initiative
  - City’s Endangered Species Act (ESA) Program and Framework
  - Tualatin basin TMDL development and allocation process
  - Others as appropriate
- Identify and review existing plans and policies, as well as planning efforts underway, with which the watershed plan project should be coordinated. Develop “parallel” process steps and identify critical links between the processes.
- Incorporate objectives for Coordination and Consistency with Plans and Policies into draft goals and objectives as appropriate.

Task 1.2 Identify and Expedite Appropriate Early Actions or Projects

- Conduct a streamlined process for identifying projects and actions that can and should be considered for implementation right away. Build on the good work already done! Don’t “reinvent the wheel”. Identify the obvious, “low hanging fruit” and move forward with appropriate interim or early actions.
- Conduct this process and justify implementation that is expedited but still true to the overall seven-step process envisioned in this watershed planning. The process will include:
  - Developing criteria for identification and selection of early action projects

  - Identify potential actions or projects based on the criteria, should be implemented promptly.
  - Implementing identified actions and projects.

Deliverable: *Memorandum of Recommended Early Actions or Projects*

Task 1.3 Outline Strategy for Regulatory Compliance

- Assess technical, legal, policy needs and strategies for ensuring that the Watershed Management Plan will achieve compliance with key regulations, such as the Endangered Species Act (ESA), Clean Water Act (CWA), etc.
- Conduct initial consultation meetings with key regulatory agencies on Watershed Management Plan goals, objectives, and approach.

Deliverable: *Memorandum Summarizing Regulatory Compliance Needs and Strategy (as needed)*

Task 1.4 Seek and Integrate Stakeholder/Public Participation

- Review draft goals and objectives with Stakeholders. Conduct a workshop to present and seek comment on the Watershed Management Plan's goals and objectives.
- Identify and coordinate with other Stakeholders (particularly other jurisdictions in the watershed) on possible participation in funding, performance of the work, and implementation of resulting Watershed Management Plan.

Deliverable: *Project Public Involvement Plan (as prepared in Task 2.2 described below)*

Task 1.5 Refine and Finalize Goals and Objectives

- Revisit and finalize goals and objectives for the Fanno/Tryon Creek Watershed.
- Get endorsement by City management of goals and objectives for the Fanno/Tryon Creek Watershed.
- Use goals and objectives to develop detailed Work Plan for the Watershed Management Plan project (as described in Task 2.1)

Deliverable: *Final List of Goals and Objectives*

Step 2: Plan, Endorse, and Manage the Watershed Management Plan

Task 2.1 Develop Detailed Work Plan and Charter with Team

- Develop detailed work plan that includes:
  - Scope of Work (Text description of project purpose, tasks, subtasks and deliverables – *this document*)
  - Task Status and Actions (Task assignments, actions, deliverables, and completion dates – *Attachment A*)
  - Project Schedule (Gantt chart of tasks, milestones, timing and linkages between tasks – *Attachment B*)
  - Project Budget (BES & Consultant Staff Charges and Expenses – *Attachment C*)
- Review of Work Plan by Team and City Management
- Charter the Team to gain commitment to Project goals, roles, responsibilities, rules, work plan, deliverables, schedule, and communications

Deliverable: *Final Project Work Plan*

Task 2.2 Develop Plan for Stakeholder/Public Coordination, Involvement, and Education

- See work elements specified in the Fanno Creek and Tryon Creek Watersheds Planning DRAFT Public Involvement Plan (revision dated May 14, 2001) – *Attachment D*.
- Identify internal and external stakeholders
- Identify key project or program decisions and determine the best way to involve stakeholders
- Define outreach activities that inform and involve stakeholders throughout all project phases. For example, during the life of this project, the public will be notified about the project's progress through mailings and public meetings. This task will use flyers, exhibits and handouts among other tools based on public involvement plan. The City will make presentations to the watershed council, stream groups and other community groups as needed or requested
- Establish a process to evaluate stakeholder understanding of and support for project products and recommendations.
- Define process and products for documenting and addressing stakeholder concerns and ideas.

Deliverable: *Project Public Involvement Plan (see Attachment D)*

Task 2.3 Acquire Endorsement and Funding of the Project

- Get endorsement and funding approval of the project as defined in the Final Project Work Plan (as prepared in subtask 2.1) and the Project Public Involvement Plan Work Plan (as prepared in subtask 2.2) by City management

Task 2.4 Administer, Manage, and Communicate on Project Implementation and Progress

- Overall project management, including planning and implementation of the project, team coordination and leadership, resource allocation and budgeting, and reporting on project progress and status. In addition, project management will involve quality assurance/control, procedures for scope amendments, and managing changes.
- Coordination of Project teams and committee. Project teams and committee, composition, function and meeting frequency are listed in Table 1. Develop and maintain meeting schedule for teams and committee. Conduct team meetings throughout the project process to discuss progress, make decisions and present work products. Core team meetings will be frequent; some of these meetings may involve specific staff only and others involve everyone on the Core Team.

Deliverables: *Brief Monthly Project Status Reports*

Task 2.5 Prepare List and Description of Deliverables and Reports

- Prepare list of Project deliverables and reports and their due dates
- Describe how deliverables comprise components or modules of the overall Watershed Management Plan
- Discuss responsibilities for preparing report(s) and describe report format, style, content

Deliverable: *List and Description of Deliverables and Reports*

TABLE 1
Fanno and Tryon Creek Watershed Planing Project Teams, Composition, Function and Meeting Frequency

Team	Composition	Function	Meeting Frequency
Project Core Team	Division Manager Section Manager Project Manager Watershed Manager Project Engineer ModelerGIS/Mapper Public Involvement ESATech II Intern	Develop and Execute Project Development Tasks	BI-Weekly – Depending on the need and agenda, a few, some or all of the team maybe attending the core team meetings.
Project Technical Advisory Team	Core Team (selected) Engineering Services (Design and Maintenance) Stormwater Program ESA OPDR/ Planning Clean Water Services Tryon Creek Watershed Council Pollution Control Lab Bridlemile Stream Stewards Community Representatives City of Lake Oswego Tryon Creek State Park	Project Progress Review, Expertise, Advise and Guidance, Alternatives Evaluation and Selection	Every 6 weeks to 2 months
Oversight Team	Core Team (selected) Group Manger Regulatory Division Manager Engineering Services	Review Task Development, Provide Expertise and Program Direction, Approve Changes (budget, schedule, task details etc.)	As needed.
City Management Advisory Committee	BES Management Other Bureaus Management	Integration of Project with Other City Watershed and River-related Efforts	Monthly or as Needed

Task 2.6 Evaluate and Ensure Project Completion and Success, and Close Project

- Determine what factors and criteria will be used to determine Project success
- Upon completion of the Project, evaluate the final Project outcome and products against these factors and criteria.
- Evaluate and reconcile the final Project outcome and products with the original vision, goals, and objectives of the project.
- Perform project close-out, including a meeting to debriefs with Core Team on Project performance, demobilizing of staff and resources, closing financial elements of the project, and archiving project materials.

Deliverable: *Summary Memorandum on Project Completion and Success*

Step 3: Characterize Existing Watershed Conditions

Task 3.1 Determine Key Watershed Issues Leading to Critical Questions

- From technical standpoint, the watershed characterization process must be “scoped” by articulating the key issues and critical questions to be addressed and evaluated. Key issues and critical questions should be identified early in the process to help focus the analyses and tools to be used (such as models).

- Key issues and critical questions will encompass the following environmental categories to be addressed in the Watershed Management Plan (the main headings below follow the main headings also used to set goals and objectives):

  - Water Quantity
    - Watershed surface water hydrology and hydraulics conditions
    - Stormwater quantity management, conveyance, and infrastructure capacity
    - Sanitary wastewater quantity management, conveyance, and infrastructure capacity
    - Flood flow management, floodplain function, and property protection
    - Channel stability and geomorphology
    - Groundwater conditions
  - Water Quality
    - Watershed surface water and groundwater quality conditions
    - Water quality standards and compliance
    - Magnitude, distribution, and sources of pollutant loading
    - TMDL requirements for temperature, phosphorus, dissolved oxygen, bacteria
    - Erosion/sediment sources
    - Stormwater quality management and BMPs
    - Sanitary wastewater treatment
  - Habitat
    - Habitat conditions and ecological functions
      - Riparian and wetland areas
      - Instream habitats and fish passage
      - Upland habitats, parks, and open spaces
    - Access and use of habitats by aquatic and terrestrial species
    - Natural area protection and restoration
  - Biological Communities
    - Target species for protection, restoration, and enhancement
    - Biological communities and ecological functions
    - Indicator organisms of watershed health
    - Species life histories and watershed use
    - Species interaction
    - Urban effects on biological communities
    - Invasive or non-native species control
  - Public Health and Safety/Infrastructure
    - Land uses and development
    - Stormwater system planning, construction, operation, and maintenance
    - Sanitary wastewater system planning, construction, operation, and maintenance
    - Water supply and delivery system planning, construction, operation, and maintenance
    - Roadway system planning, construction, operation, and maintenance
    - Other public health and safety, and infrastructure matters
  - Public Involvement
    - Public input
    - Public education
    - Stakeholder coordination, partnerships, and participation in decision-making
    - Other watershed issues identified by the public

- Stewardship
  - Stewardship goals and commitment
  - Viable emerging techniques and technologies to address watershed needs
  - Sustainability
- Monitoring and Evaluation
  - Integrated monitoring strategy
  - Adaptive management approach
  - Roles and responsibilities for monitoring
- Coordination and Consistency with Plans and Policies
  - Key watershed plans and policies
  - Coordination and interaction with City plans and policies

Deliverable: *List of Key Watershed Issues and Critical Questions*

Task 3.2 Identify Parameters and Attributes to Characterize Conditions

- Identify and select environmental parameters and attributes that will be used to systematically characterize watershed conditions. Examples of parameter subjects should include, but not necessarily be limited to:
  - Impervious areas
  - Flow/hydrology/hydrograph alteration
  - Floodplain connectivity
  - Soils and Slopes
  - Groundwater Characteristics
  - Stormwater outfalls/pollutant and thermal loads
  - Infrastructure location and condition (roads, water supply and delivery system stormwater system, sanitary wastewater system)
  - Riparian areas, conditions, composition, and connectivity
  - Water quality – temperature, dissolved oxygen, nutrients, toxics (e.g., metals), bacteria
  - Known soil and groundwater contamination
  - Sediment contamination
  - Invasive plants (aerial extent)
  - Aquatic invasive species
  - Hazards/landslides/erosion
  - Fish and wildlife habitat presence and use
  - Revegetation projects, demonstration/pilot projects
  - Stormwater inflow controls (e.g., sumps, downspout disconnection)
  - Fish access/barriers to off-channel habitats and tributary watersheds

The inclusion of any parameters will be necessitated by ability to compile/acquire data in a timely manner consistent with project schedule and objectives.

Deliverable: *Matrix of Attributes and Benchmarks (to be used with Task 3.3)*

Task 3.3 Define Standards and Benchmarks for Evaluating Quality of Conditions

- Standards, benchmarks, or thresholds will be defined for each parameter and attribute (defined in Task 3.2 above) as a means of evaluating quality of conditions.

- Standards, benchmarks, or thresholds will be quantitative whenever possible, but may be qualitative or narrative in circumstances where detailed information is lacking or to augment quantitative standards.

- Define design storms and historical analyses periods. (This added by Core Team Meeting of 6/20).

Deliverable: *Matrix of Attributes and Benchmarks (in combination with Task 3.2)*

Task 3.4 Define Watershed Analysis Units and Scales

- Define appropriate units and unit area scales for characterization of the watershed, taking into consideration the results of tasks 3.1, 3.2, and 3.3.

Deliverable: *Description and Maps of Watershed Analysis Units and Scales*

Task 3.5 Gather, Review, and Organize Existing Data and Information

- The purpose of this task is to collect, review and consolidate available information and studies on Fanno and Tryon Creek Watersheds, particularly related to the parameters and attributes identified for use in characterizing watershed conditions.
- The available information shall primarily be in the form of previous studies, which include data such as rainfall data, HEC-1 and HEC-2 models, as-builts, aerial photos, topographic maps, GIS information on land use and land development, monitoring data for flow and water quality, Oregon Department of Fish and Wildlife stream survey results, stormwater quality data, and the DEQ documents on the proposed TMDLs and 303 (d) listings. Focus on information required to support the project (or planning process). Apply screening & prioritization to focus the data collection on data required to execute the project.
- Confirm watershed data available to complete characterization and problem identification for the watershed. Take into account results of previous watershed and facilities studies (e.g., RMP, UTCCA, PFP), ESA Watershed Assessment Template & Science Foundation data elements, and initial watershed goals and objectives in identifying these data and information needs***.***
- Develop inventory of relevant data and information sources.
- Perform Literature Review
    - Review relevant scientific literature to identify the best available science regarding watershed conditions and effects on watershed processes, functions, and resources in urban and urbanizing areas.
    - Review relevant literature to identify strategies and actions that have been implemented in Portland and elsewhere to address such watershed conditions and effects.
    - Review relevant literature on monitoring and evaluation of the effectiveness, feasibility, and costs of alternative strategies and actions to address such watershed conditions and effects.

Deliverable: *Background Information Report (to be included as part of the Characterization Report - see Task 3.9)*

Task 3.6 Create Watershed Analysis GIS Database and Base Maps

- Develop framework to organize & store data and information at the watershed and subwatershed planning area scales. Include relevant data/information fields and analytical functions as appropriate. Data/information fields must include at a minimum, key parameters (as identified in Task 3.2), and associated metrics for comparison with standards/benchmarks/thresholds (as identified in Task 3.3).
- Create GIS base maps for the watershed analysis process. Base maps will include the stream network, watershed and subwatershed boundaries, roads, legal boundaries, etc. Base maps will be in electronic form to support modeling as appropriate. Hardcopy base maps can be produced as needed for field or desktop use by analysts or for report presentation purposes.
- Organize and enter (into database) available data & information coverages and layers needed to complete the characterization. These data & information coverages and layers will comport with the attributes and parameters as determined in Task 3.2.

- Examples of tools and formats:
    - MS Access™ table structures
    - GIS coverages (MapInfo™, Arcinfo™)
    - Scanned images
    - Text and tables from previous reports (e.g., data analysis and interpretation, assessments, standards/targets, policy, and programs directions).

Deliverables: *GIS DATA Framework, GIS Base Maps (as needed), and Data Dictionary*

Task 3.7 Identify Data Gaps, Collect Additional Data, and Identify Other Analytical Tools as Needed

- Assess the relevancy and utility of existing data compiled from both Task 3.5 and Task 3.6. Identify key data/information gaps relative to list of parameters and benchmarks from Tasks 3.2 and 3.3. Evaluate variability of data gaps across study areas and/or topics.

- Identify any additional future field investigation, data collection, and analysis necessary to finalize the Watershed Characterization and Condition Assessment Tasks beyond year one activity. Additional tasks may include:
    - Facilities Inventory
    - Stream Assessment and Survey
    - Upland Assessment and Survey
    - Water Quality Data
    - Flow/Level/Water Quality Monitoring

- Confirm available modeling capability, identify model development and refinement needs, and plan for construction or refinement of additional models needed to support the project (to be built in Task 3.8).

- Identify key data for system analysis to be obtained from existing models and analysis tools (task added by Core Team at 6/20 meeting).

Deliverable: *Data and Modeling Needs and Development Report (to be included as part of the Characterization Report - see Task 3.9)*

Task 3.8 Build Models and Other Needed Analytical Tools

Subtask 3.8.1 Build Hydrologic, Hydraulic, Pollutant Loading and In-stream Water Quality Models.

- Review existing flow and water quality monitoring for each watershed, as inventoried from Task 3.5.

- Evaluate suitability of existing monitoring data for explicit watershed model calibration.

- Prioritize calibration needs of model, by watershed and constituent (flow, SS, temp, etc.) for defensible calibration of watershed model. Consistent with goals and objects from Task 1.5.

- Review targets and determine implications to project goals and objectives.

- Develop/implement monitoring plan for model calibration. Monitoring plan review and endorsement by stakeholders, team, management.

- Develop specific modeling plan and assignments. Determine which modeling components to be included (SW, UZ, GW, Water Q). Modeling plan needs to accommodate data sharing activities with other watershed modeling throughout City (ESA).
- Confirm available modeling capability, identify model development and refinement needs, and plan for construction or refinement of models needed to support the project.
- Build and parameterize model(s) as needed to complete characterization (as per Step 3), and also to be used for subsequent problem/opportunity identification (as per Step 4) and analysis of management alternatives (as per Step 5). For example:
    - Water quality models will be needed to characterize pollutant loading and effects instream, with a focus on parameters for which TMDLs will be established and other pollutants of concern.
    - Develop a water quality model that will reflect the existing conditions and future water quality conditions in the watershed. It will also help identify sources and subbasins that contribute high amounts of pollutants to the streams. This task will include characterization of the modeled hydrologic units for prioritization to implement effective water quality improvement measures. The deliverable for this task will be a water quality model and specific implementation strategies to address water quality with specific achievements/results within specific timelines.
    - Develop an explicit hydrology/hydraulic and groundwater model. The refinement of the hydrology and hydraulic models are such that they can be used to model more frequent events and provide information on shear and scour potential erosion and sediment transport potential. The deliverables for this task are explicit models that are to be used to assess impacts for the bank-full (approx. 2 year), 10-year, 25-year, and 100-year storm events.
    - EDT likely will be used to assess fish and wildlife habitat conditions, limiting factors, and capacity/productivity. Data coordination with this will be necessary.
- Test, calibrate and verify model(s) for existing watershed system and conditions using best available data suitable for such.
- Review of model by qualified, outside expert. Document and incorporate needed changes, as deemed appropriate by the modeling team.
- **Deliverable:** *Watershed models, modeling report covering assumptions, calibration, and preliminary results. Data appropriate for UHA modeling use by ESA program (subtask 3.8.2).*

Subtask 3.8.2 Develop Urban Habitat Assessment (UHA) Model

- Conduct Urban Habitat Assessment (UHA) modeling[1] for target fish and wildlife species[2], that will be used to identify existing conditions as they affect watershed ecosystem health, particularly as related to ESA-listed species and their habitats.
- Delineate subwatersheds, channel geomorphic types, and distinct channel/habitat reaches to serve as the basis for subsequent data and modeling analysis, and also serve as basis for assignment of recovery objectives and subsequent recommended actions.
- Prepare maps of species and life stage presence and use in the watershed (by subwatersheds and reaches).

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[1] UHA is a species-habitat relationship model developed by the ESA Program to assess habitat conditions in the City's watersheds, and determine the effects of these conditions on species abundance, productivity, and diversity. UHA is patterned after the Ecosystem Diagnosis and Treatment (EDT) model.

[2] Emphasis will be placed on species listed or proposed for listing under the Endangered Species Act (particularly key salmonid fishes).

- Obtain existing information (such as ODFW habitat survey information) to assess current conditions of key habitat attributes or habitat-forming processes in the watershed[3].
- Use the UHA process to relate attributes and benchmarks to abundance, productivity, diversity and spatial structure of key fish and wildlife species (i.e., "build the rules" for the UHA modeling process).
- Use these UHA species-habitat relationships to develop "survival landscapes" that depict how current environmental conditions across each watershed and over time likely affect species abundance, productivity, diversity and spatial structure (i.e., "apply the rules").

Deliverable: *Technical Memorandum on UHA Modeling and Results (to be included as part of the Characterization Report - see Task 3.9)*

Task 3.9 Complete Detailed Inventory and Draft Characterization Report

- Update information in the Fanno Creek RMP and Tryon Creek UTCCA. The Fanno RMP and the UTCCA include an assessment of the creeks and the creek corridors. They do not include a comprehensive upland assessment. Apply results of above tasks to verify the information included in the RMP and UTCCA, which were completed in 1997/98, and revise and augment the information as necessary. The most current ODFW surveys will be integrated into this task if available. Included in this task is an evaluation of upland vegetation and habitat conditions, land use pattern, slopes, soils and other factor affecting infrastructure and watershed health. Prepare a revised assessment table for the creeks and creek corridors and an assessment table for the upland areas.
- Develop Characterization Report
    - Compile the results of tasks 3.1 through 3.8 to characterize watershed conditions.
    - Document data and information collected and applied; present maps, tables and descriptions of watershed conditions.
    - Include updates and revisions to the Fanno Creek RMP and Tryon Creek UTCCA as described above.
    - Draft Characterization Report will be circulated to the Project Advisory Team and independent technical review (e.g., Science Team) for review and comment. These documents will be revised to reflect comment.
    - Finalize Draft Characterization Report.

Deliverable: *Draft Watershed Characterization Report (the Watershed Characterization Report will be finalized when it is incorporated as part of the Watershed Analysis Report as described in Task 4.5)*

Step 4: Determine Potential Watershed Problems and Opportunities

- Review of modified models (existing and future base) by qualified, outside expert. Document and incorporate needed changes, as deemed appropriate by the modeling team.
- Develop maps and other graphics as appropriate to depict the types and locations of current and potential watershed condition problems and opportunities for existing and future Conditions. Major items of interest include:
    - Hydrology & Hydraulics (Impervious Area, Stormwater Controls, Vegetative Cover, Storm drainage network, Streambank & Channel Physical Conditions, Floodplain Connectivity)

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[3] Hydrology and hydraulics, riparian condition, instream habitat and water quality (Level 2)

  - Water Quality (Temperature, Sediments, Nutrients, Bacteria, Dissolved Oxygen)

Deliverable: *Technical Memorandum on Conditions and Potential Problems and Opportunities (to be included as part of Analysis Report – see Task 4.5)*

Task 4.1 Evaluate Quality of Conditions and Identify Potential Problems and Opportunities

- Modify model to represent future base conditions (i.e. “No Action” or base conditions as specified in PFP). Incorporate the effects of established standards such as the Stormwater Management Manual or other standards as the technical team deems applicable.

- Perform necessary statistical, modeling, GIS, and other qualitative analyses of existing and future base conditions for comparison to standards and benchmarks for watershed attributes and parameters (as determined in Task 3.3).

- Describe current and potential future problems and opportunities relative to which standards and benchmarks are or are not met taking into consideration frequency, location and duration of impacts.

  - Express watershed standards and objectives in terms of clear numerical or qualitative criteria to serve as a Problem Statement or Problem Identification

  - Determine and document the frequency, location and duration of when criteria is met or not

  - Conduct analysis and compare analysis results against know historical problems

- Use models (as developed in Task 3.8) and other analytical tools as appropriate to characterize quality of conditions and identify potential problems and opportunities.

  - For existing and future conditions, identify existing and potential problem areas, and identify potential “opportunity sites” or areas that appear viable for addressing problems and meeting watershed goals and objectives.

  - For existing conditions, compare results against known historical problems. Estimate potential problems associated with future conditions as warranted by model results.

  - Use the UHA “survival landscapes” (developed in Task 3.8) to identify key environmental problems (“valleys” in the survival landscapes) and opportunities (“valleys” in the survival landscapes) related to target fish and wildlife species and their habitats, and to set detailed protection, restoration, or enhancement objectives tailored to the watershed by subwatershed or reach.

- Review of modified models (existing and future base) by qualified, outside expert. Document and incorporate needed changes, as deemed appropriate by the modeling team.

- Develop maps and other graphics as appropriate to depict the types and locations of current and potential watershed condition problems and opportunities for existing and future Conditions. Major items of interest include:

  - Hydrology & Hydraulics (Impervious Area, Stormwater Controls, Vegetative Cover, Storm drainage network, Streambank & Channel Physical Conditions, Floodplain Connectivity)

  - Water Quality (Temperature, Sediments, Nutrients, Bacteria, Dissolved Oxygen)

  - Fish & Wildlife Habitat (Fish Barriers, Substrate, Pools, Refugia, Riparian Conditions)

  - Biological Communities

Deliverable: *Technical Memorandum on Conditions and Potential Problems and Opportunities (to be included as chapter or section of Analysis Report – see Task 4.5)*

Task 4.2 Perform Sensitivity Analysis to Quantify Cause and Effect Relationships

- Establish and document cause-effect links between problems and known or possible factors causing or contributing to problems, as established using steps in Task 4.1 and Step 3 tasks.
- Perform sensitivity analysis to assess which problems, causal factors, and assumptions have greatest effect on condition of watershed parameters and attributes.
- Estimate confidence level associated with the documented cause-effect links. This will be based on professional judgement based on level and weight of evidence associated with a documented cause-effect link.
- Prioritize cause-effect links using sensitivity analysis and stakeholder/public input on watershed problems or opportunities and their causes/factors. Prioritization will assist in focusing and targeting potential management strategies and actions identified and assessed in Step 5.

Deliverable: *Technical Memorandum describing the sensitivity of various parameters and the relationship they have on Problems and Opportunities (to be included as part of Analysis Report – see Task 4.5)*

Task 4.3 Establish Areas of Opportunity for Protection and Restoration Actions in the Watershed

- Based upon sensitivity analysis results of Task 4.2, identify locations and possible methods of operation to protect, restore, or enhance watershed problems or opportunities identified in Task 4.1. This will be in accordance with benchmarks established in Task 3.3. Analysis shall be done using a combination of GIS, watershed modeling techniques, and UHA results, as appropriate.

Deliverable: *Maps and Technical Memorandum delineating areas of opportunity for protection and restoration actions in the watershed (including BMPs and other watershed practices).*

Task 4.4 Seek and Integrate Stakeholder/Public Input

- Review results of watershed characterization condition assessment, and problem/ opportunity identification and causal factors with Stakeholders. Consider Stakeholder input in confirming and prioritizing of problems and opportunities to be addressed in subsequent tasks.

Deliverable: *Summary of public response to problems and opportunities identified in Task 4.2 and proposed areas of opportunities identified in Task 4.3.*

Task 4.5 Prepare Analysis Report on Watershed Conditions, Problems, and Opportunities

- Document process and results of Tasks 4.1 through 4.4.
    - Characterization of the system (watershed or facilities systems) that the plan covers. Provide background information
    - Description of the problems (water quality parameters, flooding, fish habitat, etc.) including magnitude, frequency and spatial distribution of the problem. This shall be done in terms of standards and benchmarks established in Task 3.3.
    - Maps showing the location and magnitude of the problems
    - Description of the opportunities (healthy areas to be preserved, sites for potential activities or facilities, etc.) identified where opportunities should be focused based upon the sensitivity analysis of Task 4.2 and prioritization from stakeholder input in Task 4.4.

  - Maps showing the location of the potential opportunity sites

- Develop Analysis Report
  - Document any additional data and information collected and applied since the characterization report from Task 3.9. Include analysis processes, both watershed modeling and GIS specific, and results. Results will include any maps, tables and descriptions of the types and locations of problems, and the magnitude and frequency of current and future events.
  - Draft Maps and Report will be circulated to the Project Advisory Team and independent technical review (e.g., Science Team) for review and comment.
  - Refined Maps and Report will be circulated to the Project Oversight Team and other Stakeholders for review. These documents will be revised to reflect comment.

Deliverable: *Analysis Report on Watershed Conditions, Problems, and Opportunities*

Task 4.6 Expedite Appropriate Interim or Early Actions or Projects Based on Analysis Report

- (Need to provide steps/tasks.)
  - Identify the obvious, “low hanging fruit” that emerges from the Analysis Report and move forward with appropriate interim actions.
  - Use streamlined process for documenting such actions and justifying expedited implementation but still true to the overall step-wise process envisioned in this watershed action planning program.

Deliverable: *Memorandum of Recommended Early Actions or Projects*

Phase II: Solutions

Step 5: Develop Alternative Management Strategies to Address Watershed Problems and Opportunities

Task 5.1 Prepare Objectives to Guide Watershed Management Strategies

- The setting of Objectives is a key transitional step in the Watershed Management Plan process. The objectives describe how specific watershed conditions (in terms of environmental parameters and attributes) should change to achieve desired watershed functions, qualities and values as envisioned by the Watershed Management Plan goals and objectives.

- These "action objectives" are quite specific so as to provide clear targeted guidance of potential actions, including specific targeted condition, parameter and attribute, locations, timing, and performance measure.

- Suggest specific word model template for crafting "action objectives" such as used in ESA Framework.

Deliverable: *List of Objectives to Guide Watershed Management Strategies*

Task 5.2 Develop Decision Criteria for Initial Screening of Alternative Management Strategies

- Develop preliminary lists of criteria for initial screening of alternatives AND for detailed evaluation of the refined alternatives list. Evaluation criteria will reflect watershed goals and objectives, as well as stakeholder values as identified over the course of the project.

- Screening criteria will reflect project and watershed goals and success criteria, and will establish "fatal flaw" and "suitability" factors relating to issues such as public health and safety, water quality impacts, fish and wildlife impacts, Constructibility, permitability, cost and public acceptance.

- Criteria for use in the detailed evaluation of alternatives that pass the screening will incorporate specific metrics for each criterion allow determination of absolute and/or relative strengths and limitations.

Deliverable: *Criteria for Initial Screening of Alternative Management Strategies*

Task 5.3 Identify Potential Alternative Management Strategies to Address Watershed Problems and Opportunities

The objective of this task is to identify potential project or program alternatives to meet the specific objectives from Task 5.1. It will also be necessary to understand the proper application, potential benefit and limitations of each alternative. There are three major elements to this task:

- Hold a brainstorming session and develop an initial list of alternatives to be investigated. This session will include all members of the project core team and special technical experts as required.

- Conduct a literature review to determine if additional alternatives are available. The literature review will also gather details on effectiveness, typical application and costs of each alternative.

- Summarize the details developed during the literature review in a technical memorandum. This memorandum will describing the available technologies and management strategies and will include a summary matrix of the alternatives.

Below is a general example list of categories for these alternatives. Categories will include, but not necessarily be limited to:

Nonstructural

- Revegetation– Riparian, Wetland, Floodplain, Upland
- Land Acquisition, Conservation Easements, Leases
- Neighborhood Education, Stewardship
- Fish and Wildlife Management Strategies
- Monitoring/Analysis
- Partnership and Funding Opportunities
- Incentives
- Refinement codes and standards (e.g., zoning, Stormwater Management Manual) to protect and restore watershed function (e.g., temperature management, groundwater recharge areas, etc.)

Structural

- Stormwater BMPs/PRFs
- Pipes and pump stations
- Culvert replacement or retrofit
- In-channel obstruction
- Building removal
- Road removal/realignment
- Exit or entry pool retrofit/enhancement
- Creation of oxbow or meander creation
- Floodplain reconnection
- Pond reconfiguration
- Bank stabilization (bioengineering)
- Large wood placement
- Rock grade control

Deliverable: *Technical Memorandum Describing Potential Alternative Management Strategies*

Task 5.4 Seek and Integrate Stakeholder/Public Input

- Hold a stakeholder workshop to review/brainstorm screening and evaluation criteria, and project/program options for inclusion in alternatives. The workshop will include:
    - Presentation of watershed and project goals and objectives
    - Presentation summarizing watershed assessment/characterization and problem identification
    - Key information and recommendations from existing studies, plans, and other relevant documents
- Review/brainstorm preliminary screening and evaluation criteria and preliminary alternatives options with workshop attendees. Organize the options into multiple distinct alternatives or alternatives packages.
- Prepare a package of workshop materials for review by Stakeholders and Project Team.
- Document and use input from the workshop to refine criteria and alternatives for use in next tasks.

Deliverable: *Initial screening and evaluation criteria.*

Task 5.5 Complete Initial Screening of Potential Alternative Management Strategies

- Apply initial screening criteria to identify "fatal flaws" and develop a manageable final "short list" (e.g., 5 or fewer) of specific recommended strategies and actions (or groups of actions) for detailed evaluation.

Deliverable: *Final "Short-List" and Summary of Potential Alternative Management Strategies*

Step 6: Evaluate and Select Preferred Strategies, and Develop the Watershed Management Plan

Task 6.1 Analyze the Technical Effectiveness and Costs of Short-listed Strategies

- Refine previous Screening Criteria (add to, subtract, clarify) from Task 5.2 to develop quantitative evaluation criteria that address the technical effectiveness of short-listed strategies.
    - Technical Advisory Committee input to ensure acceptance of evaluation criteria
- Detailed hydrologic and hydraulic analysis for design conditions
    - Determine sizing and configurations needed to meet project objectives *–incorporate into section on designing alternatives*
    - Quantify potential benefits in terms of reduced runoff, increased infiltration & recharge, reduced storm peak and volume to stream, increased vegetation and canopy, reduced flooding areas, increased flood storage / wetlands, increased streambank protection, increased stream stability / sinuosity.
- Instream Water Quality and/or Pollutant Loading Analysis
    - Quantify potential benefits in terms of reduced pollutant / thermal loads, decreased violation of water quality standards, increased effective shading, reduced instream temperature.
- Fish & Wildlife Habitat analysis and evaluation
    - Quantify potential benefits in terms of reduced fish barriers, increased large woody debris, increased off-channel habitat, increased refugia, increased riparian canopy density-width-length.
- Determine Planning Level Cost Estimates & Economic Impacts of each short-listed strategy.
    - Quantitative analysis of listed strategies
    - Constructibility
    - Capital, operating, maintenance, and total present worth costs
    - Include incentives and discounts BES gives or receives to implement actions
    - Evaluate impacts to sewer / stormwater rates (if applicable) (evaluation criterion)
    - Initial review of potential utility conflicts (evaluation criterion)
    - Qualitative analyses for non-measurable criteria
    - Potential cost-sharing or alternative funding opportunities

Deliverable: *Quantitative Evaluation Criteria. Matrix of Potential Technical Effectiveness and Estimated Costs of Short-listed Strategies.*

Task 6.2 Conduct Multi-Objective Analysis of Short-listed Strategies

The benefit cost analysis will focus on identifying the most cost-effective combination of short listed strategies and eliminating inefficient or ineffective solutions. This analysis will follow four basic steps to allow prioritizing implementation of the preferred strategy.

- Step 1: Formulate all possible combinations of mitigation strategies.
- Step 2: Analyze the cost effectiveness of each combination of strategies.
- Step 3: Develop an incremental cost curve.
- Step 4: Analyze the incremental costs.

The results of this analysis will be used to identify the least cost solution for each possible level of environmental output and to identify changes in costs for increasing level of environmental output.

Deliverable: *Matrix of Potential Technical Effectiveness and Benefit/Cost of Short-listed Strategies*

Task 6.3 Select and Refine the Recommended Alternative Strategy

- Use the results of Tasks 6.1 and 6.2 to prioritize or rank the short-listed strategies and develop a recommended strategy that best meets watershed goals and objectives, and criteria for technical effectiveness and multi-objective feasibility.
- Include stakeholder review and refinement. Prepare report on Alternatives Development and Evaluation
    - Document Alternatives Developed and Results of Screening
    - Document Evaluation Criteria
    - Document Results of the Analyses of the “Short Listed” Alternatives
    - Present and Circulate Recommended Alternative and Next Steps for BES and Stakeholder Review
    - Obtain Technical Advisory Committee review of alternatives development and evaluation

Deliverable: *Report on Alternatives Development and Evaluation (to be included as part of Watershed Management Plan - see Task 6.4)*

Task 6.4 Develop the Draft Watershed Management Plan

- Prepare a draft Fanno and Tryon Creek Watershed Management Plan. The draft plan will provide specific course of action to address the topic/issues covered. The plan will document the process and results of above tasks and include the following components:
    - Maps showing location of benefits / problems solved / objectives met / problems still present
    - Tables showing numerical results of problems solved / objectives met / benefits obtained
    - Description of alternatives identified, screened, and evaluated
    - Text narrative clearly documenting the process, criteria, and results of the qualitative and quantitative analyses of alternatives, demonstrating that the analysis reflects good science and data, and that cost-effectiveness and expected benefits of alternatives were balanced or optimized to meet project goals and objectives.
    - Description of the preferred alternative and it meets requirements for justifying capital and operating expenditures for next steps to implementation.

  - Description of how stakeholders were involved and how stakeholder input was addressed throughout the project.
  - Description of implementation process, including schedule and budget for actions, monitoring, adaptive management, and plan update cycle.
  - Recommended roles and responsibilities for implementation will be presented for consideration.

Deliverable: *Draft Watershed Management Plan*

Subtask 6.4.1 Develop the Draft Water Quality Management Plan

- The Draft Watershed Management Plan, particularly those portions dealing with water quality, will be edited and formatted as needed to develop the Draft Water Quality Management Plan (WQMP). The Draft WQMP is a required document that the City will prepare in response to promulgation of final approved TMDLs in the watershed.

Deliverable: *Draft Water Quality Management Plan*

Subtask 6.4.2 Determine the Watershed Management Process Cycle

- Watershed management planning is not a one-time effort, but an on-going proactive management process. Therefore, the Draft Watershed Management Plan will provide guidance and recommendations on the need, frequency, and procedures for repeating or refining in the future the tasks and analyses performed throughout this watershed planning process.

Subtask 6.4.3 Determine the Roles, Responsibilities, Processes, and Procedures for Implementing and Monitoring the Watershed Management Plan

- Implementation of the Watershed Management Plan in the Actions phase (Phase III) is perhaps the most important of the watershed management phases, because it is during this phase that management actions are actually implemented “on the ground”, and monitored for effectiveness and success. Therefore, it is important that the Watershed Management Plan provide guidance and recommendations on the roles, responsibilities, and logistics for the Actions phase. This will ensure that the entire process has been thought through, and that the logistics of the Actions phase are considered and incorporated as appropriate in the Watershed Plan and its recommended strategies and actions. Implementation steps and tasks in the Actions phase likely will be performed by various City entities as described in the Final Watershed Management Plan and depending upon the specific strategies and actions recommended in the Watershed Management Plan.

Task 6.5 Seek and Integrate Stakeholder/Public Input

- Draft Watershed Management Plan Workshop with Stakeholders
    - Present draft Fanno and Tryon Creek Watershed Management Plan to BES Staff and Stakeholders
    - Discuss results and alternatives with respect to Project Goals & Objectives.
    - Present Preferred Alternative.
    - Document input for use in refining the plan.

Task 6.6 Refine and Finalize the Watershed Management Plan

- Develop Description of Final Recommended Alternative
- Perform Final Model Analyses of both system-wide and site-specific activities
    - Detailed hydrologic and hydraulic modeling to determine sizing and configurations needed to meet project objectives

    - Pollutant load modeling
        - If necessary and possible: In-stream water quality modeling; Stream Geomorphology Analysis; Groundwater Impacts Analysis
- Perform Final Analyses for Benefits
    - Determine and display problems prevented or solved and benefits obtained using Maps, Tables
    - Develop narrative description of non-measurable benefits obtained
- Determine Final Cost Estimates
    - Capital, Operation & Maintenance and Present Worth Costs
- Obtain Independent Technical Review of Final Recommendations Do ***this sooner?***
    - Capital, Operation & Maintenance and Present Worth Costs
- The final Watershed Management Plan components include:
    - Description and map of proposed system and planning-area activities
    - Description and maps of the proposed site-specific activities (note: a "site could range from a part of a single parcel to a larger area such as a long section of a streambank or a urban renewal district, etc).
    - Sketches of details of the actions to be taken at the site(s)
    - Sizes, configurations and performance requirements of recommended activities
    - Estimated capital and operating costs of the proposed activities (+35% / -25% Accuracy)
    - Description of programmatic actions (e.g., education and stewardship program; changes in code, etc.)
    - Description of expected benefits to be obtained – both quantifiable (measurable) and non-measurable benefits for system-wide and site-specific activities
    - Proposed demo / pilot projects and critical information required from demo / pilot projects.
    - Risk Management Actions: Items of Concern (Public, Policy, Permitting and Technical) to be examined in Predesign & Design Phases; Recommended Backup Alternative if Items of Concern are too risky.
    - Monitoring Plan and Adaptive Management Strategy
    - Implementation Schedule (Short-term actions identified for early implementation).
    - Strategy for acquiring potential activity partners, cost-sharing, and/or funding opportunities
    - Proposed plan update schedule as applicable

Deliverable: *Final Watershed Management Plan*

Subtask 6.6.1 Complete the Water Quality Management Plan

- Upon completion of the Final Watershed Management Plan, those portions dealing with water quality, will be edited and formatted as needed to complete the final Water Quality Management Plan (WQMP). The WQMP is a required document that the City will prepare in response to promulgation of final approved TMDLs in the watershed.

Deliverable: *Final Water Quality Management Plan*

Task 6.7 Gain Final Approval of the Watershed Management Plan

- Approval and endorsement by City Council of the Final Watershed Management Plan.
- ***This is the last task activity explicitly covered in this work plan***. Subsequent tasks are listed and conceptually described in pages that follow. However, these subsequent tasks likely will be performed by various City entities as described in the Final Watershed Management Plan and depending upon the specific strategies and actions recommended in the final plan.
- After final approval, the watershed management process will then transition to the Actions phase where the Final Watershed Management Plan recommended strategies and actions will be implemented and monitored.

Subtask 6.7.1 Submit the Water Quality Management Plan to DEQ

- Upon approval of the Final Watershed Management Plan, the final Water Quality Management Plan (WQMP) will be submitted to DEQ.

Phase III: Actions

The Actions phase and its associated steps and tasks are not specifically included in this work plan at this time. Realistically, many important work planning details for these steps and tasks can not be determined until previous planning steps and tasks are completed. In addition, these steps and tasks likely will be performed by various City entities as described in the Final Watershed Management Plan and depending upon the specific strategies and actions recommended in the final plan.

Nonetheless, the Actions phase is perhaps the most important of the watershed management phases, because it is during this phase that management actions are actually implemented “on the ground”, and monitored for effectiveness and success. Therefore, although this Actions phase will not occur for some time, it is important that the City identify roles, responsibilities, and logistics for the Actions phase soon. This will ensure that the entire process has been thought through, and that the logistics of the Actions phase can be considered and incorporated as appropriate in the Watershed Plan and its recommended strategies and actions.

The steps and tasks envisioned for the Actions phase include:

Step 7: Implement the Watershed Management Plan

Task 7.1 Determine Roles and Responsibilities for Implementation of Actions

Task 7.2 Develop a Final Design and Implementation Plan

Task 7.3 Seek and Integrate Stakeholder/Public Input and Participation

Task 7.4 Acquire Endorsement and Funding of the Implementation Plan

Task 7.5 Supervise and Ensure Proper Implementation of Actions

Step 8: Monitor and Evaluate Actions for Success

Task 8.1 Determine Roles and Responsibilities to Monitor and Evaluate Actions for Success

Task 8.2 Develop a Plan to Monitor and Evaluate Actions for Success

Task 8.3 Seek and Integrate Stakeholder/Public Input and Participation

Task 8.4 Acquire Endorsement and Funding of the Monitoring Plan

Task 8.5 Conduct Monitoring and Evaluate Success

Task 8.6 Recommend Modifications and Adjustments as Appropriate

Attachment A: Task Status and Actions

Attachment B: Project Schedule

Attachment C: Project Budget

Attachment D: Fanno Creek and Tryon Creek Watersheds Planning DRAFT Public Involvement Plan (revision dated May 14, 2001)

BUREAU OF ENVIRONMENTAL SERVICES
Planning Group • Environmental Management Division • Systems Analysis Section

Technical Memo

To: FILE

From: Mark Liebe – BES Systems Analysis
(with portions originally by Steve Hawkins – BES Maintenance and Bill Owen – BES Engineering Services)

Reviewed by: Binhong Wu – BES Systems Analysis
Amin Wahab – BES Fanno/Tryon Watershed
Eugene Lampi – BES Fanno/Tryon Watershed

Date: June 24, 2004

Subject: Generalized documentation of the BES Simplified Watershed Yield Model (SWYM) – *alias BES GRID Model*

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Introduction

The City of Portland, Bureau of Environmental Services (BES) has developed a GIS based grid approach to estimate runoff and upland pollutant loading for use in its watershed planning work. The method uses simple empirical and analytical methods in combination with both GIS and remote sensing data. Consistently applied, the method can help to identify relative “hot spots” or priority areas where upland pollutant loading is likely high and can help to gauge the overall effects on aggregate pollutant loading from the application of water quality facilities or other best management practices to help reduce pollutant impacts to local receiving waters. The model, called the Simplified Watershed Yield Model (SWYM), is intended to be a simple reconnaissance level tool based on relatively simple inputs and equations. Although various terms have been used in the description of pollutant loading, yield has been defined as the amount of material that moves from a source to a downstream control point (Chow, 1964). Although the model does not account for pollutant buildup for a particular land surface or pollutant, it does predict the pollutant yield from a given land area based on the Event Mean Concentration (EMC) of that area’s land use.

Basic Model Description

The model described in this technical memorandum is a GIS based reconnaissance level pollutant loading model. The model uses an array of grid cells into which detailed GIS and other spatial data is compiled. The grid size used in the model is currently 100-foot by 100-foot. The data compiled for each grid cell includes precipitation, vegetated area, pervious/impervious area, and zoning area for each grid cell. Examples of typical data compiled for a set of grid cells are shown in **Figure 1**.

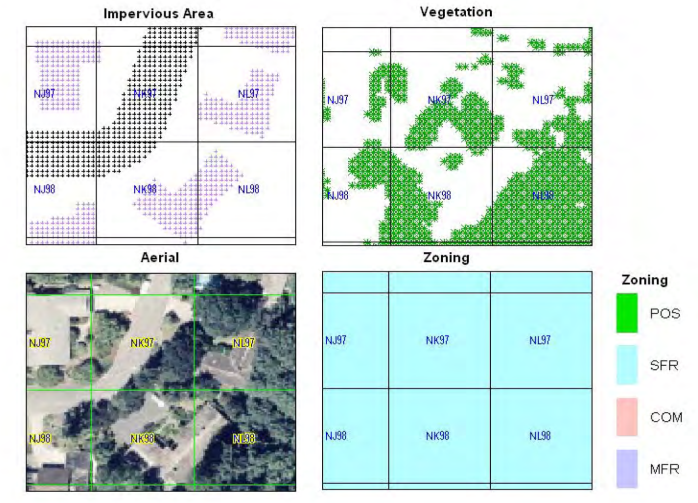

Figure 1- Typical SWYM model input detail

With these data, a set of runoff and pollutant loading equations are then applied that calculates both runoff and pollutant yields for each grid cell. Total pollutant loading (yield) from each grid cell is calculated from the effective runoff for each grid cell based upon the type of zoning (or combination of zoning) contained within each. Using the zoning type, typical pollutant concentrations are applied to the effective runoff to produce total pollutant loading (yield) for the grid cell. The resulting modeled pollutants are conservative estimate in that neither routing nor attenuation of pollutants is accounted for. A schematic of the modeling steps is shown in **Figure 2**

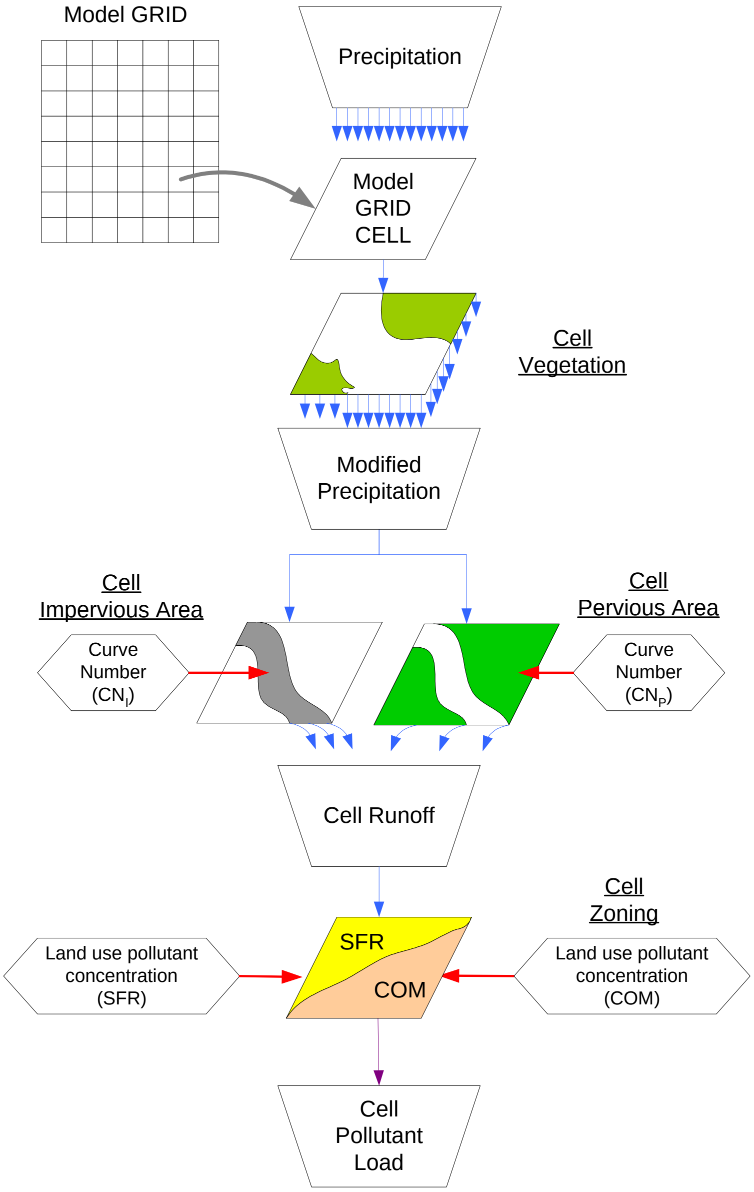

Figure 2 - SWYM model schematic

A 100-foot by 100-foot grid configuration was chosen to keep the computational effort down to reasonable levels for the typical size of watersheds encountered in the Portland area. It was also used to avoid implying a higher level of precision of the model results than is appropriate, while still capturing a reasonable level of detail beyond the sub-watershed level normally used for more traditional types of pollutant yield analyses.

Objectives of the model (and some of its advantages)

The primary objectives/functions of the GIS watershed yield grid model include:

- Estimate overall watershed runoff and pollutant yields from discrete, upland areas. This includes watershed runoff and surface yield of various pollutants, such as phosphorus and total suspended solids (TSS), for specific storm events and regulatory periods for basins within a given watershed area.

- Provide a tool to estimate pollutant loadings from uplands that can be used as input to other physically-based in-stream models

- Provide a spatial means of differentiating areas of higher pollutant loading (yield) from areas of lesser pollutant yield across a given area. This reconnaissance level assessment should be useful in helping to prioritize areas where pollutant treatment measures would likely be most effectively applied.

- Use simple, yet accepted methods for calculating pollutant loadings (yield) from various surfaces, capable of accounting for a broader range of factors than that afforded by more simplistic land use-only based approaches.

- Create a model that can be implemented in an accessible database and GIS framework, to allow for rapid modification of new modeling methods and to aid the rapid development of different model scenarios.

- Provide a rough estimate of relative removal effects of various treatment alternatives within a study area on gross pollutant loading.

- Incorporate a modular design and implementation to allow for rapid application and modification.

To meet these objectives, a simple modeling methodology had to be used. As such, the application of this methodology and thusly the model, should be limited to planning-level use. Estimating pollutant loads for pre-design or design-level activities requires more site-specific data and refined modeling methods.

What the SWYM is NOT (and other limitations)

The SWYM has many useful applications, however there are several things that the model is not and that it cannot do. These include:

- The SWYM does not account for any in-stream pollutant production, transport, or attenuation processes. It is strictly (in this version) dealing with pollutants generated from upland sources and processes.

- The SWYM has no ability to accrete pollutants. Although this is an important consideration in many instances, the SWYM uses temporally constant pollutant concentration values, so the effects of build-up and wash off are not dealt with in the model.

- The SWYM simulates, in a very simple way, the processes behind pollutant yield from a given land surface. Although the actual processes are likely much more complex.

- The SWYM will not solve the problem of where to place a BMP once a “hot spot” is identified. Although the SWYM does a reasonably good job at showing such areas of higher pollutant yield, there is still a level of professional judgment required, and if need be, more rigorous modeling

- The SWYM is not suited for more detailed site-specific determinations of pollutant runoff. It is primarily a planning tool, and as such, should be taken only down to a certain scale.

- Because the SWYM is currently designed for estimating upland pollutant loading only, it is difficult (i.e. impossible) to calibrate the model for in-stream conditions, although it is conceivable that calibration for upland loading could be accomplished with appropriate data. The model does have certain end-of-pipe applications, but due to the complexities of in-stream pollutant transport processes, accounting for such in-stream behavior is problematic.

Modeling Methodology

Methodologies for estimating pollutant yield in stormwater can be broken into two primary categories: physically based methods and empirically based methods.

Physically based pollutant models

These types of models attempt to simulate the actual accumulation and decay of pollutants as they build up and travel through watersheds and streams. Such models require substantial amounts of data (e.g. stream flow peaks, volume, in-stream pollutant concentration and rainfall distribution in relation to time of concentration, detailed stream cross-section and invert information) and calibration over the range of expected conditions. Modeling such processes requires detailed conceptual models of various physical processes affecting the pollutants. The level of confidence in a physical model relies on the number of physical processes that it attempts to incorporate and the amount of long-term historical monitoring data available, and not all models give the same treatment to the physical processes.

Empirically based pollutant models

These models use empirical equations to predict the loading of various pollutants and watershed yield based on actual monitored data. These methods do not simulate the actual physical processes that create pollutant yield, rather they attempt to estimate pollutant yield from indirect effects which are much more observable, and which are found to correlate to pollutant yield, while not explaining the root mechanisms involved.

Selected Method – The Simple Method

A widely accepted, empirically based method used for estimation of pollutant yield, and the one selected for use in the SWYM, is the called the Simple Method (Caraco, 2001). The Simple Method model provides a quick and reasonable approach to estimate pollutant yield and was determined to be well suited to the development of the SWYM. The method is suitable for sites less than a square mile in area, which is well matched with the current 100-foot by 100-foot grid configuration used in the SWYM. The Simple Method estimates the pollutant yield based on three primary inputs:

- runoff volume (R) from a specific site (model grid cell),
- pollutant concentration (C) for a given land use,
- total area (A) of a specific site (model area of grid cell)

The result of this method is an estimate of pollutant yield, for specific pollutants.

Basic Equations

The following discussion follows the primary sequence of calculations used to ultimately estimate pollutant loading with the Simple methods. Each step is described in turn, and where variations to the original method have been used, these are noted accordingly.

Runoff Volume Equation

The method used for rainfall runoff used in the Simple Method is a function of total precipitation, an effective precipitation adjusted for percent vegetation, and a runoff coefficient based on imperviousness and Natural Resources Conservation Service (NRCS) curve numbers of a site. Although this approach provides a reasonable runoff volume in most cases, a modification to this method was used in the model. This method, called the NRCS Curve Number (CN)[4] method, is more widely accepted as a standard method for determining stormwater runoff, and the Curve Numbers are more physically based than effective runoff factors used in the runoff calculations for the Simple Method. In addition, BES already uses the NRCS Curve Number method as part of the modified Santa Barbara Unit Hydrograph to estimate runoff during its development review process, as defined in the BES Stormwater Drainage Design Manual.

The following equation represents the NRCS Runoff CN method that accounts for pervious and impervious runoff separately using an area-weighted technique:

$$R = \left[\left(\frac{\left(P_m - 0.2S_{ave}\right)^2}{\left(P_m + 0.8S_{ave}\right)} \right) \right] \tag{1}$$

Where:

R = rainfall runoff (inches)
P_m =precipitation (inches)
S_{ave} = Average Surface retention after runoff begins (inches)

Surface Runoff Retention Equation

The following equation calculates the surface retention of the rainfall for both pervious and impervious surfaces:

$$S_{ave} = \frac{\left(S_p * A_p\right) + \left(S_i * A_i\right)}{A_{total}} \qquad S_{(i,p)} = \frac{1000}{CN_{(i,p)}} - 10 \tag{2}$$

Where:

CN = NRCS Curve Number^4 (1/inches) (based on land use and soil hydrologic group classification)
i,p = either "*i*" for impervious surfaces or "*p*" for pervious surfaces

CN values are empirical coefficients derived by the NRCS and are a function of the land cover type, hydrologic conditions, and soil type. These CN values are often used as calibration parameters where monitoring data exists and the NRCS method is being applied.

Modified Wet and Dry Curve Numbers

Variations to the surface retention equations for the "normal" antecedent conditions, namely "wet" and "dry" conditions use the same form of Equation 2, but use modified wet and dry CN values, which are derivatives of the normal CN values.

$$CN_{dry} = \frac{\left(CN * 4.2\right)}{(10 - (0.058 * CN))} \qquad CN_{wet} = \frac{\left(CN * 23\right)}{(10 + (0.13 * CN))} \tag{3}$$

Vegetation Interception Equation

Refinements and extensions were added to the Simple Method, to better utilize other spatial data available to BES for this analysis. To account for the rainfall interception for vegetation cover within model grid cells, the precipitation within each grid cell can be reduced by reduction factor for each vegetated unit grid cell area (0.229 acres). Reduction factors for both leaf-on and leaf-off vegetation conditions are accommodated in the SWYM. A typical value for this reduction from the literature is 18 percent (Qingfu, 1998). Equation 4 calculates the total rainfall that reaches the ground surface based on this interception efficiency (IE), using the actual vegetated area for each grid cell in the SWYM. Vegetated areas for each grid cell were derived from multi-spectral GIS data, and were developed specifically for use with the interception equation.

$$P_m = \frac{\left(IE \times P \times A_v\right) + \left(P \times \left(A_{total} - A_v\right)\right)}{A_{total}} \tag{4}$$

Where:

IE = Rainfall vegetation interception efficiency (percent)
A_v = area with vegetation cover (acres)
A_{total} = total area (acres)

Pollutant Yield Equations

The loading equations used in the pollutant yield grid model to estimate pollutant yield were developed using the Simple Method. Two primary equations are used by the model, one for sediment based pollutants, and the other for bacteria related to sediment An unmodified form of the Simple Method is retained for those pollutants that are commonly expressed in milligrams per liter (mg/l) concentrations:

$$L = 0.226 \times R \times C \times A_T \tag{5}$$

Where:

L = load (lbs)
R =runoff (inches)
C = pollutant concentration (mg/l)
A_T = total area (acres)
0.226 = unit conversion.

Similarly, the Simple Method used to estimate bacteria concentrations, which are typically expressed in numbers of colonies per 100 milliliters (# /100ml)

$$L = 1.03E - 03 \times R \times C \times A_T \tag{6}$$

Where:

L = load (10^9 colonies)
R = mass runoff (inches)
C = bacteria concentration (# /100 ml)
A_T = area (acres)
1.03E-03 = unit conversion.

Since this procedure yields only coarse loading estimates for a given rainfall depth, event mean concentration (EMC) values can be used for the *C* variables in Equations 5 and 6.

Pollutant Loading Concentrations

As there are usually wide variations in the actual concentration of pollutants between land use types, the SWYM allows for varied concentrations between different land uses. To determine the most appropriate pollutant concentrations for various land uses, various monitoring studies were consulted. The values used in the pollutant yield grid model for the four primary pollutants are shown below.

Table 1 – Land use Based Pollutant Loading Values

	SITE MEAN POLLUTANT CONCENTRATION			
LAND USE CATEGORY	TSS[e] (mg/l)	BOD (mg/l)	Total P[e] (mg/l)	Bacteria (col. #/100ml)
	EMC	EMC	EMC	
Light Residential (SFR)	51	11[a]	0.33	1800[a]
Heavy Residential (MFR)	72	11[a]	0.45	2700[a]
Commercial (COM)	93	16[b]	0.57	790[b]
Industrial (IND)	183[f]	53[c]	0.65	3958[c]
Vacant (VAC)	53	3[d]	0.22	1512[d]
Parks and Open Space (POS)	53	3[d]	0.22	1512[d]
Streets and Highways (STR)	168	21[d]	0.34	

[a] Mean based on data from Portland NPDES monitoring station R-1 (Fanno Creek) as reported in May 1996 Draft Water Quality Report

[b] Mean based on data from Portland NPDES monitoring stations C1 (Jantzen Beach) and C2 (Downtown) as reported in May 1996 Draft Water Quality Report

[c] Mean of the data from Portland NPDES monitoring stations I1 (NW Yeon) and I2 (Swan Island) as reported in May 1996 Draft Water Quality Report

[d] Mean based on data from Portland NPDES monitoring station OP-1 (Balch Creek) as reported in May 1996 Draft Water Quality Report

[a] Concentrations for all land uses derived from median concentrations for TSS and TP as reported in ACWA Urban Runoff Water Quality Monitoring Data Report

[a] Industrial TSS concentrations also used for typical Agricultural land uses as well.

Pollutant Reduction Alternatives

One of the features of the SWYM is the ability to estimate the net effects on pollutant yield from the application of various pollutant reduction alternatives in a specific area. Although the SWYM does not calculate the actual removal efficiencies of any pollutant reduction alternatives themselves, the model can use any specified removal rates to calculate the total amounts of pollutant removed in a given setting. The model has provisions for specification of specific treatment options for each grid cell where such treatment alternatives would be applied. Each grid cell can have its own unique treatment removal effectiveness specified for each pollutant modeled. Although rudimentary in its approach, such a method allows for a broad range of treatment alternatives to be considered and accounted for. Two examples of such an application are discussed below.

One example application of this pollutant reduction approach used by the SWYM is in estimating the effects of street sweeping. By designating those grid cells in the SWYM which intersect roads which are to be swept, the assumed removal rates of suspended sediments would be applied for those intersecting grid cells, and their estimated pollutant loading reduced accordingly. If variations in street sweeping effectiveness are anticipated for different regions within a watershed, these variations can be specified for the different grid cells affected.

A second example application of SWYM's ability to account for pollutant reduction is for point reduction/treatment alternatives, such as regional BMPs. Such facilities usually gather larger amounts of flow from specific regions in a watershed, and tend to treat larger amounts of stormwater when distributed treatments are either ineffective or impractical. In this instance, the area tributary to the collection point for the regional BMP alternative would be identified, and the model grid cells identified in that region. The removal rate of the regional BMP would apply to all land area tributary to the collection point, and as such the removal rate would be applied to the tributary grid cells, although the treatment would physically occur at the collection point of the BMP itself.

Either type of application of the SWYM for accounting for treatment alternative removal rates provides a means of estimating the relative amounts of total pollutants removed across various alternative configurations for a given area or in-stream compliance point.

Calculation Sequence and Related Data

Below are the basic steps used by the pollutant yield grid model. General descriptions of these are provided for each step.

1. Identify the pervious (A_P) and impervious (A_I) areas within the selected grid cell area
   Impervious areas are calculated for each grid cell. These areas are derived from explicitly digitized versions of impervious surfaces, which include buildings, large parking areas, and street surfaces. Typical source data detail and resulting impervious percentages for a number of example grid cells are shown below.

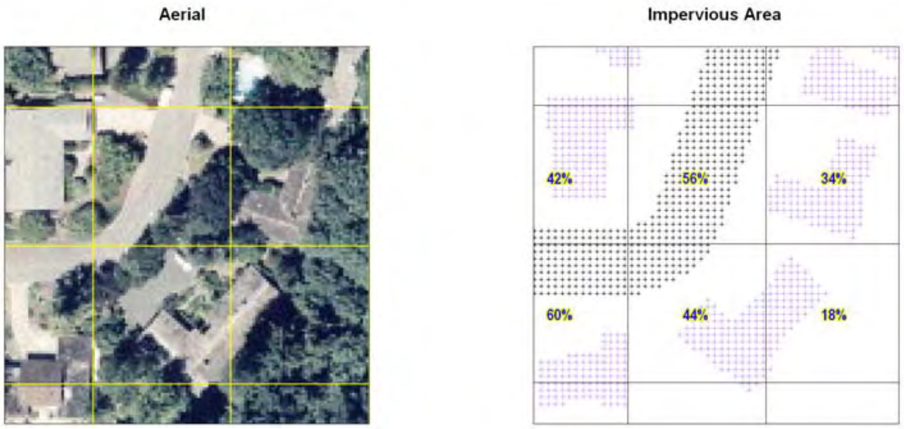

Figure 3 - Typical impervious area inputs to the SWYM.

2. Identify CN numbers for pervious and impervious areas and calculate surface retention, S_P and S_I using Equation 2.

3. Estimate the percent of vegetation for each grid cell. Vegetation percentages are normalized difference vegetation indices (NDVI), derived from BES multi-spectral imagery data, and are primarily combinations of red and near-infrared spectral bands. The specific processing for multi-spectral vegetation indices can be found in MicroImages (2001). Typical detail, and resulting percentages for a number of example grid cells is shown below.

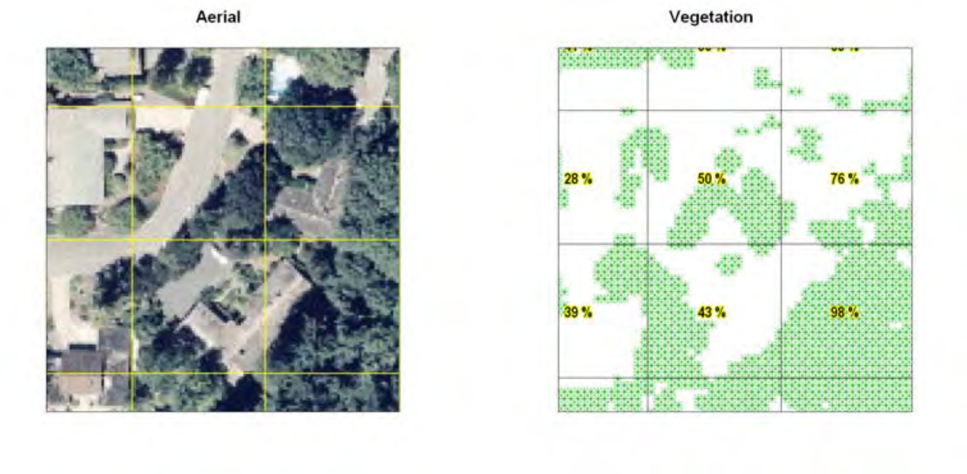

Figure 4 - Typical vegetation inputs into the SWYM.

4. Using the vegetation percentages for each grid cell, calculate the modified precipitation P_m in Equation 3.

5. With the modified precipitation and surface retention values, calculate the total rainfall runoff using Equation 1. Identify the land use type distribution for each grid cell, and prorate the pollutant loading value for each land use type found, in combination with each land use types pollutant loading rates. Percentages of each land use type are derived from the current zoning table, provided by City of Portland Corporate GIS. Zoning, rather than actual land use percentages are use due to the limited extent of complete land use data available. Zoning is typically used in place of actual land use for planning level analyses. The codes identified with the associated zoning categories are also shown in Table 1.

6. Calculate the final pollutant yield for each pollutant using either Equation 4 for sediment bound pollutants (pounds) or Equation 5 for bacteria (billions of colonies).

7. Should pollutant removal methods and alternatives be specified in the SWYM grid, they are applied to those grid cells specified as affected by such removal methods.

Modeling Framework and Architecture

The SWYM is built around two fundamental analytical tools, Microsoft Access as database and MapInfo Professional as Geographic Information System (GIS). Most of the data collection and compilation is done via the GIS interface and its spatial routines. Although certain spatial and imagery data originate in other mapping and analysis systems, all spatial data is ultimately entered into the system through the GIS. Converting the GIS interface used with the SWYM to other GIS platforms can likely be accomplished with minor effort, although compatibility issues with current BES desktop database standards are in conflict with those use in the current SWYM system.

The majority of the actual model processing is done within the Microsoft Access database, through a combination of queries, data forms, and Visual Basic for Access routines for more specialized calculations. All of the elements are standard database components. The system design is highly modular, allowing for rapid incorporation of different analysis methods, modeling components, and base model variables.

Once a particular model configuration is run, the model results for a given pollutant can be displayed in the linked GIS display. Examples of the model results are shown below (Figure 5).

Model Variables

A number of variables are used in the SWYM, and can be specified by the user for various model configurations, and can also be adjust for rough calibration. The variables, along with typical values, are shown in Table 2.

Table 2 - Typical Model Variables for the SWYM

Variable	Value	Units	Description
Cell_size	0.2295	Acres	Cell size of aggregate areas
Precip	0.83	inches	Amount of total precipitation over simulation period
leafon_int	0.2	Percent	Rainfall interception of vegetation - leaf on conditions
leafoff_int	0.1	Percent	Rainfall interception of vegetation - leaf off conditions
CN_imp	98	Percent	Impervious area SCS Curve Number
CN_per	75	Percent	Pervious area SCS Curve Number
Event_duration	24	Hours	Duration of simulation period
Baseflow	.5	cfs	Estimated baseflow rate for basin @ specified stream gage
Baseflow_cells	6845	# cells	Number of cells in basin tributary to stream gage location

Model Results

Several types of output are available from the SWYM. These include actual numerical values for accumulated estimated rainfall and pollutant yield using the equations discussed in the preceding sections. Several methods for grouping the data are available within the database portion of the SWYM.

Spatial model results – GIS display

One of the most significant outputs from the SWYM is found in its spatial display of discrete grid results. An example is shown in Figure 5, which is a GIS thematic map of four categories of relative Total Suspended Solids (TSS) yield for a Portland Watershed for the current water quality design storm of 0.83 inches/24 hour period. The color distribution shown in Figure 5 is equally split between the TSS yield values for each grid cell in this particular watershed model. Other color distributions are easily applied, depending on the needs of those using the model or applying its results. Note that this display feature is specified using the GIS display component of the SWYM, and not the database.

As seen in Figure 5, this distribution shows groupings of prominent TSS yield and other areas where the TSS is relatively lower. This relative display of yield results highlights those areas where treatment alternatives should be considered, particularly for upland treatment alternatives, or those alternatives that capture the runoff from areas that appear to produce higher pollutant yields. Figure 5 shows several prominent areas of high TSS yield that appear to be associated with major transportation corridors. Other high yield areas shown by the model correspond to areas with markedly less vegetation and apparent high impervious surfaces, as evidenced by the aerial image shown alongside the model output map. Other areas show relatively low TSS yields, due primarily to the presence of either higher vegetation coverage or lower impervious areas.

Not shown in Figure 5 is the effect of the other primary variable used in the SWYM, namely land use or zoning. This simply points out the fact that the SWYM is more than simply a land use based pollutant model in that it is accounting for other physical land cover features of imperviousness and vegetated cover.

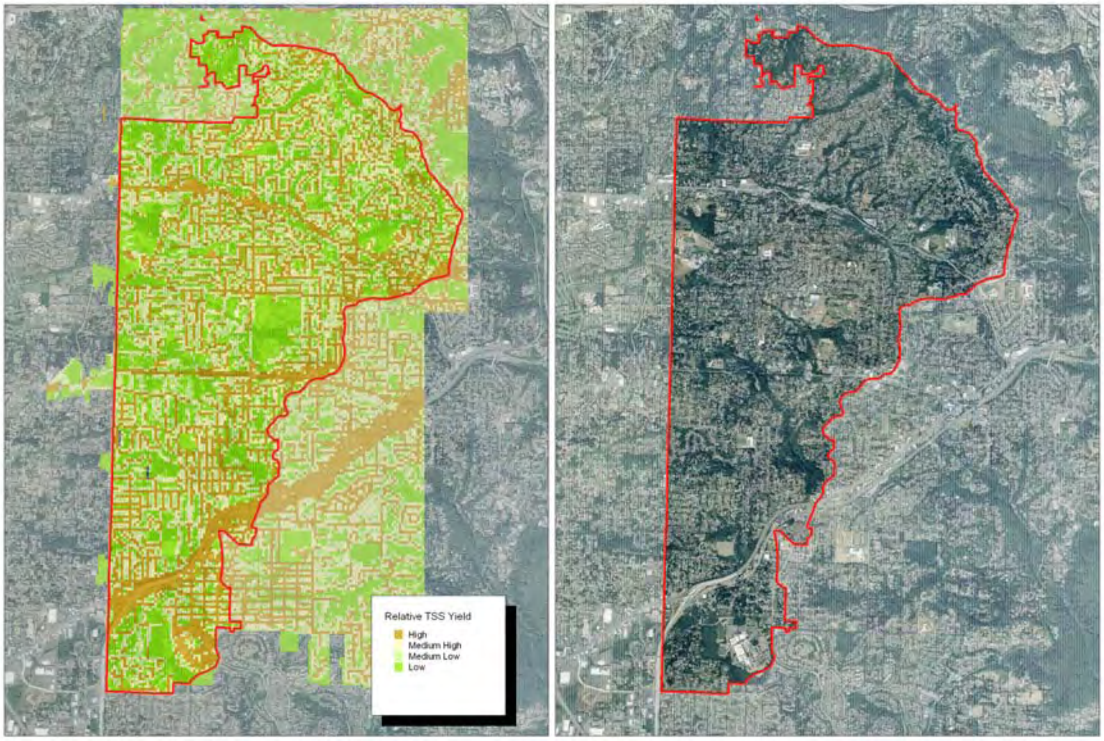

Figure 5 - Example relative SWYM model results for TSS in comparison to aerial imagery

Direct model results – grid and watershed level totals

The basic level of the SWYM output is each grid cell within watershed. The basic calculations are done at the grid cell level and the resultant yield values are stored there. Accommodations for additional groupings of various grid cells are provided within the model framework, and include sub-catchment, calibration point, and watershed level totals for the various runoff volumes and pollutant yields calculated by the model. Queries designed for the reporting of these total runoff volumes and pollutant yields are provided within the database. Typical results of these yield accumulation queries are shown in Table 3. These groupings correspond to the sub-basin groupings assigned to each grid cell, as shown in Figure 6.

As mentioned previously, the SWYM is an approximate and empirically based estimation method and is best suited for planning level assessments and relative comparisons of various combinations of treatment alternatives. As such, the SWYM results should be limited to planning activities, and regulatory activities where it is acknowledged that the values rendered are best viewed as relative.

Table 3- Typical Values of Sub-basin yield accumulation of the SWYM.

Basin	SumOfTP	SumOfTSS	SumOfECOLI	SumOfBOD	VOLd	VOLn	VOLw	acres	num_cells	Qd	Qw	Qn
1	12	1,908	1.6E+14	110,033	354,664	527,440	1,738,521	1,898	8,268	426	2,087	633
2	1	162	2.0E+13	14,226	49,283	50,928	201,729	247	1,078	59	242	61
3	5	779	6.3E+13	43,687	158,781	212,190	706,796	789	3,439	191	848	255
4	3	461	4.4E+13	31,545	118,320	141,054	488,785	565	2,460	142	587	169
5	2	256	2.5E+13	19,304	55,150	80,520	282,669	316	1,378	66	339	97
6	3	439	2.5E+13	18,928	74,831	123,144	334,322	329	1,433	90	401	148
7	7	1,055	4.2E+13	34,799	164,486	263,785	596,961	532	2,317	197	717	317

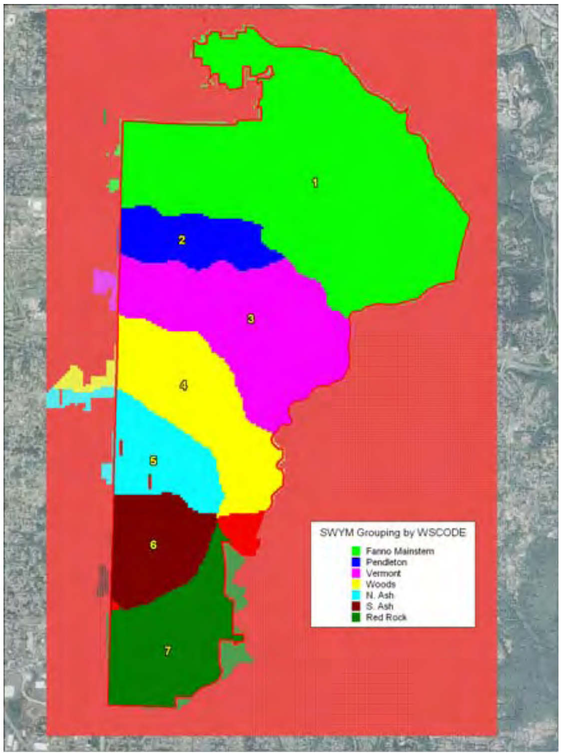

Figure 6 - Typical Sub-basin grouping with the SWYM

Conclusions

Although the scope of this document prevents a fuller description of the specific modeling interface, nor the more specific steps in outlining the many data processing steps leading up to the actual inputs into the model, this discussion has attempted to show the primary analytical basis for the SWYM and the flexibility in its application, both for producing relative numerical and mapping results and accounting for various treatment alternatives.

Although not a “shrink-wrap” tool, the interface to the model was designed to allow for relatively simple input and adjustments of the basic model parameters (Table 2), thus allowing for a wider audience to apply the model for various test cases. Also, as the spatial display of the SWYM results is performed by a GIS, anyone able to use the GIS for thematic mapping and querying can perform complex output functions.

Other models exist which closely mimic the SWYM in terms of overall targeted objectives and functions, including other grid based and watershed level GIS methods, including Reginato and Piechota (2002) and the PLOAD model (US EPA, 2001). The similarity of these approaches further supports the work done to develop the SWYM for specific Portland watersheds while incorporating some of the more specialized and unique GIS data available to BES for this work.

Status of Portland Watersheds

Currently, discrete SWYM models exist for each of Portland’s five primary watersheds. These are contained in separate Microsoft Access databases and (currently) MapInfo GIS formats. Conversions from the MapInfo to ESRI GIS data have been done many times for the GIS results of the SWYM, and have proven reliable in each case. However, some work is yet required to completely transfer the GIS function of the SWYM system to be completely seamless with the database analytical engine.

Planned Improvements

The most immediate planned improvement in the SWYM models for each of Portland’s watersheds is to update the vegetation and portions of the impervious area determinations loaded into each SWYM model grid cell. Although older versions of the BES multi-spectral vegetation data were available during the initial loading of the SWYM watershed models, the spatial registration and data processing methods have both been improved upon since that time, increasing the accuracy of these. Also, methods for estimating impervious areas from the multi-spectral data have also been developed since the time of the initial data development, and will be loaded into the model where such data was not available from more conventional GIS data.

Other possible improvements include:

- Adding spatial variability of NRCS curve numbers (CN) to the model, where the NRCS CN could be varied by parameters such as land use and/or soil types. The model currently holds the CN constant, although as noted in Equation 3, both wet and dry antecedent conditions are accommodated in the model already.

- Allowing for pollutant decay and other attenuating factors of upland processes.

- Providing a time based pollutant buildup, possibly by coupling the model with other models already established by BES, such as SIMPTM.

- Incorporation of additional variables in addition to the current impervious area, vegetation, and land use (zoning) inputs.

- Incorporating additional or modified equations for pollutant yield, as further research is made available.

- Adding a storm sequencing capability to better determine effective runoff and pollutant yield over longer periods of time. There are limitations to the current equations used which limit the period of time which can be run through the model in its current configuration.

- Adding the ability to deal with certain in-stream processes, both for pollutant loading and attenuation, thus allowing for in-stream applications of the SWYM.

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Technical Memorandum

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Subject: Fanno Creek Main Stem Hydrodynamic Model Calibration and Verification

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TABLE OF CONTENTS

Summary

This technical memorandum summarizes the following work that has been performed by the planning group for the Fanno Creek main stem hydrodynamic model:

1. The improvements that have been made for the Fanno Creek main stem Mike SHE and Mike 11 model to increase the peak flows for larger design storms (i.e., 25-year and 100-year design storms);

2. Model performance evaluation through qualitative and quantitative measures based on the most recent model calibration/verification results;

3. Literature review on model calibration/verification and acceptance criteria;

4. Conclusions and recommendations on the Fanno Creek main stem hydrodynamic model usage.

1. Background

The Mike SHE/ Mike 11 hydrodynamic model for Fanno Creek main stem was initially developed by BES but refined and optimized by DHI Water & Environment (DHI) as part of a contract between BES and DHI. Calibration of the Fanno Creek main stem hydrodynamic model was also performed by DHI under the same contract. In addition to the hydrodynamic model, DHI also developed and calibrated the water quality model for Fanno Creek main stem. The model development and calibration procedures, and results are presented in a report titled "Fanno Creek Watershed Model" by DHI in August 2002.
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One of the watershed modeling goals is to evaluate the conveyance capacity of the existing stormwater drainage system and identify expected conveyance capacity problems for roadway crossings and stormwater pipes in the watershed. To achieve this goal, different recurrence interval design storm events, including the 2-year, 10-year, 25-year and 100-year design storms, were run through the Fanno Creek main stem hydrodynamic model to evaluate the peak flow in relation to pipe capacities. The total rainfall depth for the design storm was obtained from the Rainfall Intensity, Duration, Frequency Curves (IDF Curves) from the City of Portland's Sewer Design Manual. The design storm distribution is based on the 24-hour SCS Type I-A distribution that applies to the Pacific Northwest.

Since the design storms are not real storm events, no observed flow data is available for calibration. For comparison purpose, the peak discharges for Fanno Creek main stem at the 56th Avenue obtained from the DHI model were compared with the results obtained from U.S. Geological Survey (USGS) empirical equations, flood-frequency analysis of the observed flows at 56th Avenue, and a previous hydrologic/hydraulic study for the watershed. The comparisons were particularly helpful for higher recurrence interval storm (i.e., 100-year) as most of the calibration model runs that DHI performed occurred during regular storm events. Although DHI's calibration period did include an extreme storm event in February 1996, the USGS gage at 56th Avenue was reportedly having problems measuring high peaks during that period. The February 1996 storm event was generally regarded as a 50-year to 100-year recurrent event in the Portland area. Information on the USGS empirical equations and previous studies are described below:

USGS Regression Equation

The regression equations developed by Laenen (Laenen ,1983) for use in the Willamette Valley were used in the comparisons. The regression equations are used to define the relationship between correlated random variables. Detailed information can be found in the USGS Water-Resources Investigations Report titled "Storm Runoff as Related to Urbanization Based on Data collected in Salem and Portland, and Generalized for the Willamette Valley, Oregon". The regression model equations are as follows:

$$Q\ (2\text{-yr}) = 26.8\ A^{0.90}\ (EIA)^{0.34}\ (0.1+ST)^{-0.20}\ (SKEW+2)^{-0.26}$$

$$Q\ (10\text{-yr}) = 42.2\ A^{0.87}\ (EIA)^{0.37}\ (0.1+ST)^{-0.22}\ (SKEW+2)^{-0.06}$$

$$Q\ (25\text{-yr}) = 43.8\ A^{0.86}\ (EIA)^{0.4}\ (0.1+ST)^{-0.22}\ (SKEW+2)^{0.23}$$

$$Q\ (100\text{-yr}) = 43.8\ A^{0.84}\ (EIA)^{0.42}\ (0.1+ST)^{-0.23}\ (SKEW+2)^{0.57}$$

Where Q is the flood-peak flow in cfs, A is the drainage area in square miles, EIA is the effective impervious area in percent, ST is the surface area of lakes, ponds, marshes, flood plains, depressions, and detention –storage facilities, in percent of the total drainage basin, where water can be stored during a storm event. SKEW is the skewness coefficient is a numerical measure or index of the lack of symmetry in a frequency distribution.

For the Fanno Creek watershed, the total drainage at the 56th Avenue USGS gage was estimated to be 2.4 mile^2, the EIAs were estimated to be 30%. EIA includes street surfaces, paved drives connecting to the street, sidewalks adjacent to curbed streets, rooftops that are hydraulically connected to the curb or storm sewer system, and parking lots. For Fanno Creek main stem watershed, street and rooftop coverage was used to estimate the EIA. The total surface area for lakes, ponds, marshes, floodplains and detention–storage facilities in the watershed was estimated to be 0.5% using various related GIS coverages. The skewness coefficient is 0.0 as recommended in Laenen's report for areas in Portland. The peak flow results based on the regression equations are presented in Table 1.

56th Avenue Gage Flow Flood-Frequency Analysis

USGS's water resources application software "PEAKFQ" was used to perform a flood-frequency analysis on the annual flood peaks collected at the 56th Avenue gage. PEAKFQ uses the method of moments to fit the Pearson Type III distribution to the logarithms of annual flood peaks. The program can be downloaded from the USGS website at: *http://water.usgs.gov/software/surface_water.html*

The annual peak flows collected at 56th Avenue from 1974 to 1978 and from 1991 to 2001 were used as the input to the PEAKFQ program. These annual peak flows were obtained from USGS. The program results include the expected probability peak flow estimates and their 95% confidence limits. The estimated peak flows and corresponding 95% confidence limits for the 2, 10, 25 and 100-year storms are presented in Table 1.

Fanno Creek Public Facilities Plan (PFP)

Hydrologic and hydraulic models were developed for the main stem of the Fanno Creek as part of the City's Public Facilities Plan effort in 1998. The hydrologic model was developed using HEC-1 and the hydraulic model was set up using HEC-RAS. The models incorporated drainage area characteristics and conveyance system characteristics and were calibrated to a limited extent. The peak flows for Fanno Creek main stem at the 56th Avenue are presented in Table 1.

As shown in Table 1, the 25-year and 100-year peak flows obtained from Mike SHE/ Mike 11 hydrodynamic model developed by DHI are considerably lower than the peak flows estimated from USGS equations and the previous HEC model, and are below the lower 95% confidence limits from the flood-frequency analysis. A review of the calibration work by DHI indicated that the model performed relatively well in predicting peak flows during low flow events, although it sometimes underestimated peak flows for higher flow events. In order to further investigate the model performance under high flow conditions, a model QA/QC check was performed to investigate if there were any constrictions in the model that were restraining the high flows. The results from the model QA/QC check are presented in the following section.

Table 1: Design Peak Flow Comparisons for Fanno Creek Main Stem at the 56th Avenue

				Flood-Frequency Analysis			
				Expected Probability Estimate	95% Confidence Limits		
Peak Flow (cfs)	Mike 11 Results (DHI)	Mike 11 Results (Updated)	USGS Equation		Lower	Upper	HEC Results*
2-yr	170	175	205	191	148	244	315
10-yr	294	354	338	420	318	645	502
25-yr	346	497	471	577	416	990	588
100-yr	436	655	630	867	580	1741	751

Note: *HEC peak flows at segment KK031 under existing landuse conditions are taken from City of Portland's PFP study for Fanno Creek.

2. Fanno Creek Main Stem Hydrodynamic Model Improvement

A general review of the high flow hydraulics in the Fanno Creek main stem Mike SHE/ Mike 11 hydrodynamic model indicated that the predicted peak flows for the main stem segments were not persistently increasing towards the downstream direction, as indicated should be the case given the facilities inventoried in the main stem. Although the modeled system encompasses a number of detention ponds, the available storage capacity from detention ponds do not seem to fully account for the peak flow losses at several main stem locations. A more detailed analysis of the 100-year peak flows on the main stem revealed that the significant flow loss typically occurred at roadway crossings where the culverts at these locations appeared to constrain the peak flow at these locations.

During a storm event, high flows may exceed the capacity of a culvert. This creates a situation where there is a build up of the water level upstream of the culvert. If an overflow structure at this point is not incorporated into the flow model for such situations, this backing up of water would continue indefinitely. Such a condition in the flow model forces the culvert to behave as an orifice in the model, allowing only a limited amount of flow to pass beyond the culvert. The modeled flow that can pass through the surcharged culvert in this case is estimated by an orifice equation in the model. This model set up may be appropriate for simulating culverts located far below the roadway crown, where the water level may never reach the roadway. However, it is not a good representation of flow hydraulics for a culvert located just a few feet below the road, particularly during a high flow event. In cases where the water level upstream of the culvert reaches the roadway, an overflow structure should be implemented in the model to facilitate the flow passing over the roadway. A review of the Mike 11 model set up for the main stem and available topographic and survey information indicated that although overflow structures have been incorporated in the model for a few roadway culverts by DHI, the model was not set up to account for all overflows that were estimated to occur at roadway crossings for the 100-year design storm.

As described in the previous section, when DHI developed and calibrated the Fanno main stem model, they made several model simplifications and optimizations that helped in the calibration of relatively low flows used for water quality applications of the model. These simplifications worked reasonably well in terms of estimating flow under normal storm events. During high flow events, however, these simplifications caused unanticipated flow constrictions at several culvert locations. In order to refine the model and more accurately replicate high flow hydraulics at these culvert crossings, the 100-year water level estimated by the DHI model at the upstream end of a culvert was compared to the roadway elevation at the same crossing and an overflow structure was added to the model at the culvert location when the water level was within inches of the roadway elevation. Such overflow structures were added to approximately 30 additional roadway crossings in the Fanno Creek main stem model. The roadway elevations at these culvert locations were obtained by first looking for data collected from the field survey conducted in 2001. When field survey information was not available, topographic information was used to estimate the roadway elevations.

It should be noted that the improvements for the Fanno Creek main stem hydrodynamic model were focused on developing overflow structures for roadway crossings. The hydrologic component of the model, or the MIKE SHE model, was not modified. Other simplifications and assumptions made by DHI on the Mike 11 model were left unchanged to keep the integrity of the calibration work that DHI performed for the hydrodynamic and water quality model for the Fanno Creek main stem.

After the model improvements were made, the design storms were run through the updated model. These results from the updated model are also presented in Table 1. As shown in Table 1, the addition of overflow conveyance structures (representing roadway overtopping) in the model resulted in significantly increased modeled flows for Fanno Creek main stem at the 56th Avenue for the 25-year and 100-year storm events. As anticipated, the peak flows from the original DHI model and the updated model were similar under the 2-year and 10-year storm events. This shows that the low flow characteristics of the DHI model were unaltered, and thus the DHI calibration of that model is still valid. The updated model results for the 25-year and 100-year storm events are more comparable with USGS equation estimates and are within the range of 95 percent confidence limits of estimated peak flow from the flood-frequency analysis.

In addition to the design storm, additional model calibration and verification runs were also performed to further evaluate the model performance and the results are presented in the following section.

3. Model Performance Evaluation

In order to further evaluate the performance of the Fanno Creek main stem hydrodynamic model, several model verification runs were performed using the updated model for the periods from October to December 1996, and from December 2001 to February 2002. The hydrologic input parameters developed by DHI during their model calibration were not changed for the updated model, the comparisons of modeled flow versus the observed flow for storm events in November 1996 and winter 2002 are considered as verification exercises rather than calibration exercises.

The model verification results are presented by two ways:

1. Graphical comparison using time series plots of observed and simulated flows in 15-minute intervals
2. Statistical tests, including error statistics and correlation tests

Figures 1 through 4 present the observed and simulated flows for Fanno Creek at 56th Avenue for the verification periods. Table 2 shows model statistical test results for the verification periods. The statistical tests performed for verification periods were consistent with the quantitative measures developed by DHI for the Fanno Creek model calibration. The calibration criteria used by DHI to determine whether the calibration of the model was acceptable is also included for reference.

As shown in Figures 1 through 4, the updated Mike She and Mike 11 model for Fanno Creek main stem can capture the variation in the observed record, although it occasionally underestimates the larger peaks. The good fits shown in these figures are also reflected in the correlation test results in Table 2 where the daily average flow correlation coefficients are above 0.95 for the verification periods. In general, the total runoff volumes of the simulated and observed data match well, and the average cumulative volume error is below 10% (Table 2). Except for the peak error, the updated Fanno Creek main stem hydrodynamic model appears to meet the calibration criteria developed by DHI, indicating that the model is capable of adequately simulating most hydraulic components of the watershed during the verification period. The following factors likely contribute to the relatively large discrepancies between the simulated and observed instantaneous peak flows:

- Uncertainties in the observed data – There are several uncertainties in stream flow records provided by the USGS: First, due to the channel and stream condition, the USGS flow data collected at the 56th Ave were rated fair to poor in terms of the accuracy during the verification periods by USGS. A fair rating is defined as such that 95% of daily discharge are within 15% percentage of the true value. For a poor rating, the error percentage is higher than 15%. Secondly, a continuous record of stage is collected at the 56th Avenue gage and the corresponding discharges are obtained from a stage-discharge rating table developed by USGS based on a series of discharge measurements made at various stages at the gage location. Additional discharge measurements are performed periodically, usually bi-monthly, to verify the stage-discharge relationship or to define any change in the relationship caused by changes in channel geometry and (or) channel roughness. Since discharge measurements are not collected continuously, the rating table developed generally has more calibration data in the "normal" flow zones as compared to the high and low flow zones. It is a normal practice that the stage-discharge rating curve or table will have to be extrapolated beyond the "fitted" or "calibrated" range to obtain a high or low flow value. Based on BES's conversation with USGS staff, a measurement threshold for high flows at the 56th Avenue gage is usually around 400 cfs. Discharge estimates for stage records corresponding to flows greater than 400 cfs are generally obtained by linear extrapolations of the established USGS stage-discharge rating curve. It should be noted that the November 1996 storm event had an observed peak flow of 502cfs, which is higher than the 400 cfs threshold for the USGS rating curve. Lastly, the peak flow comparisons were based on the 15-mintute interval flow data. The 15-minute flow data provided by USGS are provisional and not usually QA/QC checked.

- Uncertainties in the precipitation data – As indicated in the DHI report for the Fanno Creek main stem model, some of the discrepancies between simulated and observed flow may be the result of inaccuracies in the distribution of rainfall data used in the model. Rainfall in the area is likely affected by the hilly nature of the area. As such, the temporal and spatial distribution of the rainfall used in the model, which is sensitive to peak flow, cannot be fully defined by the three rain gages currently used to define rainfall in the Fanno Creek watershed. An example of possible rainfall uncertainties can be found in Figure 1. As shown in Figure 1, there is virtually no precipitation observed during the period of November 8 to 11. However, the measured flow data shown in the figure during the same period indicates that there was likely a very localized but relatively intense storm event occurring during the period somewhere upstream of the 56th Avenue gage. If the flow surge observed in the flow data and shown in Figure 1during the period was not caused by sources other than precipitation induced runoff, the discrepancies in the rainfall and measured flow response may be responsible for discrepancies found between the simulated and observed discharge at the 56th Avenue gage.

- Uncertainties in the model input data – Although the model input was based on the best available information and substantial efforts have been taken to improve the quality of the input data of the model, there are still some uncertainties involved in some model input data. For example, highly resolved soil and groundwater information such as the spatial and temporal distribution of groundwater tables is not available. Certain aspects of the flow modeling are sensitive to this type of information, which is not available at this time to better refine this aspect of flow behavior. Also, although efforts were made to survey many key flow components of the watershed, time and budget did not allow for all flow components to be surveyed. As such, survey information is not always available for all modeled open channel sections and roadway crossings. These uncertainties and data gaps translate directly into uncertainties of the simulated flow calculated by the Mike/11 and Mike/SHE models for this watershed.

Table 2: Statistical Test Results of Model Verification for Fanno Creek Hydrodynamic Model

Criteria	November 1996 Event	January 2002 Event	February 2002 Event	Average for Three Events	Target[3]
Daily Correlation Coefficient	0.975 [1]	0.956	0.97	0.967	0.7
Peak Error	-42%	-43%	-50%	-45%	15-30%
Peak Time Error (hrs)	2.2	0.35	0.1	0.9	2-6 hours
Cumulative Volume Error	2%[2]	23%	-3%	9%	10%

Notes:
1. Daily correlation coefficient calculated for period from October 13 to December 14,1996, excluding the periods of November 9-11 and November 20-23 where the observed flow data are incomplete or do not match with precipitation data.
2. Cumulative volume error calculated for the period from October 13 to December 14, 1996, excluding data from periods from November 9 through 11 where the observed flow do not match with precipitation data.
3. Targets are consistent with those developed in DHI's Fanno Creek Watershed Model report.

4. Literature Review on Model Performance Criteria

A literature review on model calibration and acceptance criteria was performed to help further quantify the performance and robustness of the Fanno Creek main stem hydrodynamic model. The following summarizes the outcome from that review effort.

In general, quantitative criteria for model calibration/verification, sometimes referred to as "model performance criteria", have been contentious topics in the environmental modeling community for more than 20 years. Unfortunately, there is no consensus on what constitutes a quantitative level of acceptability or accuracy for model validation. Although there is no universal performance criteria, a number of basic truths are evident and are accepted by most model developers for the simulation of natural systems:

- Models are approximations of reality; they cannot precisely represent natural systems.
- There is no single, universally accepted statistical test that determines whether or not a model is valid.
- Both graphical comparisons and statistical tests are required in model calibration and verification.
- Models cannot be expected to be more accurate than sampling and the level of statistical error (e.g., confidence intervals) in the input and observed data.

Model performance expectations developed in several reports published by the Environmental Protection Agency (EPA) are provided below for comparison purpose. A Quality Assurance Project Plan developed for an EIS for the proposed Nicollet Mine in northern Wisconsin used the HSPF (Hydrological Simulation Program-Fortran) program and specified the following acceptability criteria:

"The targets for acceptable calibration and verification of monthly flows are a correlation coefficient greater than 0.85 and the coefficient of model-fit efficiency greater than 0.8." (EPA, 1998)

Table 3 lists general calibration/validation tolerance or targets that have been provided to model users as part of HSPF training workshops over the past 10 years. The values in the table attempt to provide some general guidance, in terms of the percentage mean errors, or differences between simulated and observed values, so that users can gage what level of agreement or accuracy may be expected from the model application.

Table 3: General Calibration/Validation Targets or Tolerances for HSPF Application (Donigian, 2002)

	Very Good	Good	Fair
Hydrology/Flow	<10	10 - 15	15 - 25
Sediment	<20	20 - 30	30 - 45
Water Temperature	<7	8 - 12	13 - 18
Water Quality/Nutrients	<15	15 - 25	25 - 35

Notes: 1. Percent variance (+/-) between observed and simulated values.
2. Relevant to monthly and annual values; storm peaks may differ more. 3.
Dependent upon: quality and detail of input and calibration data; purpose of model application; availability of alternative assessment procedures; and resource availability.

The notes at the bottom of the table indicate that the tolerance ranges should be applied to mean values, and that individual events or observations may show larger differences and still be acceptable. In addition, the level of agreement to be expected depends on many site- and application-specific conditions, including the data quality, purpose of the study, available resources, and available alternatives assessment procedures that could meet the study objective.

For the Fanno Creek main stem hydrodynamic model, although there is a considerable discrepancy in terms of instantaneous peak comparison, the averages parameters seems to be well within the tolerance ranges as shown in Table 3. As indicated in Table 2, the average daily flow showed a correlation coefficient of more than 0.95 for all storm events during the verification periods. Also the cumulative runoff volume has an average error of 9%. Considering the points addressed in the literature review, and the correlation of model results with monthly or annual stream gage values and not instantaneous ones, the Fanno Creek main stem hydrodynamic model is within the acceptance criteria listed in Table 3.

5. Conclusions and Recommendations for Fanno Creek Main Stem Hydrodynamic Model Use

Based on this overview of model calibration and verification results, the modeling team recommends the approval of this phase of the hydrodynamic model. The following decisions were also made on the November 18, 2002 meeting:

Given current staff levels, the pace of the modeling to date, the remaining work to be done, and the project deadlines and milestones, it was decided by the modeling team and design engineers from the Engineering Services that the updated Fanno Creek Hydrodynamic model was acceptable for the following work:

- Provide flow information for ESA group
- Pre-design activities for flow sizing to City Design Standards
- Identification of culverts and pipes which are currently undersized for the appropriate storm events
- Estimation of approximate flood damages from LARGE storm events (i.e., storm events that are considered more than a 10-year storm event).

6. References

1. A. Laenen, USGS Water-resources Investigations Report 83-4143, “Storm Runoff as Related to Urbanization Based on Data Collected in Salem and Portland, and Generalized for the Willamette Valley, Oregon”, Portland, Oregon, 1983

2. EPA, “Quality Assurance Project Plan for Rainfall-Runoff Simulation Using the Hydrological Simulation Program – FORTRAN (HSPF) for the Proposed Crandon Mine Area, Crandon, Wisconsin”. Prepared under contract by U.S. Geological Survey, Urbana, IL, and AQUA TERRA Consultants, Mountain View, CA, U.S. EPA, Region 5, Chicago, IL. 1998

3. Donigian, Jr., HSPF Training Workshop Handbook on Calibration and Verification Issues.. Presented and prepared for U.S. EPA, Office of Water, Office of Science and Technology, Washington, DC. January 2000

4. EPA, “Quality Assurance Project Plan, Modeling Study of PCB Contamination in the Housatonic River”. Prepared under environmental remediation contract by U.S. Army Corps of Engineers, U.S. EPA, Region I, Boston, MA. October 2000.

Figure 1. Comparison of Measured Flow and Model Simulated Flow from October-December, 1996 for Fanno Creek Main Stem at 56th Avenue

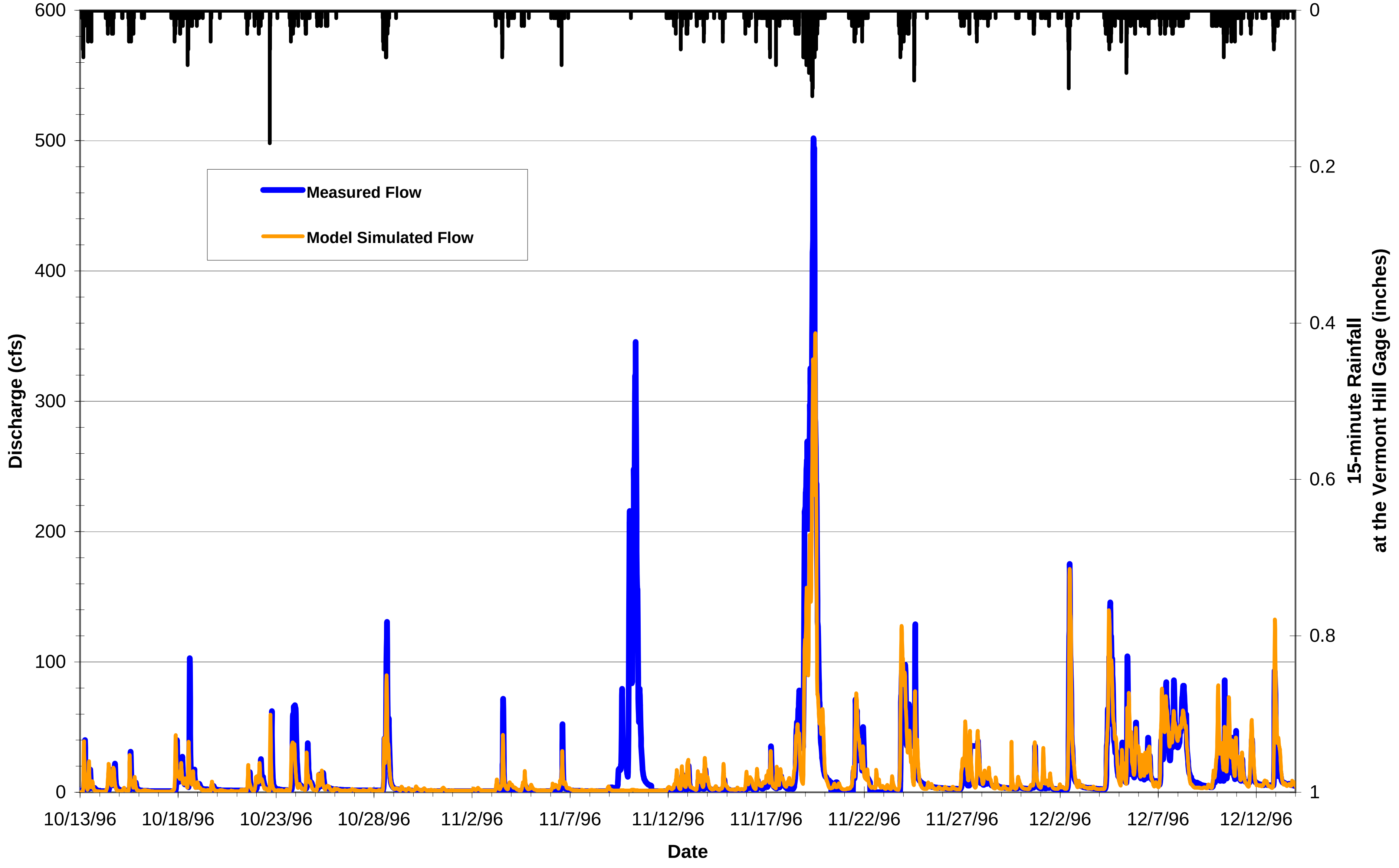


Figure 2. Flow Compairsons for Period of November 16-22, 1996 at USGS Gage on Fanno Creek at 56th Ave.

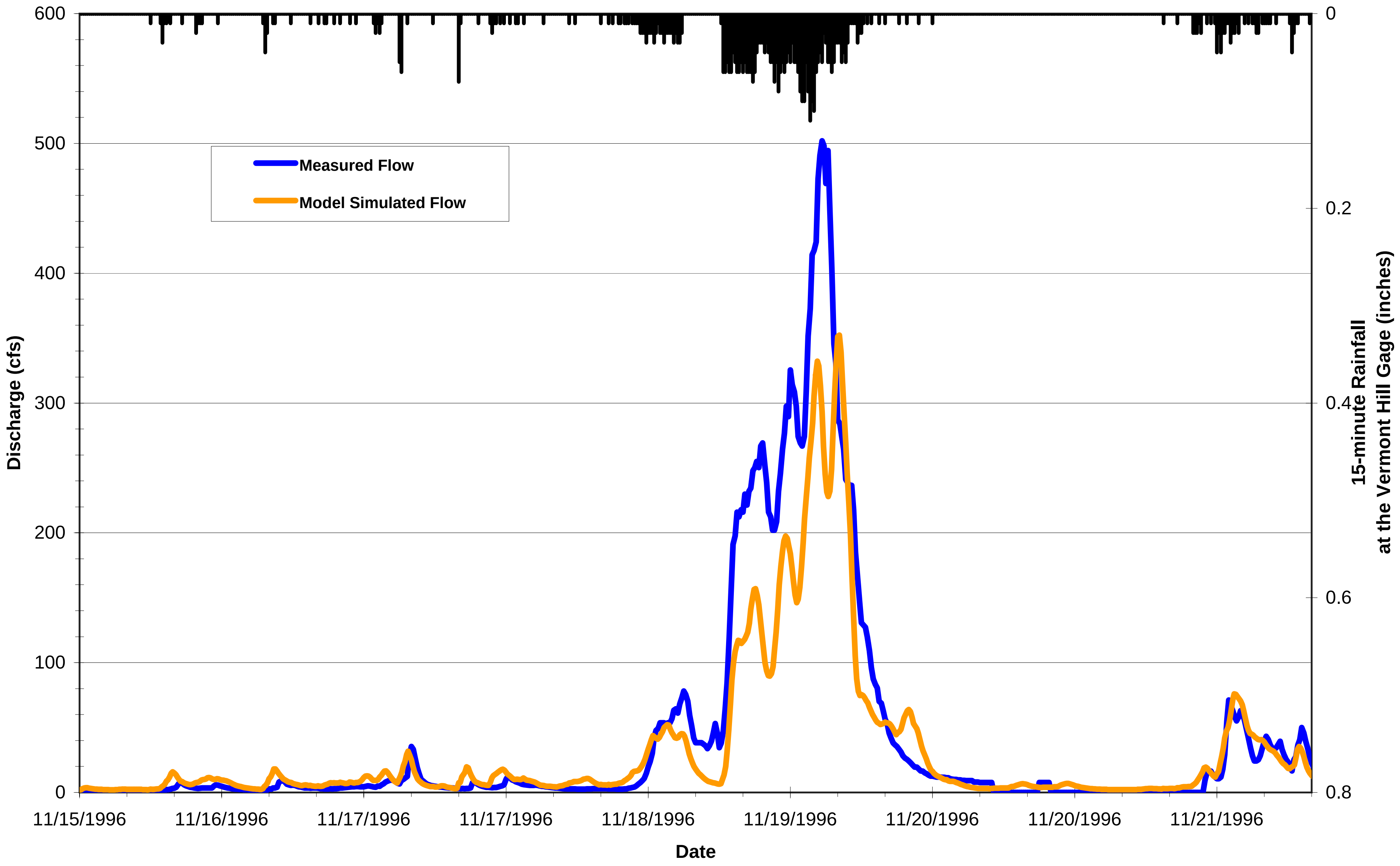


Figure 3. Comparison of Measured Flow and Model Simulated Flow from January 1-31, 2002 for Fanno Creek Main Stem at 56th Avenue

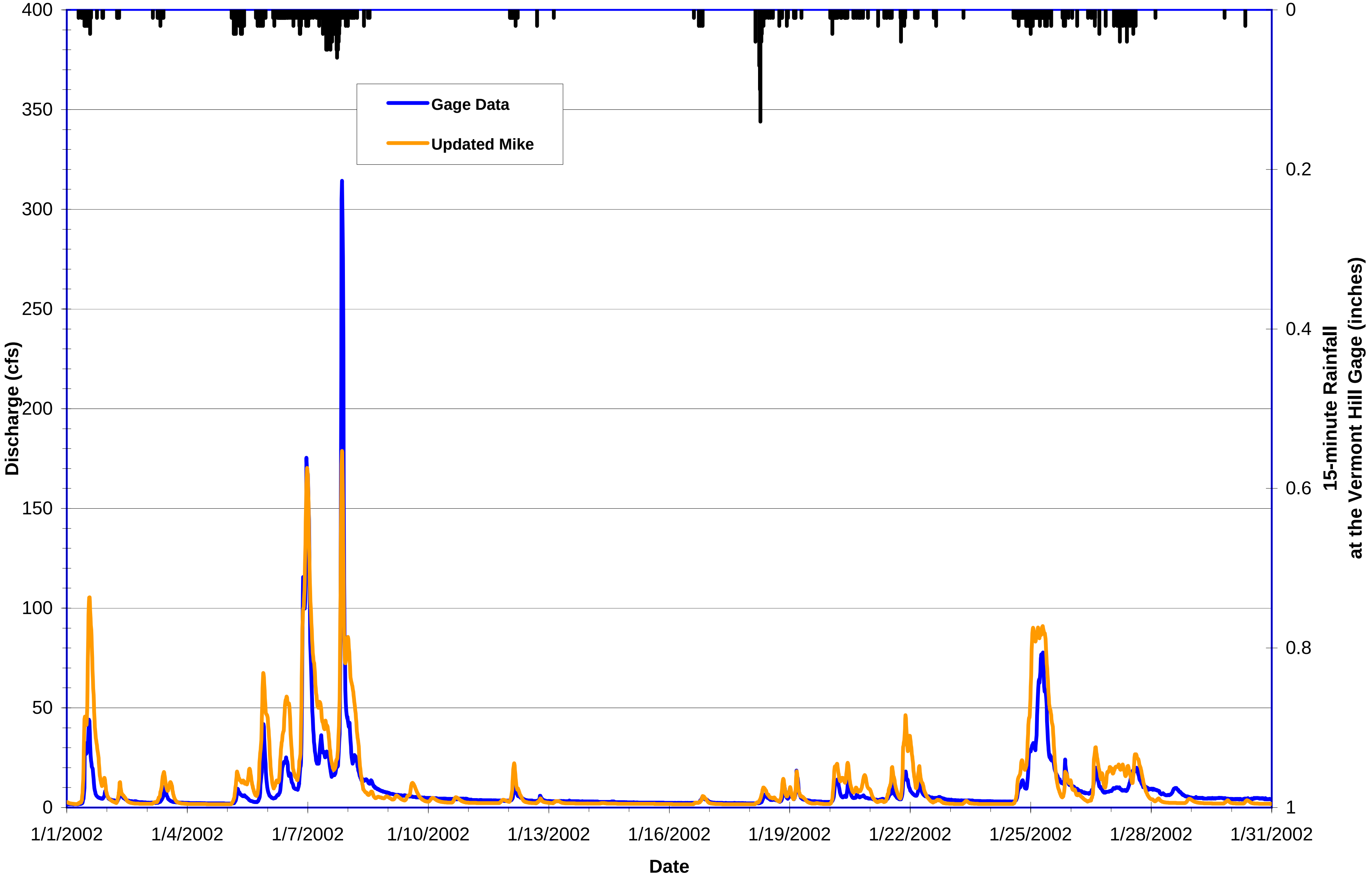
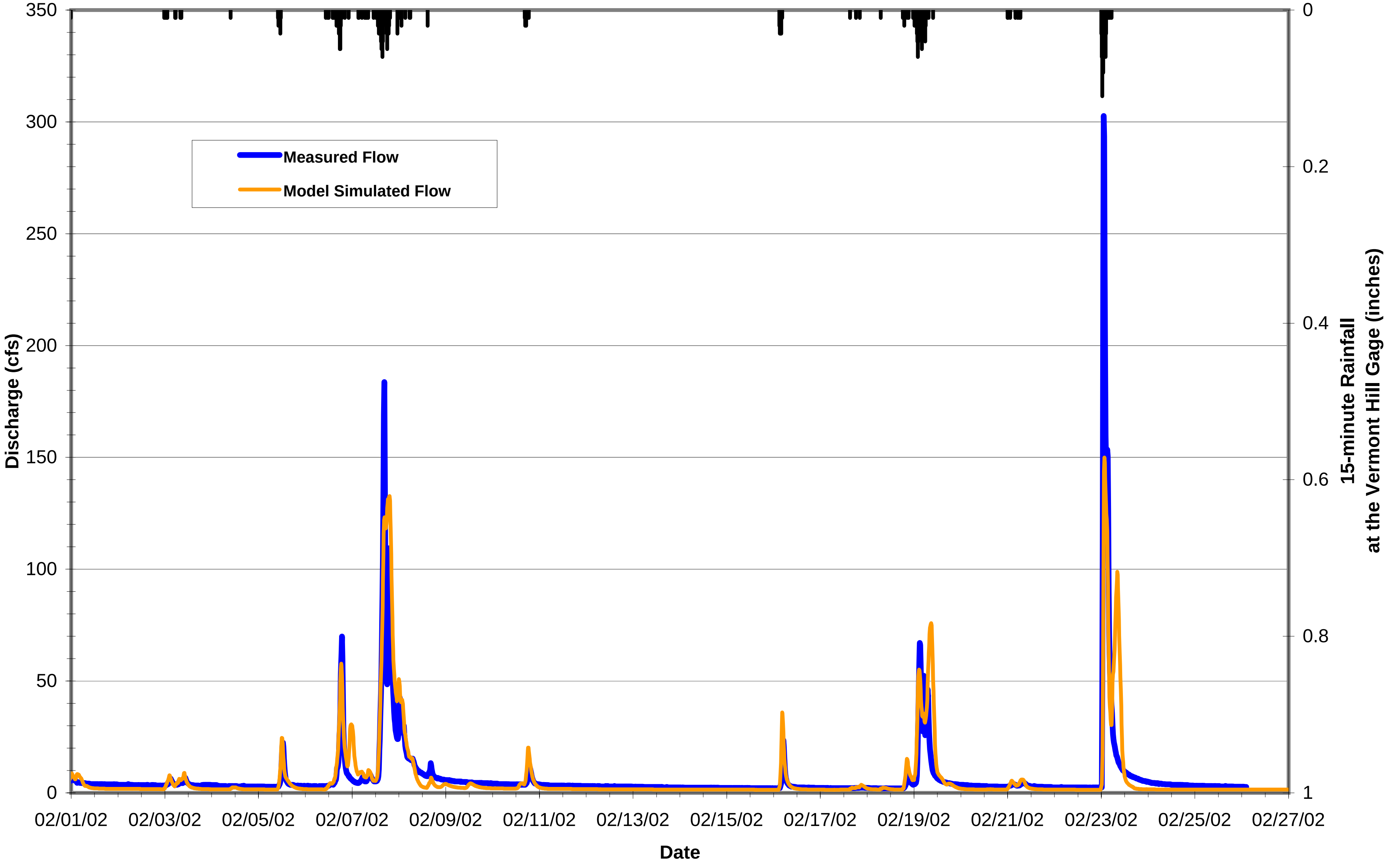


Figure 4. Comparison of Measured Flow and Model Simulated Flow from Feburary 2-25, 2002 for Fanno Creek Main Stem at 56th Avenue



environmental services
systems analysis

Technical Memorandum

To: Amin Wahab, BES Fanno/Tryon Creek Watershed

From: Binhong Wu, BES Systems Analysis

Reviewed By: Mark Liebe, BES Systems Analysis
John Houle, BES Engineering Services
Gregory Savage, BES Systems Analysis
Bill Owen, BES Engineering Services

CC:

Date: April 18, 2003

Project: Fanno/Tryon Watershed Plan

Subject: Fanno Creek Main Water Quality Model Calibration

TABLE OF CONTENTS

Summary

This technical memorandum provides the following information for the Fanno Creek main stem water quality model:

1. The calibration work that has been performed for the Fanno Creek main stem Mike 11water quality model;
2. Review and summaries of preliminary water quality calibration results;
3. Identify potential causes for the discrepancies between simulated and observed data and discussions on model and supporting data limitations;

4. Recommendations on the Fanno Creek main stem water quality model usage and future improvement to the model.

1. Introduction

The Mike 11 water quality model for Fanno Creek main stem was developed and calibrated by DHI Water & Environment (DHI) as part of a contract between BES and DHI. The model development and calibration procedures, and results are presented in a report titled "Fanno Creek Watershed Model" by DHI in August 2002. (\\Oberon\GRP104\Watershed_Plans\Fanno_Tryon\FTP Technical Memos\Modeling\DHI\TM_Fanno_BES_12.doc). In November 2002, BES made several improvements for the Fanno Creek main stem hydrodynamic model to increase predicted peak flows during larger storm events. Since river hydrodynamics are the driving forces for in-stream pollutant transporting and mixing, revisiting the water quality calibration for Fanno main stem was necessary.

Calibration of the input parameters involved in water quality model is more difficult than hydrologic/hydraulic calibration due to the following:

- The inherent uncertainties in pollutant time-varying accumulation, antecedent conditions, transporting, mixing, degradation, and alternate pathways of uptake;
- The approximate nature of model formulations trying to capture the complexities of pollutant movement;
- The inherent errors in input and observed water quality data;
- Lack of continuous monitoring water quality data for individual storm events;
- Poorly defined state-of-the-art in water quality model performance criteria.

In-stream pollutant concentration is mainly controlled by the external loading of contaminants from the watershed, pollutant degradation, transformation, deposition and re-suspension of pollutants within the stream channel. The external loading of a pollutant to a stream can vary widely depending on precipitation, storm runoff, soil characteristics, topography, land uses, and erosion occurring over the watershed. There are two major sources of external pollutant loads: non-point source loads from watershed land uses and point source loads from known sources such as a wastewater treatment plant. For Fanno Creek main stem, there are no identified point sources in the watershed. Consequently, pollutant sources currently considered in the water quality model consists solely of non-point pollutant loads from watershed land uses.

The non-point source pollutant loads are conveyed by runoff through stormwater collection systems such as storm pipes or roadside ditches before they enter Fanno Creek main stem. The non-point pollutant loads were originally estimated by DHI using DHI's Load Model. DHI's Load Model is an ArcView GIS based program that calculates pollutant loads for computational grids in the watershed using land use based runoff coefficients and pollutant event mean concentrations (EMCs). Degradation of the pollutant from a computational grid to the nearest downstream stormwater collection point is accounted for in Load Model by applying a constant decay coefficient that is correlated to the travel distance to the receiving channel. BES developed a similar GIS tool to estimate upland pollutant loads for watershed. The BES GIS grid loading model was originally developed to estimate upland pollutant loads for Fanno Creek watershed and identify areas of water quality concern in absence of a detailed water quality model. To be consistent with the watershed study, the non-point pollutant loads used in this update water quality calibration work were estimated using the BES grid model. Detailed information on the GIS grid loading model can be found in a technical memorandum titled "Determine Upland Pollutant Loads through GIS modeling". The non-point pollutant loads, calculated for selected locations along Fanno Creek main stem, are input to stream reaches modeled in the Mike 11 hydraulic model. Once the non-point pollutant contributions from all land uses in the watershed were available, the modeled hydrologic and hydraulic processes were superimposed in the water quality model to provide transport mechanisms that affect pollutant degradation, deposition and re-suspension. The water quality modeling allowed adjustments in transporting parameters and re-evaluation of upland non-point pollutant loads as part of the calibration process.

2. Water Quality Model Calibration Results

The water quality calibration involved numerous model runs and iterations at two water quality stations on Fanno Creek main stem: 56th Avenue and 39th Avenue. The water quality model was calibrated for the entire year of 1996, consistent with the calibration period used by DHI. The following steps were performed for water quality calibration:

1. Estimate all water quality model parameters, including non-point pollutant loads and various in-stream water quality parameters such as deposition and re-suspension rates.

2. Compare simulated and observed in-stream concentrations at the two calibration stations.

3. Analyze the results of comparisons from step 2 to determine appropriate in-stream and /or non-point pollutant load adjustment.

The essence of watershed water quality calibration is to obtain acceptable agreement between observed and simulated concentrations (i.e. within defined criteria or targets if they exist), while maintaining the in-stream water quality parameters within physically realistic bounds and the non-point source loading rates within reasonable ranges. The realistic bounds and reasonable ranges for water quality parameters can be obtained from literature review. A list of references that were used to develop water quality model can be found in August 2002 DHI report titled "Fanno Creek Watershed Model".

The water quality constituents calibrated include total suspended sediments (TSS), total phosphorus, temperature and E. Coli bacteria. These are the pollutants of concern for the Fanno Creek Total Maximum Daily Load (TMDL). For water quality constituents, model performance is based primarily on visual and graphical presentations because of the sporadic nature of observed data and because the frequency of observed data is often inadequate for reasonable statistical measure. For this calibration work, the main calibration check consists of visual comparisons of monitored data points and model predictions for modeled water quality constituents. An alternative model performance check was performed only for TSS and total phosphorus. The alternative check involves comparing the monthly moving average of simulated pollutant concentration with monthly statistics of the observed data and checking if the modeled averages fall within the limits of the monitored data. The monthly statistics for the observed data include monthly maximum, minimum and median. This check was only performed for the 56th Avenue water quality station, since water quality data collected at the 39th station were not adequate to perform statistical comparison.

Fanno Creek water quality model calibration results are summarized below by pollutant type.

Total Suspended Sediment

Figures 1 and 2 display the simulated and observed TSS concentration for the Fanno Creek main stem at 56th Avenue and 39th Avenue, respectively for the 1996 calibration year. Weekly grab samples were collected at the 56th Avenue station in 1996. Monthly samples were collected at the 39th Avenue station during 1996. As shown on Figures 1 and 2, the observed values of TSS scattered widely, especially during the winter season. Due to the scale on Figure 1, four observation points with TSS concentrations higher than 500 mg/L are not shown on the graph. The comparison of simulated and observed TSS concentration indicates that the dynamics and background level for TSS are captured well by the model at both 56th Avenue and 39th Avenue throughout the entire calibration period. However, the model failed to match the peak TSS concentrations (i.e., concentrations larger than 100 mg/L) at both stations. Figure 3 illustrates TSS concentration comparison between the simulated monthly moving average and monthly observation bounds at the 56th Avenue station. The monthly observation statistics were obtained based on weekly grab samples collected at the 56th Avenue station. As shown in Figure 3, the simulated data appears to match well with the observed monthly median during the summer season. The simulated data show considerable discrepancies from observed median value for some winter months. The possible causes for such discrepancies between the simulated and observed peak TSS concentrations and potential methods to improve model's capability to capture peak concentrations during individual storm events are discussed in Sections 3 and 4.

Figure 1. Simulated and Observed TSS for 56th Avenue Station

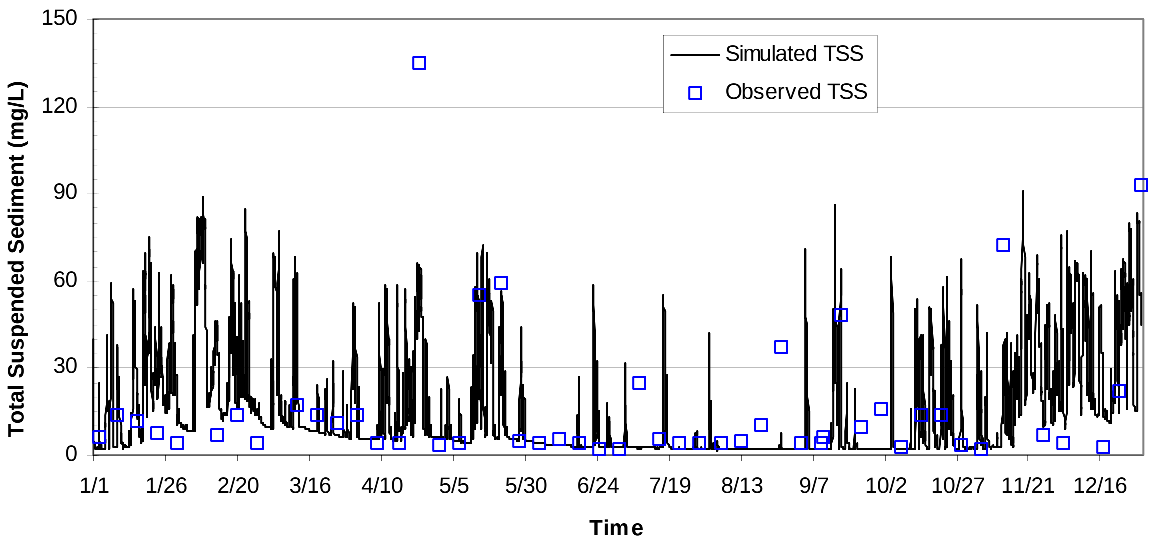


Figure 2. Simulated and Observed TSS for 39th Avenue Station

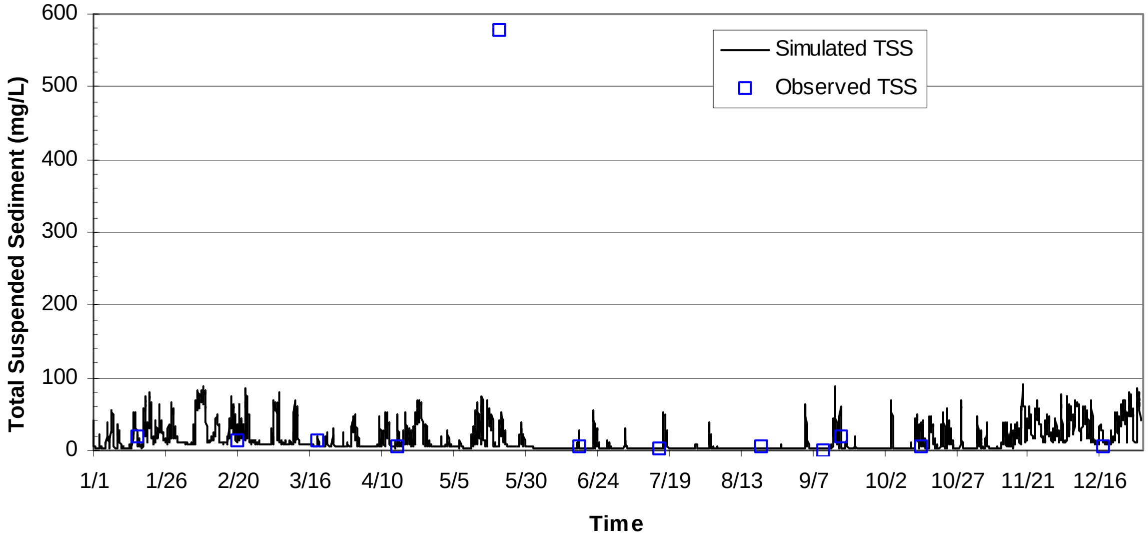
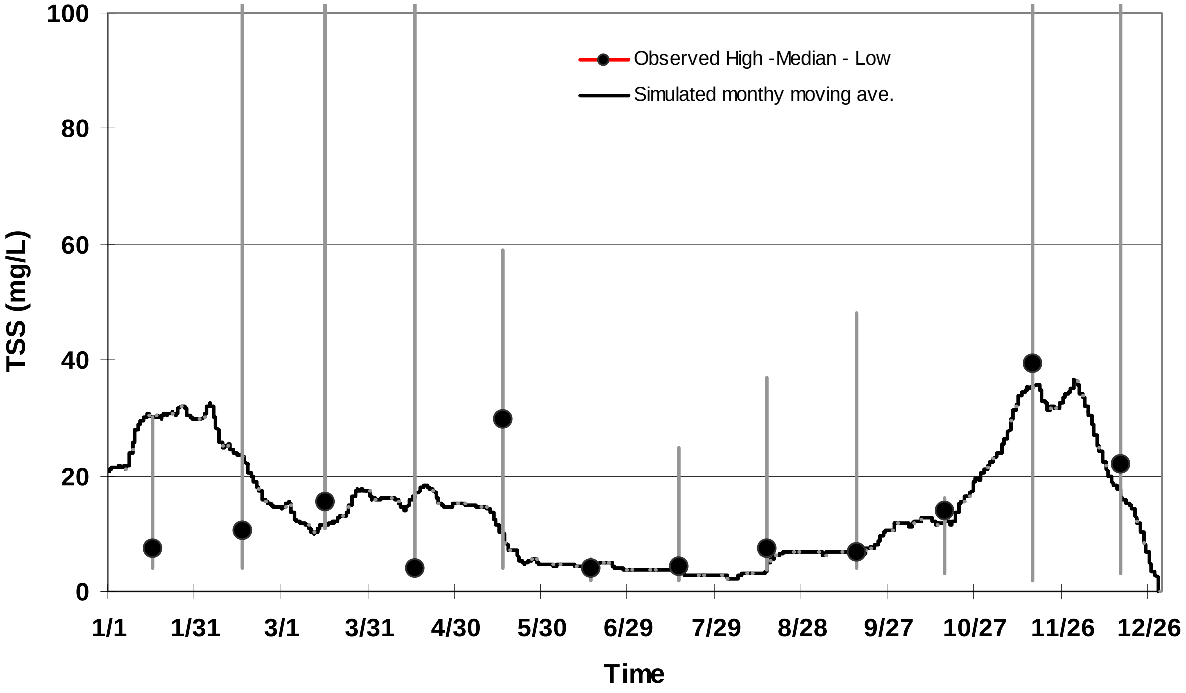


Figure 3. TSS Calibration at 56th Avenue Station for Year 1996



Total Phosphorus

Figures 4 and 5 compare the simulated and observed total phosphorus for water quality stations located at 56th Avenue and 39th Avenue, respectively for the 1996 calibration year. As shown in figures, the modeled data matches with observed data reasonably well for both stations. However, as was the case with TSS, the model underestimates peak concentrations during a few time periods. Also there seems to be some inconsistency in the background level estimate between modeled and observed concentrations. The model shows a good correlation with observed background levels during the 1996 summer season at the 56th Avenue station, while the model appears to over-estimate the general background levels observed during winter months of 1996. Figure 6 presents the comparison of the monthly moving average of simulated total phosphorus and the monthly maximum, minimum and median of monitored data collected at the 56th Avenue station. Like TSS, the simulated data show better match with the observed monthly median values during the summer of 1996 than the winter. Factors that likely influence the water quality model's capability to match peak concentrations and seasonal fluctuations are discussed in Section 3.

Figure 4. Simulated and Observed Total Phosphorus for 56th Avenue Station

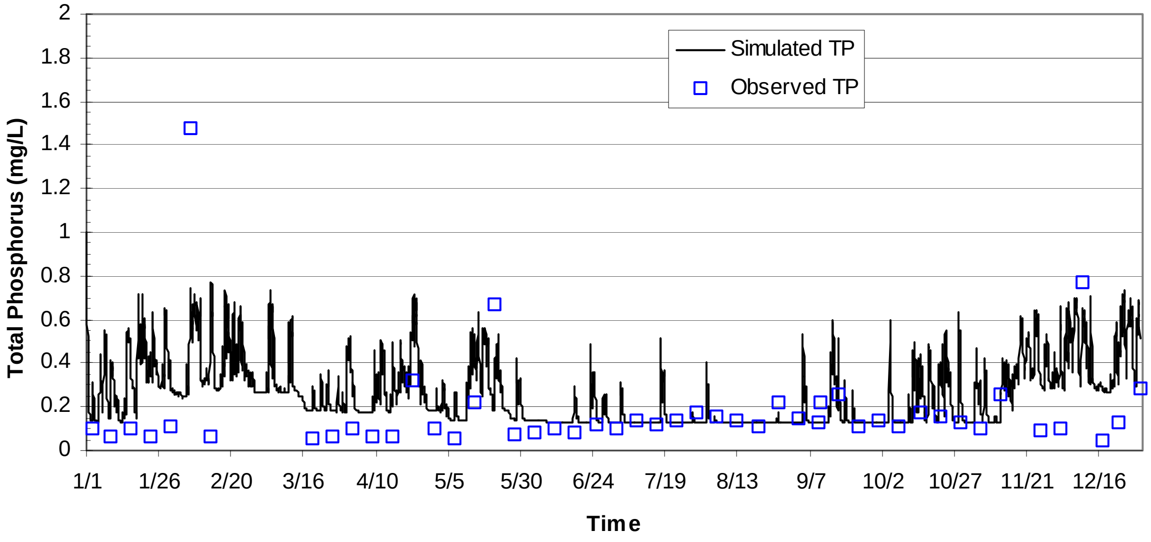


Figure 5. Simulated and Observed Total Phosphorus for 39th Avenue Station

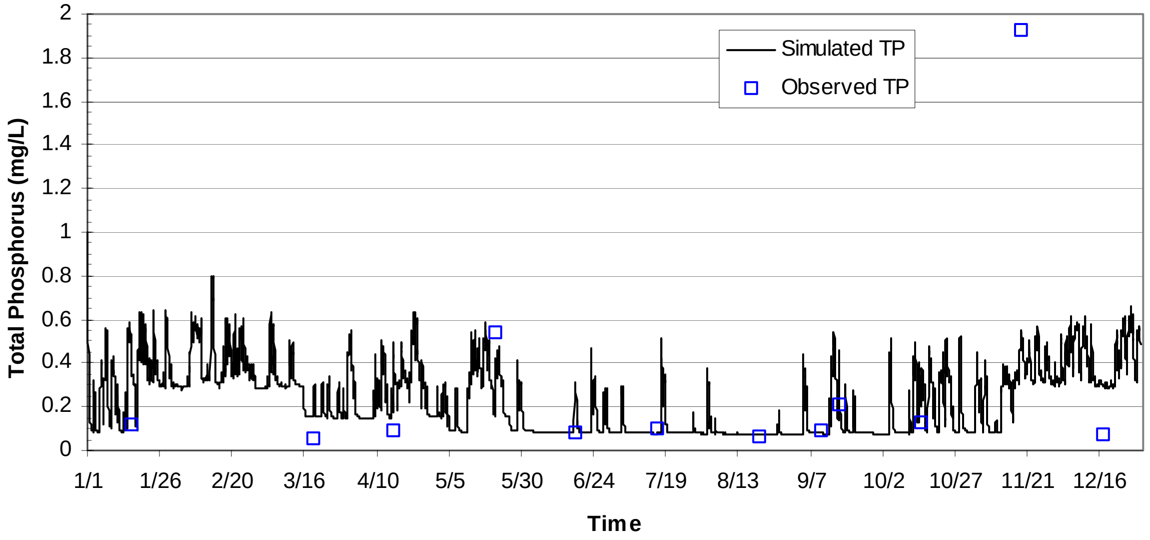
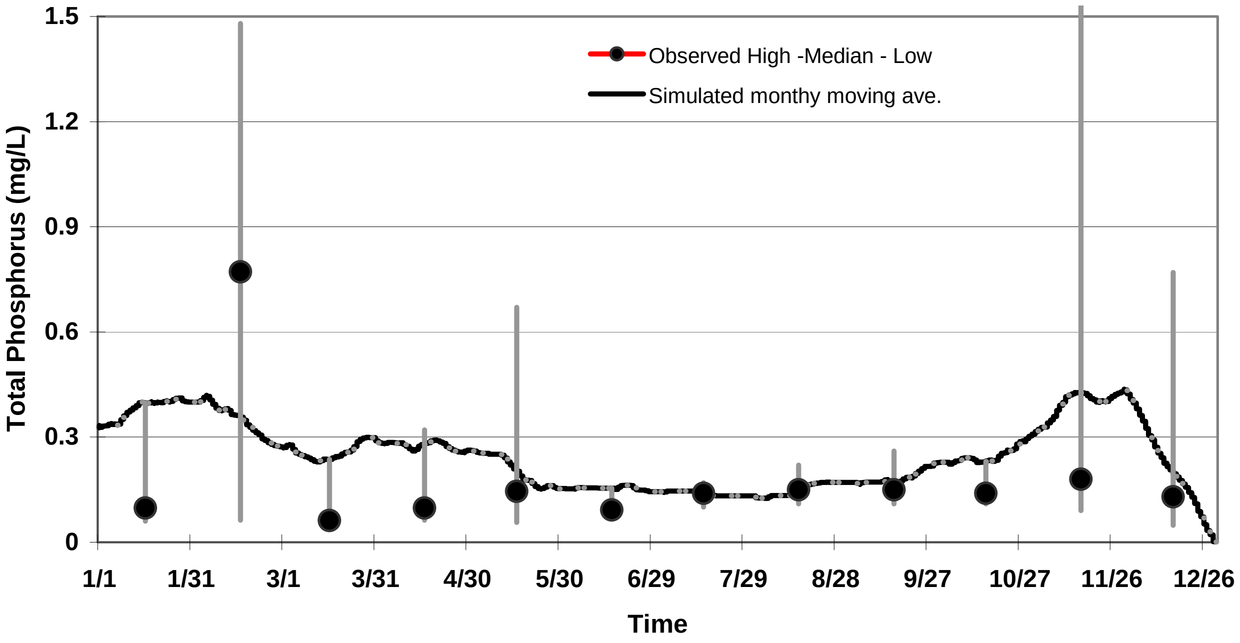


Figure 6. TP Calibration at 56th Avenue Station for Year 1996



E. Coli

- 7

Figures 7 and 8 show the simulated and measured E. Coli concentrations for the 56th Avenue and 39th Avenue stations, respectively. The general shape of the simulated concentration profile matches that of the observed for both stations. The model captures the overall behavior of E. Coli concentrations during storm events. However, the model was unable to match the extreme high or low observations (due to the scale of the plot, some extreme high E. Coli concentrations observed during 1996 are not shown). Given the level of difficulty that is related to bacteria simulation and the sporadic nature of observed E. Coli data, developing a stringent measure of goodness of fit is unlikely for most water quality models.

Figure 7. Simulated and Observed E. Coli for 56th Avenue Station

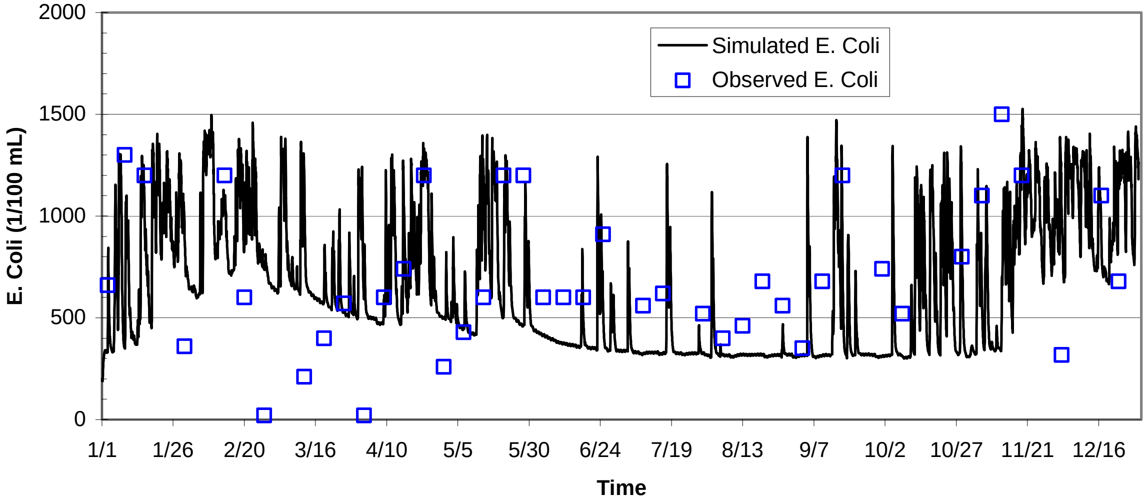
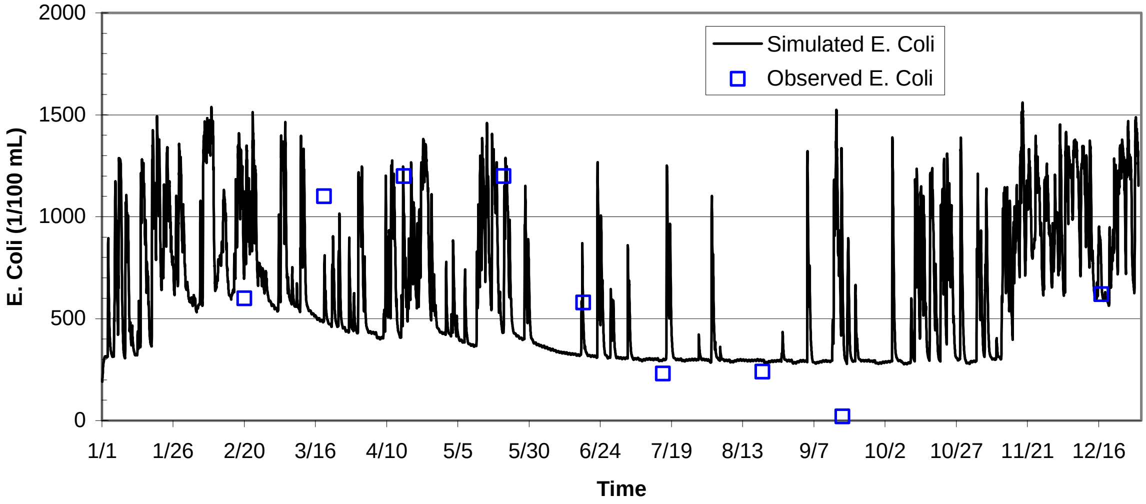


Figure 8. Simulated and Observed E. Coli for 39th Avenue Station



Temperature

Figures 9 and 10 represent the comparisons between the simulated and measured temperature data collected at the 56th Avenue and 39th Avenue stations on Fanno Creek main stem. As can be observed in Figures 8 and 9, a fair correlation exists between the observed and measured trends for both stations. However, some large discrepancies between the simulated and observed data exist for both stations. Several major factors may contribute to the discrepancies:

1. The simplified nature of temperature model algorithms;
2. The use of constant parameters for inflow temperature and the heat exchange during the long-term simulation;
3. Uncertainties (i.e., lack of information on exact time of the day when sample collected) involved in the instantaneous temperature measurements collected at both stations;
4. Uncertainties with regards to groundwater influence.

The temperature model can be improved by decreasing the simulation period from a whole year to individual season or month so that the more timely correct inflow temperature can be defined and also by using continuous temperature data for model calibration. Continuous temperature data are collected at Fanno Creek 56th Avenue station after May 1998.

Figure 9. Simulated and Observed Temperature for 56th Avenue Station

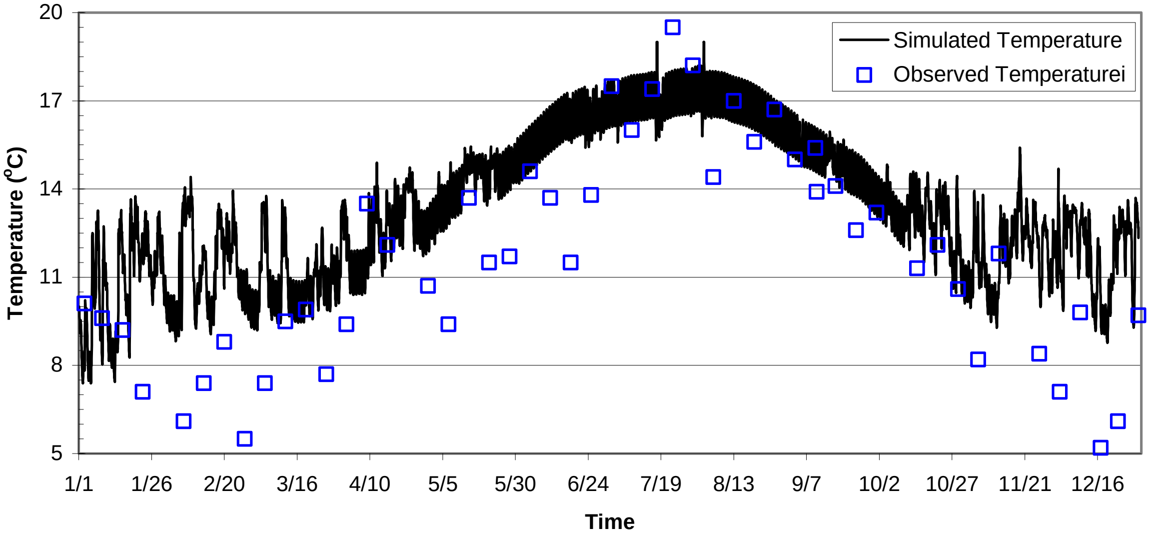
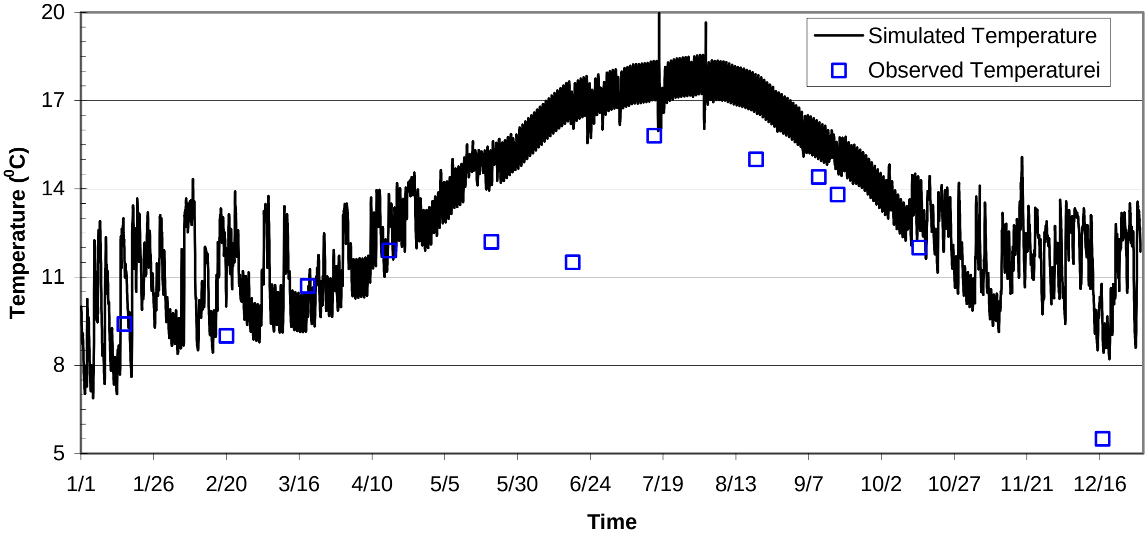


Figure 10. Simulated and Observed Temperature for 39th Avenue Station



3. Model and Model Supporting Data Limitations

As discussed in Section 2, one of the major issues of the Fanno Creek main stem water quality model is its inability to duplicate peak pollutant concentrations during individual storm events. As storm events are usually considered major contributors to stream pollutant loading and regulatory limits typically include peak concentrations, the relatively large discrepancies between the simulated and observed peak concentrations are of concern for the water quality model. The following discussion is focused on potential causes for the poor model performance during individual storm events.

Model Limitations

One of the major limitations of the water quality model is its use of constant values to represent certain water quality input parameters that actually vary through time. For example, the non-point pollutant load is assumed to be transported to the river system with a constant concentration in the model. Since pollutant load is estimated by multiplying the pollutant concentration by the flow that carries the pollutant, the time-variance of non-point pollutant loads is justified by stream flow only. This makes it difficult for the model to capture the temporal fluctuations of pollutant concentrations in-stream during individual storm events. Water quality input parameters that are kept constant during the model simulation also include in-stream transporting and mixing parameters such as deposition and re-suspension rate, etc.

The long-term TSS calibration for Fanno Creek main stem is a good example to illustrate the concentration limitation. The overall dynamics and background levels for TSS are captured well by the model at the 56th Avenue station throughout the entire calibration period. However, the model is unable to match the more sporadic peak TSS concentrations measured at 56th Avenue station. This is because high TSS concentrations in a stream are not only caused by the increased flows and the scouring action of higher flow, but also by higher TSS concentrations from non-point sources due to high runoff. Table 1 contains statistical results for TSS data collected by the City as part of its NPDES MS4 Stormwater Permit since 1991. As shown in Table 1, the observed EMCs for TSS varied widely, usually on the order of 2 to 3 magnitudes, for land use based monitoring stations. Since the model is currently limited to using a TSS concentration to represent TSS loading from non-point sources throughout an entire simulation period, the model would likely underestimate peak concentrations during individual storm events as there would not be any high concentration in the non-point source loading into the stream.

Table 1: Total Suspended Solids Data Collected by the City of Portland from May 1991 to January 2003

Monitoring TSS results (mg/L)	**Land Use Based Monitoring Stations (City of Portland)**											
	R-1	***R-2***	***R-3***	***C-1***	***C-2***	***I-1***	***I-2***	***M-1***	***M-2***	***M-3***	***T-1***	***OP-1***
# Samples	30	11	11	12	16	11	8	32	19	6	12	24
Max TSS	1900	130	140	380	295	1080	317	1100	329	158	250	326
Min TSS	10	18	43	14	47	78	37	35	10	40	58	5
Median TSS	346	64	62	40	81	119	116	155	66	116	102	61
Mean TSS	462	66	75	95	119	271	127	251	82	103	120	94

The inability to simulate temporal variation for certain model input parameters is also evident with the simulated temperature. Although it is possible to set temperature values for different components of inflow, i.e., the overland flow, the interflow and the groundwater flow, these temperatures are considered constant during the entire simulation period. The use of constant parameters for inflow temperatures throughout the long-term model simulation determines that the model is unlikely to match well with instantaneous temperature data collected during individual storm events.

Another model deficiency is that simplified analytical solutions are inadequate to predict the transport and mixing behavior of pollutants in the natural world. For example, the in-stream processes of deposition and re-suspension of particulate pollutants are evaluated by three parameters in the water quality model: deposition rate, re-suspension rate, and critical velocity. Deposition is modeled as a first order process, and is assumed to occur if the flow velocity is below a critical velocity. Re-suspension from river and streambeds is assumed to be constant in time and occur where the flow velocity exceeds the critical value. Although river hydrodynamics and the physical characteristics of particulate pollutants are accounted for in developing values for these model parameters, the physical processes have been much simplified as the model does not take into consideration the physical characteristics of different particles, such as cohesiveness, effective diameter, specific gravity, and settling velocity. The model also uses a lumped number to estimate the amount of re-suspension from the streambed and does not account for changes in flow velocities and bed material caused by sediment deposition or re-suspension.

Another simplification of the TSS modeling is that the model does not address the influence of bank erosion, which may be the main cause for most of the extreme high TSS concentrations collected in stream during large storm events.

The other weakness of the water quality model is its inability to address pollutant contributions (except for temperature) associated with subsurface flows. Unlike temperature, the pollutant concentration constant from non-point sources applies for all inflow components, including overland flow, drainage flow and groundwater flow. A review of total phosphorus data collected at the 56th Avenue on Fanno Creek main stem indicates that there appears to be elevated background concentrations during summer periods. A report published in 2000 by U. S. Geological Survey (USGS) titled "Phosphorus and E. coli in the Fanno and Bronson Creek Subbasins of the Tualatin River Basin, Oregon, During Summer Low-Flow Conditions, 1996" suggests that the elevated concentrations during summer season may be related to phosphorus from groundwater inflow. For areas where pollutant contributions are also associated with subsurface flows, the in-stream pollutant concentration may be better depicted by the model if different concentration values can be assigned for interflow and groundwater inflow in the model. This functionality is not available in current version of water quality model software.

Supporting Data Limitation

It is important to balance the available data with the level of complexity in a model, since any the model is only as good as the data that supports it. Calibration data should compliment the model and test the parts of the model that are the most uncertain.

As stated earlier, one of the model limitations is using constant values to represent temporal variables. An example to illustrate the problem is non-point pollutant loading to the river. Non-point pollutant loading to river is controlled by precipitation, water runoff, soil characteristics, topography, land uses, and erosion over the watershed. Often one does not know the total pollutant loading to river systems and its temporal variation. Unlike precipitation, velocity or water depth data, it is very difficult to measure non-point pollutant loads to river systems. Therefore, a simplified analytical solution, in this case the BES GIS grid loading model, was used to estimate non-point pollutant loads. The non-point pollutant load is assumed to be transported to the river system with a constant concentration in the water quality model due to model limitations and the lack of temporally variable non-point pollutant loading data by storm events. Even when this model limitation is overcome, the non-point pollutant concentration input would still need to be adjusted and calibrated against measured in-stream pollutant concentration to confirm whether the model assumptions are valid.

Another issue is whether the sampled water quality measurements are complimentary to the output available from the model. The monitoring data should be collected such that they can be used to calibrate and test the model. Weekly grab samples were collected at the 56th Avenue station on Fanno Creek main stem during TMDL periods. A large portion of the water quality data was sampled during non-storm events. In order to evaluate the water quality model performance during storm events, and for the model to better capture the in-stream pollutant concentration variations during storm events, continuous water quality data during storm events would be very useful. The instantaneous point measurements are most appropriate for parameters that do not vary much over the diurnal cycle or a storm event. Certain pollutants, such as TSS, tend to fluctuate significantly in both space and time during a storm event. For these pollutants, instantaneous measurements represent only part of the data set needed to fully evaluate whether the model assumptions are valid. An example of rapid variation in observed TSS concentration is illustrated by the grab samples collected on May 21, 1996 at both stations on Fanno Creek main stem. The grab sample collected at the 39th Avenue station showed a TSS concentration of 667 mg/l, while the sample collected on the same day at the 56th Avenue station has a TSS concentration of 59 mg/l. Without specific information such as when the samples were collected during the day, good model calibration would unlikely to be achieved or effectively evaluated.

4. Potential Measurements to Improve Model Performance

As indicated in the previous section, one of the major problems in running longer simulations is that certain time-dependent variables are kept constant in the model. The problem can be alleviated by decreasing the model simulation time, allowing for the application of more representative non-point pollutant concentration for the simulation period, and adjusting the parameters accordingly. Figures 11 through 16 present TSS, TP and E. Coli bacteria calibration results at the 56th Avenue for two short model runs in 1996. As shown in the Figures, by using a different set of land use pollutant concentrations for non-point pollutant loading estimate and modified in-stream transporting parameters in both calibration runs, the model is able to capture the peak pollutant concentrations that are missed during long-time simulation. The shorter calibration runs also show a good match in background level. The results for short-term model simulation indicate that the water quality model, when carried out in short durations, can be calibrated to depict the temporal variation of pollutant movements in stream during individual storm events.

Figure 11. Simulated and Observed TSS at the 56th Avenue Station for April,1996

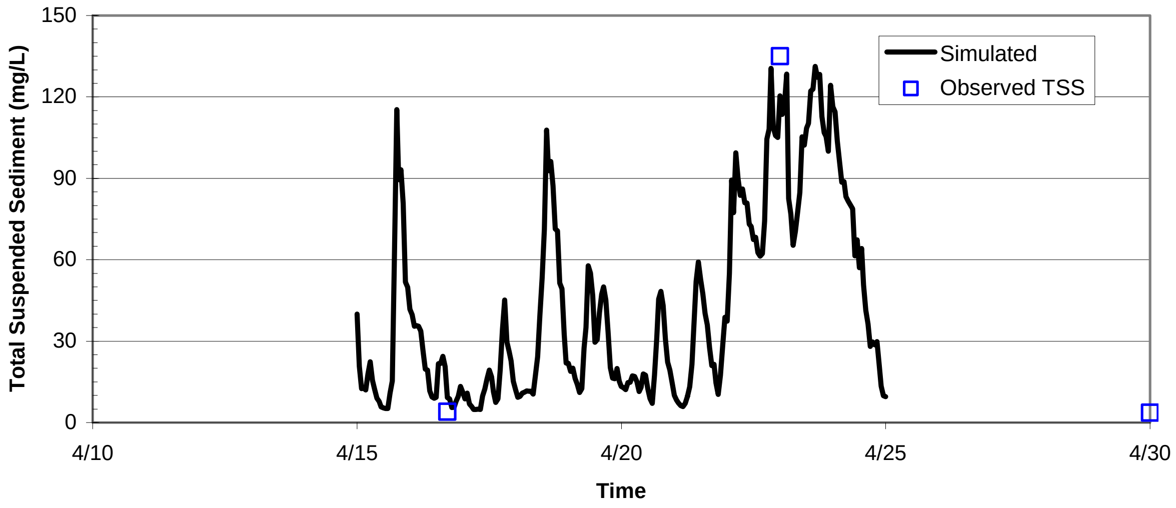


Figure 12. Simulated and Observed TP at the 56th Avenue Station for April,1996

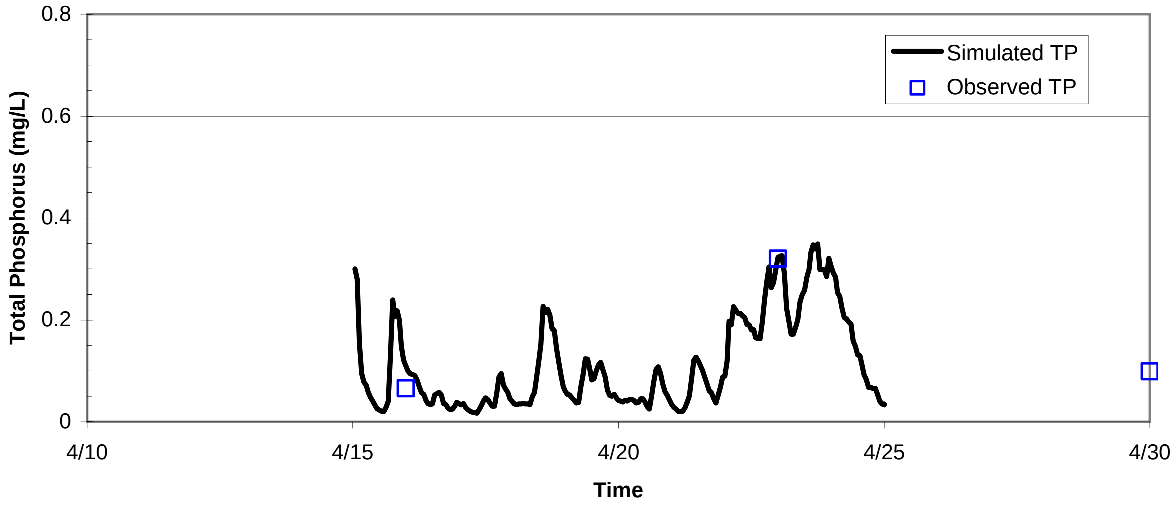


Figure 13. Simulated and Observed E. Coli at the 56th Avenue Station for April,1996

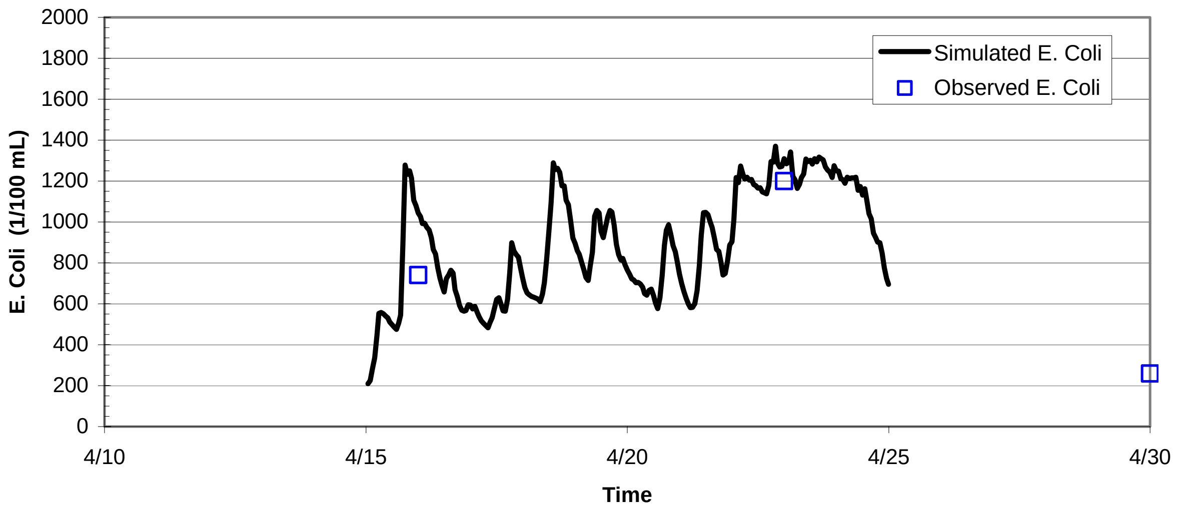


Figure 14. Simulated and Observed TSS at the 56th Avenue Station for May,1996

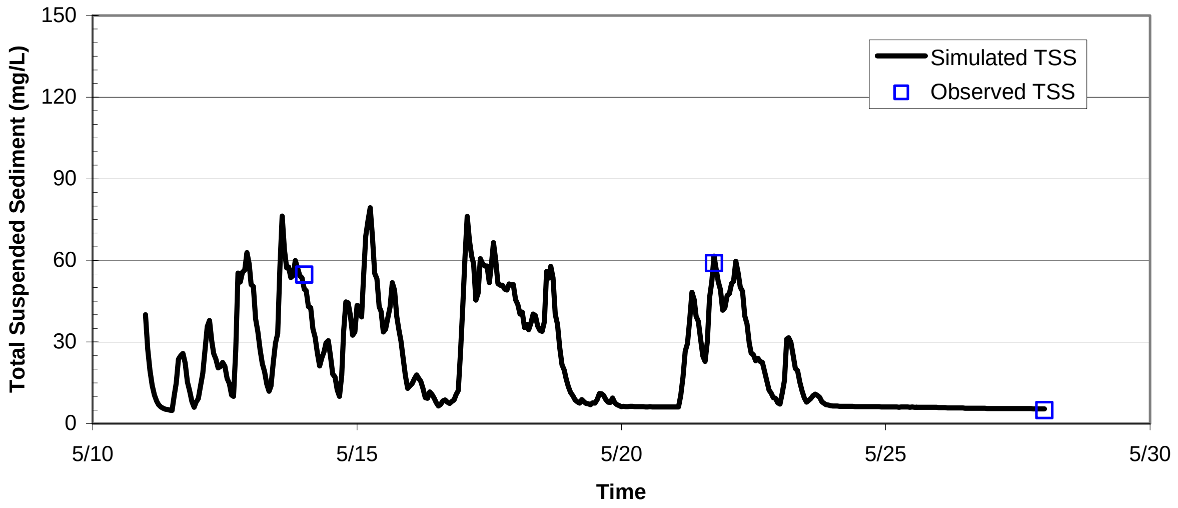


Figure 15. Simulated and Observed TP at the 56th Avenue Station for May,1996

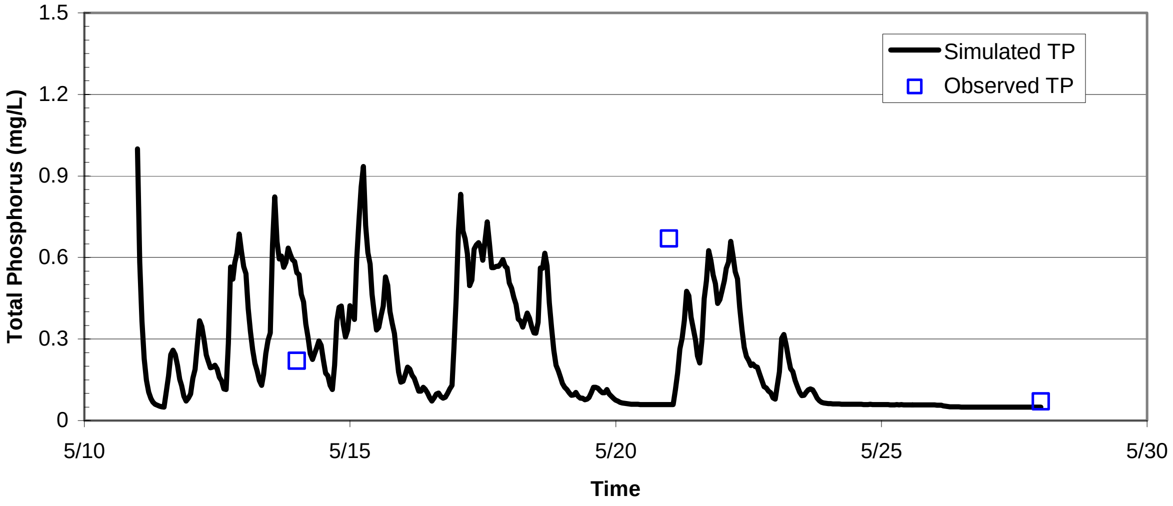
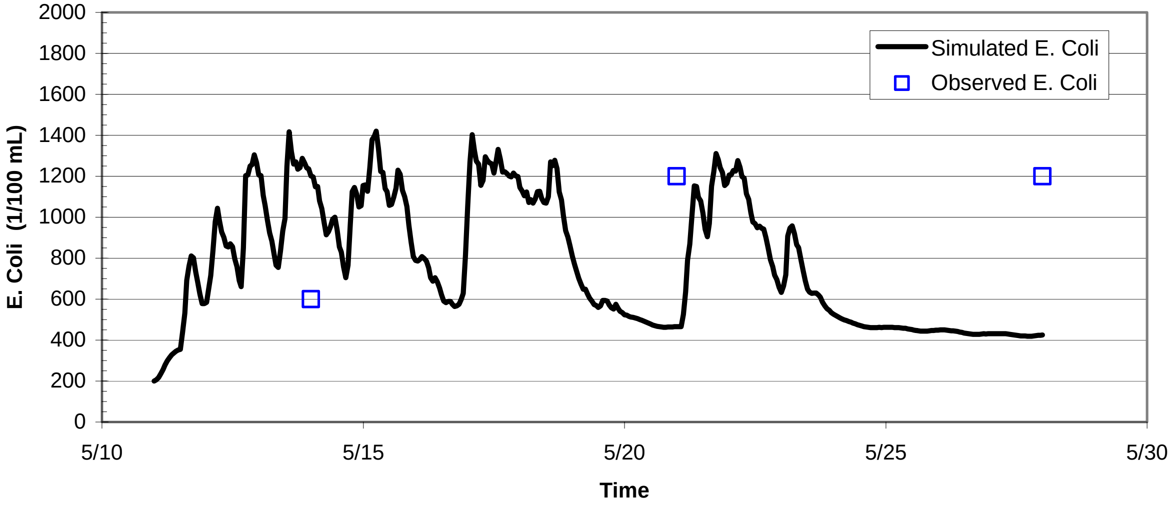


Figure 16. Simulated and Observed E. Coli at the 56th Avenue Station for May,1996



Since one of the major tasks of the water quality model is to estimate in-stream concentrations and pollutant loading for various locations on Fanno Creek main stem during the TMDL period, the following steps are recommended for the TMDL simulation:

1. Based on the long-term precipitation data collected at the City rain gages in the watershed, find out average total precipitation for the TMDL months (i.e., May through October) and select a calendar year that has the closest precipitation amount compared to the average value for the TMDL period;

2. Check if monitored water quality data at 56th Ave station is available for the calendar year selected in Step 1. If not, identify another calendar year that has rainfall total for the TMDL period close to the number obtained from Step 1. This selected calendar year must also have water quality data collected at 56th Avenue gage.

3. Calibrate the water quality model for TMDL period for the calendar year identified in Step 2. If necessary, the calibration can be carried out in shorter durations, such as individual month.

4. Once the in-stream pollutant transporting parameters are calibrated, use BES grid loading model to estimate non-point pollutant loads using land use based pollutant concentrations based on the Oregon Association of Clean Water Agencies (ACWA) database;

5. Run the water quality model for TMDL period for the calendar year identified in Step1 using adjusted in-stream transporting parameters obtained in Step 3 and non-point pollutant loads from Step 4;

6. Estimate in-stream pollutant concentrations and pollutant loads at confluences, monitoring sites and watershed outlets on Fanno Creek main stem for the TMDL period based on the water quality model run results from Step 5.

It would be difficult to evaluate whether the water quality model under-estimates or over-estimates pollutant loading at various points on Fanno Creek main stem as the actual loading is usually unknown. To balance the actual fluctuations in pollutant loads to stream, using average land-use based pollutant EMCs for non-point loading estimate is recommended.

In addition to decreasing the model simulation period, collecting continuous or representative water quality data that are spatially distributed during storm events are recommended. This would provide a more detailed and improved calibration of the water quality model.

5. Model Use Recommendation

Based on the comparison of simulated results with available data from the study area and an overview of model and input data limitations, we recommend that the BES GIS grid loading model in conjunction with Mike 11 model be used to estimate in-stream concentrations and loading for pollutants of concern during the TMDL period in the Fanno Creek watershed. The model can also be used to evaluate watershed management alternatives. We make the recommendation based on the following:

- While Mike 11 water quality model has certain limitations, it includes and couples with a calibrated and validated hydrodynamic model. Therefore, the important hydrologic processes are represented by the model.

- Unlike most simplified GIS-based load models, the Mike 11 water quality model takes into account the in-stream hydrodynamics induced deposition and re-suspension processes. The Mike 11 water quality model also accounts for in-stream degradation for certain pollutants.

- While Mike 11 water quality model tends to underestimate peak pollutant concentration in the modeled stream system, the problem can be alleviated by decreasing the simulation period and adjusting input parameters accordingly when proper calibration data is available. If needed, the long-term simulation could be carried out as a series of sub-simulations to account for seasonal variations and fluctuations during individual storm events.

- Long-term calibration results for 1996 indicate that the water quality model produces a better overall agreement between simulated and observed values during the TMDL period (i.e., May through October) than the non-TMDL period. This is probably due to the fact that there are less storm events during TMDL periods.

- When properly calibrated and using a short simulation time, the Mike 11 water quality model appears capable of depicting the temporal variation of pollutant concentration in stream during individual storm events. However, continuous water quality data during storm events are needed to verify this.

Technical Memorandum

To: Amin Wahab

From: Binhong Wu, P.E.; Gregory Savage, P.E.; Bill Owen. P.E.

Reviewed By: Shannon Axtell, Eugene Lampi, Naomi Tsurumi, Amin Wahab

CC:

Date: June 30, 2003

Project: Fanno/Tryon Watershed Plan

Subject: Fanno Main Stem and Tributary Hydrodynamic and Water Quality Model Development

Summary

This technical report summarizes the following work that has been performed by BES System Analysis group for the Fanno Creek watershed modeling:

1. Fanno Creek watershed model selection and modeling data collection;
2. Fanno Creek watershed hydrodynamic model development;
3. Fanno Creek watershed hydrodynamic model calibration, verification and results for design storms;
4. Fanno Creek watershed hydrodynamic model potential usage.

Information on Fanno Creek main stem water quality model development and calibration is currently not available in the report, although it is listed in the Table of Contents. The information on water quality model for both Fanno Creek and its tributaries will be included once the water quality models are finalized and completed.

Table of Contents

1 Modeling Purpose & Objectives

The City of Portland (City), Bureau of Environmental Service (BES) initiated the development of the Fanno/Tryon Creek Watershed Plan in 2001 to address watershed issues within this southwest region of the City. The purpose of the Watershed Management Plan is to complete and augment the work started in the *Fanno Creek Resource Management Plan (RMP) and the Upper Tryon Creek Corridor Assessment (UTCCA),* and recommended by the BES Public Facilities Plan. Specifically, this Watershed Plan will recommend a comprehensive, strategic set of projects and programs to improve water quality, fish and wildlife habitat, and watershed "functions" in Portland's Fanno and Tryon Creek Watershed.

To accomplish its purpose, the Watershed Plan will address Clean River Plan priorities, and contribute substantially to the City's Clean Water Act and Endangered Species Act (ESA) compliance efforts. The Watershed Management Plan will guide key City programs and projects in the Fanno and Tryon Creek Watershed including water quality and performance monitoring, stormwater Best Management Practices (BMPs), watershed re-vegetation, habitat restoration, and infrastructure projects. Finally, the Watershed Management Plan will also provide a basis for development of the City's operating and capital budget to fund priority actions.

The BES project team requested that the Systems Analysis (SA) Section provide technical assistance to support the development of the Fanno/Tryon Creek Watershed Plan. As defined by the project Work Plan (August 30, 2001), the SA Section would build a set of modeling tools to simulate hydrologic, hydraulic, upland pollutant loading, and in-stream water quality processes within this watershed. This Technical Memorandum summarizes the development, calibration and verification of the Fanno Creek main stem and its tributary modeling systems and their potential usage in the watershed plan. Additional information pertaining the main stem and tributary models for the Fanno Creek watershed is available in related documents (DHI, 2002; CH2M HILL, 2002; and BES, 2002).

2 Model Selection and Data Collection

As part of the model selection process, the City reviewed a number of popular watershed models including EPA's SWMM and HSPF, and Army Corps' HEC programs. Based on the evaluations of the needs for the project and model performances, the project team decided that the Danish Hydraulics Institute's (DHI) MIKE SHE and MIKE 11 models were best suited for the project. MIKE SHE and MIKE 11 are integrated surface water and groundwater programs that can be used to simulate hydrologic, hydraulic, upland pollutant loading, and in-stream water quality processes within a watershed. MIKE SHE is a hydrologic model that converts precipitation falling onto the watershed into runoff. MIKE 11 is a hydraulic model that routes MIKE SHE generated runoff through modeled stream system.

MIKE SHE is a physically based hydrologic model that simulates all major hydrological processes occurring in the land phase of the hydrological cycle. The hydrological components in MIKE SHE model include interception-evapotranspiration, infiltration, snow melt, overland flow, subsurface flow, groundwater flow and river-aquifer exchange. All these components are fully coupled in MIKE SHE. In this project, MIKE SHE is used as a hydrologic model to generate all the water to stream networks.

Flows generated in MIKE SHE are routed through the one-dimensional hydraulic model, MIKE 11, in a coupled manner. Mike 11 is a modeling tool for simulation of flows and water quality in estuaries, rivers, channels, storm pipes and other narrow water bodies of limited depth. It is a dynamic, one-dimensional modeling tool for the design, management and operation of both simple and complex river and channel systems. Mike 11 is capable of simulating the flow in a network of the branches and in which there is no significant stratification. Mike 11 models were developed for major streams and stormwater collection systems in the Fanno Creek watershed.

Mike SHE and Mike 11 require various input data in order to perform the various overland, channel, and groundwater computations. The following subsections describe the data collection process to fulfill the requirements of the MIKE SHE and Mike 11. More detailed information on model input data selection is provided in Section 3.0.

2.1 Model Area and Boundary Conditions

Separate Mike SHE and Mike 11 models have been developed for each of the following six major drainage basins in the Fanno Creek watershed:

- Fanno Creek Main Stem
- Pendleton Creek
- Vermont Creek
- Woods Creek
- North and South Ash Creek
- Redrock Creek

Each drainage basin was defined using the topographic water divide in the watershed. The extent of the drainage basin and the modeled area for the six drainage basins is illustrated in Figure 2-1. Since some drainage areas in Woods Creek, Ash Creek and Redrock Creek basins are located outside the City boundary, not all area in these drainage basins are modeled. Table 2-1 lists total drainage basin area and modeled area for each drainage basin. Each model area is discretized in a network of square grids. A constant 100-foot square grid was used in the Fanno Mike SHE models. The total number of columns and rows of grids for each basin are also provided in Table 2-1. The grid size was chosen primarily based on basin characteristics and computational constrains in the model.

The boundary conditions for the basin models were set such that there would be no flow along the entire basin boundary, with the exception that a constant head boundary, allowing water to flow in and out through the model boundary, was set at the most downstream of each basin model.

Table 2-1: Drainage Basin Model Information

Drainage Basin	Total Drainage Basin Area (acre)	Total Modeled Basin Area (acre)	Number of Modeled Grid Columns	Number of Modeled Grid Rows	Number of Active Modeled Grids
Fanno Creek Main Stem	2093	2093	150	120	9137
Pendleton Creek	246	246	75	35	1179
Vermont Creek	812	812	110	75	3355
Woods Creek	879	674	80	95	2936
North and South Ash Creek	1486	826	55	90	3600
Redrock Creek	1053	810	118	72	3731

2.2 Meteorological Data

Meteorological data sets are some of the primary inputs needed to run a physical-based hydrologic model. Mike SHE requires precipitation data, potential evapotranspiration (ET), and solar radiation data for the model to simulate both surface and groundwater effectively.

Precipitation Data

BES' Hydrologic Data Retrieval and Acquisition (HYDRA) system contains 5-minute rainfall data throughout the City, including in and around the Fanno Creek watershed. Table 2-2 lists the four operational rainfall gages in the Fanno Creek region for the period from the mid-1990s through present.

Table 2-2: Rain Gages Used in Fanno Creek Watershed Models

BES HYDRA ID	Rain Gage Name	Mike SHE ID
006	Collins View	1
032	Vermont Hills	2
040	Thomas	3
005	Sylvania	4

Figure 2-2 depicts the locations of these and a national meteorological station. Spatial distribution of precipitation was accomplished using Theissen polygons developed for those rainfall gages. Figure 2-2 also shows the Theissen polygons used in Mike SHE models. The precipitation gage data for these sites were converted to units of mm/hr and compiled into a specially formatted time-series file that is read by the MIKE-SHE model. Periods of record with missing data for one particular gage were filled in by copying data from the closest gage in the watershed or averaging the values from the other watershed gages for the same time period.

Evapotranspiration Data

The potential evapotranspiration used in the Fanno Creek Mike SHE models was based on a 30-year average (1961-1990) monthly pan evaporation measurements collected at the National Weather Service Station in Portland International Airport. The Oregon Climate Service provided BES with this data. The monthly potential evapotranspiration data that was used throughout the Fanno Creek watershed are shown in Table 2-3.

Table 2-3: Monthly Potential Evapotranpiration Data Used in the Fanno Creek Mike SHE Models

Month	Millimeter/Hour	Inch/Month
January	0.031	0.908
February	0.051	1.349
March	0.078	2.285
April	0.120	3.402
May	0.175	5.126
June	0.210	5.953
July	0.259	7.586
August	0.233	6.825
September	0.168	4.762
October	0.084	2.460
November	0.039	1.106
December	0.026	0.762

Solar Radiation Data

Finally, monthly solar radiation data (from 1999 through 2001) were obtained from the University of Oregon's Solar Radiation Monitoring Laboratory, Gladstone station (*http://solardat.uoregon.edu/*). A secondary source of solar radiation data was also available for the Fanno Creek watershed in the Tualatin Basin Total Maximum Daily Load report (ODEQ, 2001). More detailed information on solar radiation input is provided in Section 3.3.

2.3 Surface Data

Surface data for the Mike SHE model simulates the behavior of rainfall collection and runoff. Major sources of information were collected from the City and Metro, which provide land use, topographic data and other basic watershed Geographical Information System (GIS) coverages. More detailed information on Mike SHE model development is provided in Section 3.1.

2.4 Subsurface Data

Several sources of information on soil classification and their hydraulic parameters were available to develop model representations of the subsurface. These included the following:

- Natural Resources Conservation Service's (NRCS') soil surveys (NRCS, 1983 & 1985)
- NRCS lab analysis of selected soil types in Multnomah County [illegible]CS, 1985& 2001)
- Borehole data collected by the BES Material Testing Lab and the Oregon Department of Water Resources (BES/Adolfson Associates, 2001), and
- Published literature (Freeze and Cherry, 1979).

Mike SHE Model subsurface data development details are provided in Section 3.1.

2.5 Stormwater Network

Surface water in Fanno Creek watershed is conveyed through a series of stormwater pipes, drainage ditches, culverts, and natural creek channels. The principle data source for storm pipe network is the BES Facilities Inventory and Mapping Data which exist, along with most other forms of spatial data, in the form of a GIS coverage. This data set contains information pertaining to pipe and culvert length; invert elevations, material, and other miscellaneous characteristics. The BES Facilities Inventory Database is being updated on a frequent basis. For purposes of this analysis, a snapshot of the GIS version of this data set was taken in October 2001, and was used as the initial drainage network in the model.

Several additional sources helped supplement the storm pipe data provided by the BES Facilities Inventory database. The 2001 Fanno Creek assessment survey and data collection contains information on major roadway crossings along Fanno Creek main stem, Vermont Creek and Ash Creeks (W&H Pacific, 2001). As-built information obtained from Oregon Department of Transportation (ODOT) helped to fill data gaps on storm pipes along I –5 corridors, especially in Red Rock basin. For storm pipes and culverts that still have data gaps, estimates on size, length, inverts or material were made based on best engineering judgment.

Stormwater ditches and natural creek channels are included based upon topography data and field surveys. The 2001 Fanno Creek field survey also detailed many open channel cross-sections adjacent to the major culverts in the watershed. Cross section data were obtained from the existing 1- and 2-foot contour mapping data, previous BES project channel surveys such as the Fanno Creek Resource Management Plan and the 1999 Public Facilities Plan, and 5-foot Digital Elevation Model (DEM) data to fill-in any voids left by the 2001 survey.

2.6 Flow Gage Monitoring Data

Continuous stream flow data was collected at SW 56th Avenue on Fanno Creek main stem by U.S. Geological Survey (USGS). Figure 2-3 depicts the location of the gage. Fifteen-minute interval continuous flow data are available from this USGS gage (USGS ID#14206900) since 1990. Stream flow data collected at the 56th Avenue gage were very useful for Fanno Creek main stem hydrodynamic model calibration and verification. There is no flow gage on any of the Fanno Creek tributaries.

2.7 Water Quality Monitoring

BES has been monitoring the water quality of Fanno Creek and its tributaries since 1989. BES monitors water quality at eight locations within Fanno Creek watershed (Figure 2-3). Three of eight sites were monitored weekly and the rest were monitored monthly. Water quality analyses included the parameters of interest for this modeling analysis: total phosphorus (TP), total suspended solids (TSS), *Escherichia coli* (E. coli), and water temperature. A summary of the water quality data available for model calibration and verification is presented in Table 2-4.

In addition to the grab samples collected at eight locations listed in Table 2-4, BES also maintains and operates continuous temperature monitoring gages at SW 56th Avenue on Fanno Creek main stem and in Hideaway park on Woods Creek tributary. These two gages record temperature data on an hourly basis for the TMDL period (i.e., May through October) each year since 1998.

BES also collected stormwater composite samples of land-use specific runoff at two sites in Fanno Creek. Results from the three storms sampled at these sites represented runoff from single-family residential and commercial land-uses. Along with similar sites in the Tryon Creek watershed that monitored multi-family residential and transportation runoff, this information was useful in establishing Event Mean Concentrations (EMCs) used in the upland pollutant GIS grid loading model. More information pertaining to the development of this model is presented in Section 3.3.

One of the City's NPDES stormwater monitoring stations is located on Fanno Creek main stem at SW 56th Avenue. Flow-weighted composite samples are collected at this station for three or four storm events every year since 1991. The 56th Avenue NPDES station is designated as a predominant single-family land use station.

Table 2-4. Fanno Creek Watershed Water Quality Monitoring Station Summary

Drainage Basin	Location	Sampling Interval	Start Date	End Date	Source	Comments
Fanno Creek Main Stem	4916 SW 56th Avenue	Weekly[1]	5/30/90	Present	BES	Weekly or monthly grab samples for conventional stormwater pollutants; Continuous temperature monitoring[2].
Fanno Creek Main Stem	3975 SW Beaverton-Hillsdale Highway	Monthly	5/30/90	Present	BES	Monthly grab samples for conventional pollutants
Fanno Creek Main Stem	5415 SW Beaverton-Hillsdale Highway	Storm	9/1/2001	January 2002	BES	Land use (commercial) based storm water sampling
Fanno Creek Main Stem	SW 34th Avenue and SW Martha Terrace	Storm	9/1/2001	January 2002	BES	Land use (residential) based storm water sampling
Fanno Creek Main Stem	6900 SW Beaverton-Hillsdale Highway	Weekly[1]	7/20/93	Present	BES	Weekly or monthly grab samples for conventional stormwater pollutants
Pendleton Creek	6500 SW Boundary Street	Monthly	5/30/90	Present	BES	Monthly grab samples for conventional pollutants
Vermont Creek	SW Dover Lane and Oleson Road	Weekly	5/30/90	Present	BES	Weekly grab samples for conventional pollutants
Woods Creek	SW Oleson Road	Monthly	5/30/90	Present	BES	Monthly grab samples for conventional pollutants
Woods Creek	Hideaway Park	Hourly	1998	Present	BES	Continuous temperature monitoring[2]
North Ash Creek	6315 SW Dolph Drive	Monthly	5/30/90	Present	BES	Monthly grab samples for conventional pollutants
South Ash Creek	10610 SW 63rd Street	Monthly		Present	BES	Monthly grab samples for conventional pollutants

Notes:

1. Grad samples are collected weekly during TMDL period, i.e., May through October. Monthly grab samples are collected during rest of the year.
2. Hourly temperature data collected during TMDL period.

3 Model Development and Assumptions

Once the available information and data were collected, the next step in model development was to process these data so that they can be used by MIKE SHE and MIKE 11. The general approach for developing the models was to extract data, for different model components, from either the City's GIS databases or directly from other survey databases, and import them into some specially formatted data files for direct import into the model. The spatial data was formatted for subsequent importation to MIKE 11 or MIKE SHE using the DHI extension within the ArcView GIS program. Other data files developed as model inputs include time series files used to define temporally varying parameters such as rainfall, evapotranspiration and crop rotation (namely seasonal changes in tree foliage). Detailed information on hydrologic model (MIKE SHE), hydraulic model (MIKE 11) and water quality model (MIKE 11) development are discussed in following subsections.

3.1 Hydrology (MIKE SHE)

In a MIKE SHE model, all precipitation inputs in a watershed are accounted for by: runoff or overland flow in the surface zone, infiltration and groundwater recharge in the unsaturated zone, change in storage and interflow movement through the saturated zone, and evapotranspiration in conjunction with all zones. Through the use of vegetation database and a number of other input parameters, the model also accounts for interception, depression storage and direct evaporation. The hydrological components or modules considered in the Fanno Creek MIKE-SHE models include the following:

- Catchment Definition
- Evapotranspiration
- 2-Dimensional overland flow
- 1-Dimensional unsaturated flow
- 3-Dimensional saturated flow
- 1-Dimensional dynamic hydraulic model for simulating flow in rivers, channels, and other water bodies (MIKE 11) coupled with the saturated flow model to simulate aquifer/river exchange

The setup of the MIKE SHE modules is detailed in sections 3.1.1 through 3.1.5.

3.1.1 Catchment Definition

The basic catchment data comprises catchment or drainage basin delineation, horizontal discretization, surface topography and rainfall data. The initial delineation of drainage basins in Fanno Creek watershed were taken from Metro's RLIS GIS data set that was derived from 10-ft contours from USGS 7.5 minute quadrangle maps. These were further refined using overlays of the City's 2-ft contour and storm drainage layout information. Given the geographical extent of the watersheds relative to the City limits, the Fanno Creek system was broken into six separate catchments or drainage basins, each as a stand-alone model. The modeled drainage basins within the Fanno Creek watershed consist of: the upper portion of Fanno Creek main stem above Scholls Ferry Road, Pendleton Creek, Vermont Creek, Woods Creek, Ash Creek and Red Rock Creek. Each modeled drainage basin was discretized in a network of 100-foot by 100-foot grids.

Digital Elevation Models (DEM), based on the pre-defined 100-ft grid cell definitions, were created for the drainage basins utilizing the City's 2-ft contour data in the GIS. A DEM is a raster (a uniform grid or array of cells) data set that represents the surface of the earth with the value of a particular cell representing the land elevation at the cell's location. The surface topography were stored in a MIKE-SHE matrix file that has the default extension ".T2".

Time-series of rainfall rates are specified in a MIKE SHE T0 file. ".T0" is the default extension for a MIKE SHE time-series file. Time-series may be distributed inside the catchment area using a grid code file where the code value refer to the column number of the specific time-series in the specific time-series file. For Fanno Creek watershed, there are four city rain gages and the rainfall stations were distributed in catchment areas using Thiessen polygons. The grid code assigned to each rain gage can be found in Table 2-2.

3.1.2 Surface Zone and Overland Flow

The surface zone components of the MIKE-SHE model simulate the behavior of rainfall collection and runoff (overland flow) and include parameters for surface topography, surface detention storage and surface runoff friction factors. No initial water depth was specified for the models but a surface storage value of 0.01 m (0.39 in) was globally specified for all the watersheds, representing rainfall that is captured and detained in numerous small depressions and not immediately converted to runoff. The surface storage was initially estimated based on topographic data for the watershed using GIS tool and was later adjusted as a calibration parameter. The surface storage assigned in MIKE-SHE only applies for pervious areas. Runoff from paved areas goes directly into the closest storm network modeled and do not have any storage or infiltration losses. The surface topography was defined under Catchment Data.

The rate of overland sheet flow is a function of the surface's slope and the surface roughness factor "M". The MIKE-SHE model internally computes the slope for each grid cell based upon the elevation of each cell and the elevation of its nearest neighbors. The model uses surface roughness factor "M", which is the inverse of Manning's "n", to account for the friction factor for overland flow. Overland Manning's n values were based on land use types and the values assigned to each land use are given in Table 3-1. Surface roughness factor "M" values were assigned to individual grids by performing a query on the land use and grid table files. If more than one "M" value occurred within a specific grid due to multiple land uses, the roughness factor "M" value that corresponded to the greatest land use area within that grid was assigned to that grid.

Table 3-1: Surface Roughness Factors for Different Land Use Types

Land Use Code	Land Use	Manning's n	Surface Roughness Factor "M"	Manning's n Source
COM	Commercial	0.25	4.0	CH2M HILL (1994)
MFR	Multi Family Residential	0.25	4.0	CH2M HILL (1994)
VAC	Vacant	0.035	28.6	Chow (1959) – short grass
SFR	Single Family Residential	0.25	4.0	CH2M HILL (1994)
TRN	Transportation	0.013	76.9	Chow (1959) – Concrete/Asphalt
FOR	Forest	0.1	10.0	Chow (1959) – heavy stands of timber

IND	Industrial	0.25	4.0	CH2M HILL (1994)
AGR	Agricultural	0.035	28.6	Chow (1959) – short grass

The overland flow component of MIKE-SHE also includes variables for overland-groundwater exchanges and channel flow routing. Full contact within the entire catchments for overland-groundwater exchange were specified in the models, and all the channels flows were routed through the MIKE-SHE-Mike 11 coupling, utilizing Mike 11's more robust computational channel hydraulics. This coupling emulates the natural process where overland sheet flow is eventually concentrated into flow channels and flows out to the basin's outlet.

3.1.3 Unsaturated Zone and Soils

The MIKE SHE model includes modules for simulating surface and groundwater interactions and flux through an unsaturated zone (UZ) to (or from) a groundwater saturated zone. The parameters used for modeling UZ behavior were derived from Natural Resource Conservation Service (NRCS, formerly SCS) soil surveys, limited borehole data in the watershed, land use information and aerial photo data.

Soil data for the Fanno Creek watershed was taken from the NRCS Soil Survey Geographic database. The distribution of soil types in the Fanno Creek watershed is shown in Figure 3-1 and Table 3-2. Soil distribution was obtained by overlaying the grid coverage with NRCS soil cove[illegible] and defined by a soil type T2 file, for each of the drainage basin in the Fanno Creek watershed. After analysis of soil data, an assumption was made that the soils were vertically homogenous for the first 30 inches (0.75 meters). This assumption was verified through random checks of all three NRCS layers (i.e., Multnomah, Washington and Clackamas) throughout the Fanno Creek watershed. In order to prevent the water table from dropping below the unsaturated zone soil column, a Xenocrepts basalt profile was added to each unsaturated zone soil column from 3 to 10 meters below land surface. The water-table elevation provides a boundary condition for the unsaturated zone module and is required for the numerical UZ solution. The vertical discretization was defined by the geological layers whose attributes were defined in the UZ soil property database.

The following parameters are specified in the UZ soil property database for each soil type:

- Soil moisture at saturation (θ_s, unitless)
- Soil moisture at effective saturation (θ_{eff}, unitless)
- Capillary pressure at filed capacity (pF_fc, pF unit)
- Capillary pressure at wilting point (pF_W, pF unit)
- Residual soil moisture content (θ_{res}, unitless)
- Exponent in hydraulic conductivity function (Expo, unitless)
- Saturated hydraulic conductivity (K_s, m/s)

NRCS laboratory data were used to determine UZ soil moisture retention data in the UZ soil database. Hydraulic conductivity for some soil types were obtained from a textbook titled "Groundwater" by Freeze and Cherry (1979). A global value of 10 was assigned to exponent in hydraulic conductivity function. Based on communications with NRCS Portland Office (Bill Owen, February 5, 2000) and information found in the NRCS soil survey in Washington and Clackamas counties, it was decided that soil properties for the following units were similar to those of Cornelius soil type: Kinton, Aloha, Woodburn, Quanatama, Cove, Verboort, Huberly, and Amity. Also Laurelwood, McBee and Bornstedt soil types all fall in a similar particle class family as Xerochrepts (i.e., silt loam/silty clay loam). Thus, their soil moisture retention curves can be taken from those of similar types. Table 3-3 presents input parameters in the UZ soil property database.

Table 3-2: Soil Types in the Fanno Creek Watershed

SCS Soil Unit No.	County	SCS Soil Unit Description	MIKE SHE ID
7 / 13	Multnomah & Washington / Clackamas	Cascade	1
8	Multnomah	Cascade-Urban land complex	2
10 / 11/ 23	Multnomah / Washington / Clackamas	Cornelius	3
11	Multnomah	Cornelius- Urban land complex	4
14 / 16	Multnomah / Washington	Delena silt loam	5
18	Multnomah	Goble-Urban land complex	6
48	Clackamas	Kinton silt loam	7
54	Clackamas	Laurelwood silt loam	8
56	Clackamas	McBee silty clay loam	9
8c	Clackamas	Bornstedt silt loam	10
46 / 92	Washington / Clackamas	Xerochrepts and Haploxerolls	11
93	Clackamas	Xerochrepts rock outcrop	12
21 / 19	Multnomah / Washington	Helvetica silt loam	13
1	Washington	Aloha silt loam	20
45	Washington	Woodburn silt loam	21
37	Washington	Quanatama silt loam	22
13	Washington	Cove silt loam	23
42	Washington	Verboort silty clay loam	24
22	Washington	Huberly silt loam	25
3	Clackamas	Amity silt loam	26

The simplified Richards' equation and automatic classification scheme were used in the MIKE SHE UZ module. A constant water table elevation of 0.7 meters below land surface was assigned to each unsaturated zone column. The 0.7-meter depth corresponds to the inferred elevation of the water table throughout much of the watershed due to the presence of a dense soil horizon with a permeability less than surrounding soil horizons (i.e., fragipan) 0.75 meters below land surface. The uniform depth to the fragipan was determined from a surface interpolation of mapped borehole data.

Table 3-3: Fanno Creek Watershed MIKE SHE Model UZ Soil Property Database

SHE DB Soil Name	**Soil Unit Description/ NRCS ID**	**θ_s Soil moisture at saturation**	**θ_{eff} Soil moisture at effective saturation**	**K_s [m/s] Saturated Hydraulic Conductivity**	**pF_fc Capillary pressure at field capacity**	**pF_W Capillary pressure at wilting point**	**θ_s Residual soil moisture content**
Bornstedt (8c)	Bornstedt silt loam/8c	0.587	0.587	9.17E-06	0.001	2.53	4.18
Cascade (7)	Cascade silt loam/7	0.587	0.587	9.17E-07	0.001	2.53	4.18
Cascade – Urban (8)	Cascade-Urban land complex/8-m	0.587	0.587	9.17^{E}-07	0.001	2.53	4.18
Cascade fragipan	Cascade silt loam, fragipan/7f	0.470	0.470	4.23E-07	0.001	2.53	4.18
Cornelius (10)	Cornelius silt loam/10	0.510	0.510	9.17E-07	0.001	2.53	4.18
Cornelius fragipan	Cornelius silt loam, fragipan/11f	0.615	0.615	4.23E-07	0.001	2.53	4.18
Cornelius-Urban (11)	Cornelius-Urban land complex/11	0.510	0.510	9.17E-07	0.001	2.53	4.18
Delena (14)	Delena silt loam/14	0.472	0.472	2.12E-07	0.001	2.53	4.18
Delena fragipan	Delena silt loam, fragipan/14f	0.401	0.401	7.06E-08	0.001	2.53	4.18
Goble fragipan	Goble, fragipan/18f	0.386	0.386	4.23E-06	0.001	2.53	4.18
Goble-Urban (18)	Goble-Urban land complex/18	0.427	0.427	9.17E-06	0.001	2.53	4.18
Kinton (48)	Kinton silt loam/48	0.510	0.510	9.17E-07	0.001	2.53	4.18
Kinton hardpan	Kinton silt loam, hardpan/48f	0.615	0.615	4.23E-07	0.001	2.53	4.18
Laurelwood (54)	Laurelwood silt loam/54	0.587	0.587	2.12E-07	0.001	2.53	4.18
McBee (56)	McBee silty clay loam/56	0.587	0.587	7.08E-08	0.001	2.53	4.18
Xerochrepts (92)	Xerochrepts and Haploxerolls silt loam/92	0.587	0.587	4.23E-06	0.001	2.53	4.18
Xerochrepts-rock(93)	Xerochrepts rock outcrop/93	0.587	0.587	9.17E-07	0.001	2.53	4.18
Xerochrrepts basalt	Xerochrepts rock outcropping lower basalt layer/93b	0.587	0.587	4.72E-14	0.001	2.53	4.18

The paved area option was selected in the Fanno Creek MIKE SHE UZ module. For each of the six drainage basins in the watershed, a T2 file was created that defined the distribution of paved and unpaved areas. Impervious areas were identified based on street, driveway and rooftop GIS overlays. In Fanno Creek MIKE SHE models, each grid cell is limited to being either 100% or 0% impervious. Cells containing both paved and unpaved areas were defined according to which condition made up the greater percentage of the cell's area. In some cases, the T2 files specifying paved areas were further refined using aerial photo overlays. The impervious area estimated for the six drainage basins in the Fanno Creek watershed based on street, driveway, and rooftop coverage are presented in Table 3-4.

Table 3-4: Impervious Area Estimated in the Fanno Creek Watershed

Drainage Basin	Total Number of Modeled Grids	Number of Paved Grids	Percent Impervious
Fanno Creek Main Stem	9137	2815	30.8%
Pendleton Creek	1179	311	26.4%
Vermont Creek	3355	1129	33.7%
Woods Creek	2936	980	33.4%
Ash Creek	3600	1223	34.3%
Red Rock Creek	3731	1749	46.9%

3.1.4 Saturated Zone

The MIKE SHE model also includes an integrated module for simulating groundwater flows within the saturated zone (SZ) that interacts with the UZ module. The set up of SZ module includes five components: geology, vertical numerical discretization, initial conditions, boundary conditions and definition of degree of drainage. All SZ module input data for the Fanno Creek watershed models was developed based on geotechnical bore logs obtained from the Oregon Water Resources Department and existing BES data sets.

Geology

The geology section of the SZ module is used to define the geologic layers within the model boundary. The model can be divided into a number of layers and each of these layers has assigned hydrologic values. Because of lack of data, a single layer saturated flow model was developed for the Fanno Creek models. The thickness of the saturated zone was based on borehole data located in the Fanno Creek watershed. Spatial distributions of the thickness for the saturated zone were developed and defined in T2 files for the Fanno Creek main stem, Pendleton Creek, Vermont Creek and Woods Creek. Since only limited borehole data existed for Ash Creek and Red Rock Creek basins, a uniform depth of 4.5 meters and 9.8 meters were estimated for Ash Creek and Red Rock Creek respectively based on a review of borehole data within the basins.

Basalt and basalt weathering products comprise the surficial aquifer in the Fanno Creek watershed basins. The horizontal hydraulic conductivity of the saturated flow was set at a constant value of $1\text{x}10^{-6}$ m/s and horizontal to vertical hydraulic conductivity ratio of 10 was used for all the models. The ratio of horizontal to vertical permeability is generally not known for most areas and a value of 10 is recommended by DHI in order to increase the vertical resistance to flow that is generally present in layered aquifer. The hydraulic conductivity used exceeds typical values for fractured and unfractured basalt (10^{-9} to 10^{-14} m/s) and represents a composite of basalt and basalt weathering products. In order to prevent water loss from the saturated zone, a so-called "impermeable bed" is added to the bottom of geologic layer. A very low hydraulic conductivity of $1x10^{-10}$ m/s was assigned for both horizontal and vertical hydraulic conductivities of this impermeable lower boundary layer.

Vertical Discretization

There are different options in defining the vertical discretization in the saturated zone model and the option of geological layers was selected for all basin models. The model default value, i.e., a minimum thickness of 0.5 meters, was chosen for the computational layer for all models.

Initial Conditions

The initial conditions for the saturated zone represent the initial groundwater head elevation in the computational layer. The initial heads for most basin models were developed using an iterative process. The models were first set up to run for specific time period with an initial groundwater elevation of 1 or 2 meters below the ground surface. The depth to phreatic surface at the end of simulation time step at each model grid was retrieved from the model output file and converted into a T2 file. This T2 file was used to represent the initial groundwater heads at the beginning of the same simulation. This process was repeated several times until there was no significant difference in the initial head values from last two model simulation runs.

Boundary Conditions

An impermeable boundary was assigned to all saturated zone boundaries in the Fanno Creek watershed models.

Drainage

Drain flow accounts for the interflow portion of water movement and captures the accumulative runoff effects of higher order tributaries consisting of smaller conduits and drainage ditches that are not explicitly modeled in the MIKE-11 network. Drain flow is estimated in MIKE SHE module through the use of a specified drainage level and drainage time constant. Drain flow is produced when the groundwater level in a grid rises above the grid's drainage level. The drainage level and time constant can either be constant or varied spatially in a MIKE SHE setup. A constant drain elevation of 0.15 meters below land surface and a drainage time constant of $1x10^{-4}$ sec^{-1} were used in all Fanno Creek MIKE SHE models. The values were derived from Fanno Creek main stem flow model calibration results and were used to represent drainage flows in Fanno tributary models as well.

3.1.5 Evapotranspiration

The evapotranspiration (ET) module of MIKE-SHE accounts for direct evaporation from the ground surface and transpiration from vegetation. The ET module uses meteorological and vegetative input data to predict the total evapotranspiration and net rainfall amounts resulting from the processes of:

- Interception of rainfall by the canopy
- Drainage from the canopy

- Evaporation from the canopy surface
- Evaporation from the soil surface
- Uptake of water by plant roots and its transpiration

The ET module interacts with the UZ module, providing net rainfall and evapotranspiration loss rates and using information on soil moisture conditions in the root zone. The ET module is dependent upon rainfall, vegetation root depth, moisture content in the unsaturated zone, and potential evapotranspiration rate. The potential evapotranspiration rate is specified in a time-series file that is derived from evaporation pan data taken from the Portland Airport meteorological station for a 30-year period of record dating from 1961-1990. A uniform value of potential evapotranspiration was used through the Fanno Creek watershed. The monthly potential evapotranspiration values used in MIKE SHE models can be found in Table 2-3.

The Kristensen and Jensen method was used to simulate evapotranspiration in the Fanno Creek MIKE SHE models. The Kristensen and Jensen method is an empirical method to calculate evapotranspiration based on available soil moisture, rainfall, and root zone and vegetation parameters. More information on the Kristensen and Jensen method and its implementation in MIKE SHE can be found in the MIKE SHE Water Movement User Manual.

The annual range of vegetative properties is shown in Table 3-5 and was spatially distributed based on land uses in the Fanno Creek watershed. Leaf area index is the cover of leaves over a unit area and is a dimensionless parameter. Root depth is the maximum depth of the vegetation root mass for a given vegetation type. The leaf area index and root zone depth for the transportation land use type were set to zero since vegetation for this land-use type is negligible. Leaf area index input data were obtained from a paper in the Journal of Arboriculture titled "Structure and Sustainability of Sacramento's Urban Forest" by McPherson (1998). Initial root depth data were obtained from the City of Portland's City Forester, who indicated that trees typically found in the Fanno-Tryon watersheds have moisture-absorbing roots extending 18 to 24 inches below the surface. Final root depths were obtained through model calibration efforts and the assumption they could not extend into any fragipan/hardpan layer in the soil, if applicable.

Table 3-5: Vegetation parameters used in the Fanno Creek MIKE SHE model

Land Use	Minimum Leaf Area Index	Maximum Leaf Area Index	Minimum Root Depth (m)	Maximum Root Depth (m)	Maximum Time	Kc
Urban	2	3	0.2	0.6	April-August	0.75
MFR	2	3	0.2	0.6	April-August	0.75
Vacant	1	5	0.2	1	March-May	0.75
SFR	2	3	0.2	0.6	April-August	0.75
Transportation	0	0	0	0	NA	0.75
Forest	3	7	0.4	1.2	March-June	0.75

NA – not applicable

Since the monthly potential evapotranspiration values were based on pan measurements, a coefficient Kc with a value of 0.75 to adjust estimated actual evaporation was used for all land use types. Pan evaporation is typically greater than the actual evaporation that would occur from the same water surface area in a very large lake (i.e., free surface evaporation). MIKE SHE required that potential evaporation from a given vegetation type be provided and uses the Kc parameter to scale the ET times series. A Kc value of 0.75 is a value that is commonly used when site-specific information is not available.

Seasonal variations (such as leaf-on and leaf-off conditions) in ET module for different vegetation types are represented by variations in the leaf area index and root depth. Seasonal variations of the parameters were obtained based on DHI's recommen[illegible]ons.

Other empirical parameters used to estimate plant transpiration in Kristensen and Jensen Method include the following:

- C_{int} = 0.05 meters, C_{int} is the depth of the interception storage for the vegetation type;
- C_1= 0.31, C_1 is a plant dependent empirical input parameter;
- C_2= 0.2, C_2 is soil parameter that controls the rate water can be extracted from the soil;
- C_3= 20, C_3 is an empirical input parameter that may depend on soil type and root density;
- AROOT =1, AROOT is a parameter that determines the vertical distribution of the root mass over the specified root depth.

More information on the above parameters can be found in the MIKE SHE Water Movement User Manual. The evapotranpiration parameters were not varied between the different land uses because land use specific information was not available.

3.2 Hydraulics

MIKE 11 is a standalone 1-D hydrodynamic model that includes water quality modeling capability. The model works in a coupled manner with the hydrology model MIKE SHE, and is used to route runoff flows, through networked systems of open channels (natural or artificial channels, and ditches) or closed conduits (pipes and culverts), and perform the in-stream contaminant transport and water quality modeling. MIKE 11 hydrodynamic (HD) module uses an implicit, finite difference scheme to solve the vertically integrated equations of conservation of continuity and momentum or the Saint Venant equations. The module can model sub-critical flow as well as supercritical flow conditions.

The MIKE 11 HD module set up is different from the traditional link-node type model (such as SWMM or XP-SWMM) or cross-section element model (such as HEC-2 or HEC-RAS). MIKE 11 HD module consists of points that are located at longitudinal stations called chainages. A chainage can be either a Q (discharge) point or an h (water level) point. Q points and h points are alternating computational elements that are automatically generated based on user requirements. Generally Q points are placed midway between neighboring h-points and at structures (i.e., culverts and weirs), while h points are located at channel cross sections, or at equidistant intervals between two neighboring cross sections if the distance between cross sections is greater than a maximum spacing required for numerical stability. Further details on how MIKE 11 solves the Saint Venant equations can be found in the MIKE 11 Reference Manual.

3.2.1 Flow Network

The flow network of the Fanno Creek MIKE 11 models consists of branches and chainages. The criteria applied for determining the extent of the modeled flow network was that 12-inch and larger pipes and culverts, and downstream channels, were modeled. This assumption produced typically second and some third order branches and occasional looped drainage networks within the models. The modeled points, or chainages, representing either h-points or Q-points along any particular branch, are sequentially numbered by their longitudinal distances from the uppermost point, in feet, and ending at the branch's outfall or confluence with a receiving stream. Usually "0" was assigned as the chainage number for the most upstream point on a main stem or a branch. All conveyance elements included in the model, whether it is an open channel, pipe, culvert or manhole, is identified by its branch and chainage. The naming convention used for the branches is that there is a prefix given for the stream's main stem or basin name followed by a chainage number of where it connected to the downstream branch. A higher order stream's name would be followed by second number corresponding the higher order stream's identification. For example: a small branch draining into tributary (at chainage 526) of the main stem of Fanno Creek (at chainage 3065) would have the identification of "FANNO_3065_526". There are some exceptions in Fanno Creek main stem model. For Fanno tributaries that already have common names, such as Columbia Creek and Ivey Creek, the above naming conventions were not imposed and their common name were kept in the Fanno Creek main stem model.

Although the Fanno Creek watershed MIKE 11 models were developed based on the criteria to include all storm pipes and culverts that are 12-inch or larger, a number of third order tributaries that contain 12-inch or larger storm pipes or culverts, were ignored in basin models. Also omitted in basin models were a number of 12-inch or larger storm pipes or culverts, especially private driveway culverts, that are located on modeled branches. The MIKE 11 basin models represent simplified storm drainage systems than the real world systems due to the following reasons:

Data Limitation – Although the BES Facilities Inventory Database and supplementary field survey data and data from other agencies provided significant detail of the storm drainage network in the watershed, detailed information for certain storm pipes and roadway crossings were still incomplete. Therefore, some of these storm pipes and culverts were not included in the model due to lack of critical information such as pipe size or inverts.

- Computational Time – The number of branches were reduced to decrease the number of calculation points to ensure reasonable run times;
- Numerical Model Stability – Although modeling of situations where a number of reaches go dry during the simulation is possible since MIKE 11 substitutes the momentum equation with a zero flow equation for very low flow situations, the switch from the momentum equation to the zero flow equation is done gradually and depends on the water depth. Thus to ensure that the model is stable for low flow situations, the time step should be chosen small enough so that the change from dry riverbed to full flow is suitably resolved. Because of the above, having a number of small branches that tend to go dry during low flow conditions does not enhance the stability of a model set up if a reasonable run time step is desired.
- Calibration Issue – Since the data available for water quantity calibration consists of one discharge measurement throughout the whole watershed, the complexity of the model should be consistent with the amount and quality of data available for setting-up and calibration the model. Calibration was carried out with objective of tuning the parameters of a simple model so that the model can be used as a regional model to provide appropriate boundary conditions for more refined small-scale models.

Figures 3-2 through 3-7 illustrate the modeled network for Fanno Creek main stem, Pendleton Creek, Vermont Creek, Woods Creek, North and South Ask Creeks, and Red Rock Creek, respectively.

3.2.2 Open Channels

The cross sections in the MIKE 11 model most often represent open channels describing natural streams or drainage ditches, but they are also used to define closed storm pipes. In the initial model set up, a number of closed cross sections were used to describe sections of drainage network consisting of closed conduits. Even though MIKE 11 facilitates implementing closed cross sections through the cross section database it was recommended by DHI for most of modeled closed pipes to use culvert description instead. The reason for this is that a culvert description uses the energy equation locally to model the flow whereas the flow through a closed conduit described by the use of cross sections is solved by the use of momentum equation. The momentum equation description does not take into account the local energy losses caused by contraction or expansion due to changes in storm pipe size and existence of manholes. To make sure that these local losses are incorporated, DHI recommended using culvert description as opposed to closed cross sections. The other benefit of using culvert description instead of closed cross section is related to the coupling between MIKE 11 and MIKE SHE. Flow from MIKE SHE is unable to get into closed cross sections defined in MIKE 11.

Cross sections were defined for all selected locations on modeled streams and ditches. Additional cross sections were placed in close proximity (i.e., 0.5-3 m) upstream of modeled culverts and storm pipes to represent immediate upstream condition for culverts and manholes for pipes. This was done also because all structural elements in a MIKE 11 model, like culverts, are only solved for flow and there is a need to estimate the water depth at the inlets of all culverts. The manholes between storm pipes were represented by short, narrow and rectangular cross sections. There is a requirement by the model to have cross sections located at both upstream and downstream ends of a structure.

The cross sections used in the MIKE 11 models to define creeks and ditches were obtained from a combination of surveyed data and interpreted topographic data. The 2001 Fanno Creek field survey data collected by W&H Pacific were used to develop cross section input data in the model where they were available. For certain locations on creeks or streams where no such data exist, the city’s GIS data containing 2- foot and 10-foot contours were used to interpret stream cross sectional data. In some instances, invert data from field survey or BES stormwater database were not compatible with the cross section data developed based on topographic information. Under such circumstances, adjustments to interpreted cross section data were made based on best engineering judgment. When cross sections for modeled shallow ditches were unable to derive from mapped contour data, a uniform trapezoidal shape channel section was assumed in the basin models.

Due to the lack of comprehensive stream field surveys, specific values for channel roughness were not assigned at all locations but a global value of 0.05 was used to represent the overall channel sections containing both the main channel and over-bank. The channel roughness coefficient of 0.05 usually represents streams that have trees and brush along banks and have gravel and cobbles in channel bottom (Chow, 1959). In some cases, the overall channel roughness was multiplied by a scalar in channel sections with known characteristics.

Detention facilities were defined in the model by a series of wide cross sections followed by a definition of a weir or culvert to represent the outlet structure. The use of wide cross sections in the model set up to account for storage generally satisfies the water balance of the system.

3.2.3 Culvert/Pipe Data and Other Hydraulic Structures

A majority of storm pipe and roadway crossing input in the Fanno Creek MIKE 11 models were based on the BES Hansen Facility Management System and related GIS data sources. The BES Hansen database contains information pertaining to pipe and culvert length, invert elevations, material, and other miscellaneous characteristics. The BES Facilities Inventory Database is being updated on a frequent basis. For purposes of this analysis, a snapshot of the GIS version of this data set was taken in October 2001, and was used as the initial drainage network in the model. Several additional sources helped supplement the storm pipe data provided by the BES Facilities Inventory database. The 2001 Fanno Creek assessment survey control and data collection contains information on major roadway crossings along Fanno Creek main stem, Vermont Creek and Ash

Creeks. As-built information obtained from ODOT helped filling data gaps on storm pipes along I –5 corridors, especially in Red Rock basin. For storm pipes and culverts that still have data gaps, estimates on size, length, inverts or material were made based on best engineering adjustment. For example, in the cases were pipe/culvert-length data was missing in the attribute database, the pipe length was measured directly from the CAD and GIS maps. Missing invert information was usually filled by subtracting estimated soil cover from ground level at upstream or downstream ends of a pipe segment. Soil cover was usually estimated based on nearby storm pipe information. In cases where there is no pipe information available for nearby area, a 5-foot cover was assumed to apply.

As described in an earlier section, closed conduits (i.e., storm pipes) in Fanno Creek watershed were modeled as culverts in all basin models. The geometry of the culverts was directly based on the storm pipe data. Since the culvert description in MIKE 11 does not allow varying geometry through a culvert, for a culvert to represent more than one storm pipe segments with different diameter, the size of the culvert was determined based on a length weighted average of storm pipe diameter.

For Fanno Creek main stem and all the tributaries, roadway culverts usually cause constrains to channel flow capacity due to streams' sleep slope. In many cases, especially during high flow events, these constrains may result in a build up of the water level upstream of a culvert. This build up would continue until the water level reaches the invert level of an overflow structure. The overflow structure in this case is usually a road or other crossing such as a bridge deck. Since culverts in Fanno Creek watershed sometimes cause constrains in channel capacity, overflow structures have been implemented to facilitate the flow passing under high flow conditions in the MIKE 11 basin models. Note that roadway crossing weirs were only defined for locations where the peak upstream water surface elevation for the modeled design storm exceed the lowest roadway crown elevation at the stream crossing. More detailed discussion on capacity constrains caused by culverts is presented in Fanno/Tryon Watershed Technical Memorandum titled "Fanno Creek Main Stem Hydrodynamic Model Calibration and Verification".

Weirs were also added to the models for the purposes of maintaining numeric stability of hydraulic computations. Like many other numeric models, MIKE 11 is prone to numerical instability problems when modeling steep or sudden changes in gradient in channel geometry. On steep gradients or slopes with sudden grade changes, the flow regime becomes supercritical or is no longer characterized as gradually varying open channel flow. This condition causes numeric instability within the model and can be avoided by the use of structures. In the Fanno Creek MIKE 11 model setup, broad-crested weirs were used for ensuring the proper description of critical flow caused by steep slopes. A broad-created weir was inserted at the cross section of concern and was assigned with the same geometry as the channel section at that particular location.

3.2.4 Detention ponds & Other Pollutant Reduction Facilities

There are a number of in-line detention ponds in Fanno Creek watershed. The MIKE model does not contain special structure feature for detention ponds, however, such facilities can be modeled using cross section data combined with culverts or weirs. In the case of the detention facilities in the Fanno-Tryon systems that were defined within the models, multiple wide cross sections were used to the define the storage capacity of the facility while culverts and weirs were used to define the outlet flow control structures.

3.2.5 Energy Losses and Other Modeling Parameters

Manning's 'n' roughness and inlet head loss coefficients were defined for all culvert elements including culverts that were being substituted for pipes. Typical Manning's n-values for culverts and pipes were 0.013 for concrete storm pipes (CSP), 0.022 for corrugated metal pipes (CMP) and 0.011 for pipes made from plastics. A global entrance head loss coefficient of 0.5 and exit loss of 1 was assigned for all culverts. Since majority piped sections were straight and most open channels are characterized as having gradual lateral changes in directions, no head loss coefficients were specified for bends. The head loss associated with culverts in MIKE 11 model is strongly dominated by sudden expansions and contractions such as experienced at the inlet and outlet of a culvert. The simulated head loss also depends on the head loss coefficients specified.

3.3 Water Quality (Mike 11 / Mike Load)

3.3.1 Pollutants of Interest (Temp, TSS, TP, E. coli)

3.3.2 Pollutant loading (MIKE LOAD, EMCs, decay rates, etc.)

3.3.3 In-stream hydrodynamics (MIKE 11, parameter assumptions)

4 Hydrodynamic Model Calibration, Verification and Results

4.1 Overview of Hydrodynamic Model Calibration and Verification

Calibration is a test of the model with known input and output information that is used to adjust or estimate factors for which data are not available. Hydrodynamic model calibration involves selecting individual storm events with matching rainfall and stream flow data and adjusting the model hydrologic and hydraulic inputs to reproduce the measured flow from the measured rainfall data. Model verification is in reality an extension of the calibration process. Its purpose is to assure that the calibrated model properly assesses all the variables and conditions that can affect model results. Although there are several approaches to validating a model, the most effective procedures is to use only a portion of the available record of observation data for calibration; once the final model inputs are developed through calibration, simulation is performed for the remaining period of observed data and goodness-of-fit between recorded and simulated data is reassessed.

Stream flow data are available for Fanno Creek main stem at 56th Avenue. USGS started to collect continuous stream flow data in 15-minute interval at the 56th Avenue in 1990. Continuous stream flow data were not available for any of the five tributary basin models. No groundwater time series data were available for the Fanno Creek watershed.

Since groundwater data were not available, the Fanno Creek main stem MIKE SHE and MIKE 11 model was only calibrated with surface discharge data. The following steps were used in calibration of the main stem MIKE SHE model:

1. Adjust vegetation and evapotranspiration parameters until simulated evapotranspiration is within reasonable ranges.
2. Adjust impervious areas to make changes in the proportion of runoff and infiltration.
3. Adjust overland roughness factor M values (reciprocal of Manning’s n values) to increase or decrease the timing of hydrograph peaks.
4. Adjust drainage elevations and time constants to control the height of peak events and the recession limb of hydrographs.

Io addition to changes made in the MIKE SHE model, the following adjustments were made in the main stem MIKE 11 model:

1. Channel Manning’s M values (reciprocal of Manning’s n values) were adjusted to increase or decrease residence times in channels.

2. Overflow structures were added in the model to represent roadway crossing and facilitate the flow passing over roadway during high flow events.

Both qualitative and quantitative measures were used to calibrate the Fanno Creek main stem hydrodynamic model based on stream flow data. These measures include the following:

- Water budget evaluation
- Qualitative comparison (i.e., graphical comparison) of simulated and observed hydrographs
- Cumulative flow volume comparison
- Statistical tests, including error statistics for peak and peak time, and correlation tests for peak flow

A literature review on model calibration and acceptance criteria was also performed to help further quantify the performance and robustness of the Fanno Creek main stem hydrodynamic model. The outcome from the review is presented in 4.2.1.

In addition to the comparison between the modeled flow and measured flow data under real storm events, modeled results from various recurrence interval design storm events were also compared with the estimated flow based on the USGS empirical equations and the 56th Avenue gage flood-frequency analysis by USGS. These additional checks are valuable due to the following reasons:

1. One of the watershed modeling goals is to evaluate the conveyance capacity of the existing stormwater drainage system and identify expected conveyance capacity problems for roadway crossings and stormwater pipes in the watershed. To achieve this goal, different recurrence interval design storm events, including the 2-year, 10-year, 25-year and 100-year design storms, were run through the Fanno Creek main stem hydrodynamic model to evaluate the capacity of existing drainage system.

2. The design storms are not real storm events. The design storm distribution is based on the 24-hour SCS Type I-A distribution that applies to the Pacific Northwest. The total rainfall depth for the design storm was obtained from the Rainfall Intensity, Duration, Frequency Curves (IDF Curves) from the City of Portland's Sewer Design Manual.

3. Since the design storms are not real storm events, no observed flow data is available for calibration. Therefore, the peak discharges for Fanno Creek main stem at the 56th Avenue obtained from the MIKE 11 model were compared with the results obtained from U.S. Geological Survey (USGS) empirical equations, flood-frequency analysis of the observed flows at 56th Avenue. The comparisons were particularly helpful for higher recurrence interval storm (i.e., 100-year) as most of the calibration model runs that DHI performed occurred during regular storm events.

More information on the USGS equation and 56th Avenue gage flow flood-frequency analysis are presented in section 4.2.1.

Since continuous measured flow data were only available in Fanno Creek main stem and the main stem model was calibrated using stream flow data at the 56th Avenue gage, most of the main stem parameters were assumed to be valid for the ungaged Pendleton Creek, Vermont Creek, Woods Creek, North and South Ash Creek, and Redrock Creek. Although there are some variations in overall hydrological configurations between Fanno Creek main stem basin and the rest tributary basins, it was assumed that the most of the calibrated hydrologic parameters have similar values. A comparison of runoff depth, volume and runoff coefficient based on different design storms from all drainage basins was performed and results can be found in section 4.2.2.

4.2 Flow Calibration Results/Issues

4.2.1 Fanno Creek Main Stem Hydrodynamic Model Calibration

The period from October 13, 1996 to December 14, 1996 was selected as the calibration period for the Fanno Creek main stem hydrodynamic model. The specific period is a reasonable time for calibration of the main stem hydrodynamic model since it contains periods of extended discharge. In addition to the calibration period, the model was also run for the period from December 2001 to February 2002 for verification purpose

Figures 4-1 through 4-4 present the observed and simulated flows for Fanno Creek main stem at 56th Avenue for the calibration and verification periods. Table 4-1 shows model statistical test results for the calibration and verification periods.

Table 4-1: Statistical Test Results for Fanno Creek Main Stem Hydrodynamic Model

Criteria	November 1996 Event	January 2002 Event	February 2002 Event	Average for Three Events
Daily Correlation Coefficient	0.975 [1]	0.956	0.97	0.967
Peak Error	-42%	-43%	-50%	-45%
Peak Time Error (hrs)	2.2	0.35	0.1	0.9
Cumulative Volume Error	2%[2]	23%	-3%	9%

Notes:

1. Daily correlation coefficient calculated for period from October 13 to December 14,1996, excluding the periods of November 9-11 and November 20-23 where the observed flow data are incomplete or do not match with precipitation data.
2. Cumulative volume error calculated for the period from October 13 to December 14, 1996, excluding data from periods from November 9 to 11 where the observed flow do not match with precipitation data.

As shown in Figures 4-1 through 4-4, the Fanno Creek main stem model is able to capture the variation in the observed record, although it occasionally underestimates the larger peaks. The good fits shown in these figures are also reflected in the correlation test results in Table 4-1 where the daily average flow correlation coefficients are above 0.95 for the verification periods. In general, the total runoff volumes of the simulated and observed data match well, and the average cumulative volume error is below 10% (Table 4-1). Except for the peak error, the Fanno Creek main stem hydrodynamic model is capable of adequately simulating most hydraulic components of the watershed during the calibration and verification periods.

A literature review on model calibration and acceptance criteria was performed to help quantify the performance of the Fanno Creek main stem hydrodynamic model. Model performance expectations developed in several reports published by the Environmental Protection Agency (EPA) are provided below for comparison purpose. A Quality Assurance Project Plan developed for an EIS for the proposed Nicollet Mine in northern Wisconsin used the HSPF (Hydrological Simulation Program- Fortran) program and specified the following acceptability criteria:

“The targets for acceptable calibration and verification of monthly flows are a correlation coefficient greater than 0.85 and the coefficient of model-fit efficiency greater than 0.8.” (EPA, 1998)

Table 4.2 lists general calibration/validation tolerance or targets that have been provided to model users as part of HSPF training workshops over the past 10 years. The values in the table attempt to provide some general guidance, in terms of the percentage mean errors, or differences between simulated and observed values, so that users can gage what level of agreement or accuracy may be expected from the model application.

Table 4-2: General Calibration/Validation Targets or Tolerances for HSPF Application (Donigian, 2002)

	Very Good	**Good**	**Fair**
Hydrology/Flow	<10	10 - 15	15 - 25
Sediment	<20	20 - 30	30 - 45
Water Temperature	<7	8 - 12	13 - 18
Water Quality/Nutrients	<15	15 - 25	25 - 35

Notes:
1. Percent variance (+/-) between observed and simulated values.
2. Relevant to monthly and annual values; storm peaks may differ more.
3. Dependent upon: quality and detail of input and calibration data; purpose of model application; availability of alternative assessment procedures; and resource availability.

For the Fanno Creek main stem hydrodynamic model, although there is a considerable discrepancy in terms of instantaneous peak comparison, the averages parameters seems to be well within the tolerance ranges as shown in Table 4-2. As indicated in Table 4-1, the average daily flow showed a correlation coefficient of more than 0.95 for all storm events during the verification periods. Also the cumulative runoff volume has an average error of 9%. Based on the literature review, and the correlation of model results with monthly or annual stream gage values and not instantaneous ones, the Fanno Creek main stem hydrodynamic model is within the acceptance criteria listed in Table 4-2.

Factors that may contribute to the relatively large discrepancies between the simulated and observed instantaneous peak flows include the following:

- Uncertainties in the observed data – There are several uncertainties in stream flow records provided by the USGS: First, due to the channel and stream condition, the USGS flow data collected at the 56th Ave were rated fair to poor in terms of the accuracy during the verification periods by USGS. A fair rating is defined as such that 95% of daily discharge are within 15% percentage of the true value. For a poor rating, the error percentage is higher than 15%. Secondly, a continuous record of stage is collected at the 56th Avenue gage and the corresponding discharges are obtained from a stage-discharge rating table developed by USGS based on a series of discharge measurements made at various stages at the gage location. Since discharge measurements are not collected continuously, the rating table developed generally has more calibration data in the “normal” flow zones as compared to the high and low flow zones. It is a normal practice that the stage-discharge rating curve or table will have to be extrapolated beyond the “fitted” or “calibrated” range to obtain a high or low flow value. Based on BES’s conversation with USGS staff, a measurement threshold for high flows at the 56th Avenue gage is usually around 400 cfs. Discharge estimates for stage records corresponding to flows greater than 400 cfs are generally obtained by linear extrapolations of the established USGS stage-discharge rating curve. Lastly, the peak flow comparisons were based on the 15-mintute interval flow data. The 15-minute flow data provided by USGS are provisional and not usually QA/QC checked.

- Uncertainties in the precipitation data –Some of the discrepancies between simulated and observed flow may be the result of inaccuracies in the distribution of rainfall data used in the model. Rainfall in the area is likely affected by the hilly nature of the area. As such, the temporal and spatial distribution of the rainfall used in the model, which is sensitive to peak flow, cannot be fully defined by the three rain gages currently used to define rainfall in the Fanno Creek watershed. An example of possible rainfall uncertainties can be found in Figure 4-1. As shown in Figure 4-1, there is virtually no precipitation observed during the period of November 8 to 11. However, the measured flow data shown in the figure during the same period indicates that there was likely a very localized but relatively intense storm event occurring during the period somewhere upstream of the 56th Avenue gage. If the flow surge observed in the flow data was not caused by sources other than precipitation induced runoff, the discrepancies in the rainfall and measured flow response may be responsible for discrepancies found between the simulated and observed discharge at the 56th Avenue gage.

- Uncertainties in the model input data – Although the model input was based on the best available information and substantial efforts have been taken to improve the quality of the input data of the model, there are still some uncertainties involved in some model input data. For example, highly resolved soil and groundwater information such as the spatial and temporal distribution of groundwater tables is not available. Certain aspects of the flow modeling are sensitive to this type of information, which is not available at this time to better refine this aspect of flow behavior. Also, although efforts were made to survey many key flow components of the watershed, time and budget did not allow for all flow components to be surveyed. As such, survey information is not always available for all modeled open channel sections and roadway crossings. These uncertainties and data gaps translate directly into uncertainties of the simulated flow calculated by the Fanno Creek main stem MIKE SHE and MIKE 11 models.

In addition to calibration using real stream flow data, the modeled peak flows at the 56th Avenue from different design storms were also compared with peak flows estimated using USGS empirical equations and flood-frequency analysis for measured flow data collected at the 56th Avenue. The USGS regression equations were developed by Laenen (1983) for use in the Willamette Valley, Oregon. The flood-frequency analysis was performed using the USGS's water resources application software "PEAKFQ" and annual peak flows collected at the 56th Avenue gage from 1974 to 1978 and from 1991 to 2001. PEAKFQ can be downloaded from the USGS website at: *http://water.usgs.gov/software/surface_water.html*

Table 4-3 presents the results of the comparisons between modeled flow and estimated flow from USGS equations and PEAKFQ. As shown in Table 4-3, the peak flows obtained from the MIKE 11 model are compatible with the peak flows estimated based on the USGS equations. The modeled peak flows are also within the 95% confidence limits from the flood-frequency analysis.

Table 4-3: Design Peak Flow Comparisons for Fanno Creek Main Stem at the 56th Avenue

Peak Flow (cfs)	Fanno Creek Main Stem MIKE 11 Results	USGS Equation	Flood-Frequency Analysis		
			Expected Probability Estimate	95% Confidence Limits	
				Lower	Upper
2-yr	167	205	191	148	244
10-yr	347	338	420	318	645
25-yr	492	471	577	416	990
100-yr	669	630	867	580	1741

4.2.2 Fanno Creek Tributary Hydrodynamic Model Calibration

No stream flow data was available to calibrate the Fanno Creek tributary hydrodynamic models. Since the main stem model was calibrated using stream flow data collected at the 56th Avenue USGS gage, most of the main stem model parameters were assumed to be applicable to Fanno tributary models including Pendleton Creek, Vermont Creek, Woods Creek, North and South Ash Creek, and Red Rock Creek.

The lack of stream flow data in tributary basins implied that tributary models could only be “calibrated” using an indirect method. The method for calibrating ungaged basins consisted of extracting model results for design storms from the calibrated main stem model and comparing with those results obtained from tributary models. The compared model outputs include runoff depth, volume, and runoff coefficients for the matching design storm. Design storm results were selected in the comparison since there is no variability in the total rainfall amount and distribution for design storms between main stem and tributaries. If real storm events were used in calibration, then the differences in model results caused by temporal and special variation in rainfall input would have to be considered.

Table 4-4 presents design flow comparisons between Fanno Creek main stem and its tributaries. As shown in the table, although there are variations in model results in terms of unit runoff per acre and runoff coefficient among the basin models, the outputs from tributary models are compatible with matching results from the main stem model. Most deviations in model results are reasonable and explainable. For example, the runoff coefficients for all design storms in Pendleton Creek are larger than those in the main stem. A quick review of hydrologic and hydraulic configuration of the main stem basin and Pendleton Creek basin indicates that the differences in runoff coefficients is mainly caused by the difference in basin size and layout of the stormwater collection system. The overall time of concentration for runoff in the Pendleton Creek is much smaller compared to that in main stem basin, implying that stormwater would get into the creek quicker in Pendleton Creek than in the main stem. If there is no significant difference in other hydrologic parameters (such as soil condition, slopes, impervious percentage, etc), the runoff coefficients and unit runoff per acre in the Pendleton Creek should have higher values than those in the main stem basin for the same storm events.

Table 4-4: Design Flow Comparisons Among Fanno Creek Basin Hydrodynamic Models

			Fanno Creek Gage at 56th Ave. (USGS #14206900) Basin Area = 1,517 acres				
Storm Event	Date	Rainfall (inches)	Peak Flow (cfs)	Rainfall Volume (10^6 gallon)	Flow Volume (10^6 gallon)	Flow Vol. Per Acre (10^6g/ac)	Runoff Coefficient
2-yr	12/1/- 12/2/96	2.53	167	104.2	28.95	0.019	0.28
10-yr	12/1/- 12/2/96	3.36	347	138.4	49.9	0.033	0.36
25-yr	12/1/- 12/2/96	3.84	492	158.2	64.0	0.042	0.40
100-yr	12/1/- 12/2/96	4.49	720	185.0	98.8	0.065	0.53
			Pendleton Creek **Modeled Basin Area = 240 acres**				
2-yr	12/1/- 12/2/96	2.53	23.8	16.9	10.4	0.043	0.62?
10-yr	12/1/- 12/2/96	3.36	41.7	22.4	14.2	0.059	0.63?
25-yr	12/1/- 12/2/96	3.84	53.5	25.6	16.8	0.070	0.65?
100-yr	12/1/- 12/2/96	4.49	70.3	29.9	20.4	0.085	0.68?
			Vermont Creek **Modeled Basin Area = 785 acres**				
2-yr	12/1/- 12/2/96	2.53	59.0	53.9	18.5	0.024	0.34
10-yr	12/1/- 12/2/96	3.36	100.0	71.6	29.3	0.037	0.41
25-yr	12/1/- 12/2/96	3.84	128.0	81.9	36.4	0.046	0.44
100-yr	12/1/- 12/2/96	4.49	183.0	95.7	53.5	0.068	0.56
			Woods Creek **WQ Monitored Drainage Area = 613 acres**				
2-yr	12/1/- 12/2/96	2.53	73.0	42.1	18.9	0.031	0.45
10-yr	12/1/- 12/2/96	3.36	129.0	55.9	26.5	0.043	0.47
25-yr	12/1/- 12/2/96	3.84	154.0	63.9	31.4	0.051	0.49
100-yr	12/1/- 12/2/96	4.49	188.0	74.7	43.4	0.071	0.58
			North Ash Creek **WQ Monitored Drainage Area = 266 acres**				
2-yr	12/1/- 12/2/96	2.53	44.0	18.3	6.1	0.023	0.33
10-yr	12/1/- 12/2/96	3.36	83.0	24.3	9.5	0.036	0.39
25-yr	12/1/- 12/2/96	3.84	96.0	27.7	11.8	0.044	0.42
100-yr	12/1/- 12/2/96	4.49	111.0	32.4	16.7	0.063	0.51
			South Ash Creek **WQ Monitored Drainage Area = 188 acres**				
2-yr	12/1/- 12/2/96	2.53	31.4	12.9	5.5	0.029	0.43
10-yr	12/1/- 12/2/96	3.36	54.0	17.2	8.5	0.045	0.50
25-yr	12/1/- 12/2/96	3.84	62.0	19.6	10.4	0.055	0.53
100-yr	12/1/- 12/2/96	4.49	70.0	22.9	14.7	0.078	0.64
			Red Rock Creek **Modeled Basin Area = 811 acres**				
2-yr	12/1/- 12/2/96	2.53	116.4	55.5	27.4	0.034	0.49
10-yr	12/1/- 12/2/96	3.36	171.8	74.0	39.0	0.048	0.53
25-yr	12/1/- 12/2/96	3.84	197.8	84.6	46.0	0.057	0.54
100-yr	12/1/- 12/2/96	4.49	225.8	98.8	54.7	0.067	0.55

4.3 Fanno Creek Hydrodynamic Model Results for Design Storms

The calibrated MIKE SHE and MIKE 11 models were used to evaluate the capacity of the existing drainage system to safely convey stormwater under existing land use conditions. Different recurrence interval design storms including the 2-year, 10-year, 25-year and 100-year storms, were run through the Fanno Creek main stem and tributary models to identify deficiencies in existing drainage systems. The flow and water level results for modeled Fanno Creek main stem and tributaries can be found in hydraulic summary tables in the Appendix. The conveyance capacity assessments of stormwater facilities in the Fanno Creek watershed were based on the criteria contained in the City of Portland's Sewer Design Manual (BES, 1991) as copied below:

"All storm drainage facilities shall be designed to pass a 10-year storm without surcharge. Surcharging during a 25-year storm is permitted with a storm only system. Surcharged pipes and bankfull channels are accepted for conveyance of the 100-year design storm provided that several health and safety conditions are met. The allowable headwater depth for culverts should be as great as practical, as long as it does not compromise safety, flood plain regulations, environmental considerations or property rights."

The deficiencies in conveyance capacity of the drainage system were identified for major roadway culverts but not for open channel segments between the roadway crossings. The models' capability to accurately evaluate the conveyance capacity of the stream channels was limited by lacking detailed survey information on channel cross-sections and associated floodplains. The existing field survey contains information on some road crossings and stream channels in the watershed that were relatively easily accessible. The extent of floodplains or the finished floor elevations of structures in or near the floodplain were generally not surveyed. Typical cross-sections for the stream channel and floodplain topography in areas other than those visited by the surveyors were derived from digital topography developed from aerial photographs. Maps derived from aerial photography are typically not sufficiently detailed to provide accurate topography for narrow stream channels due to heavy vegetation along stream corridors and the complex shape of stream channels.

Based on the City's Sewer Design Manual, a deficiency was identified at a road crossing when the water level reached the roadway surface for culverts. In addition to roadway overflow, surcharge problems were also identified for all modeled culverts and storm pipes. While peak flow rates and maximum surface water were reported for open channel segments, an evaluation of deficiencies was not completed. The likelihood or extent of property damage that may occur along the stream segments for each recurrence interval design storm were not evaluated due to lack of data on the elevation of buildings and channel geometry.

The model results for Fanno Creek main stem, Pendleton Creek, Vermont Creek, Woods Creek, Ash Creek and Red Rock Creek are summarized in Tables A-1 through A-6 in the Appendix A. Tables A-1 through A-6 include peak flows, maximum water surface elevations, and maximum velocity for the relevant design storm as well as hydraulic information for modeled channels and structures. The last two columns in the table indicate which roadway culverts are expected to be surcharged and/or deficient and when (i.e., under which design storm). The column titled "Note" contains information on the source of the input data (i.e., diameter, length, inverts, material, etc.) for the modeled culverts or storm pipes. The surcharged storm pipes and culverts that are predicted to have roadway flooding problems are also highlighted on Figures 4-5 through 4-10 for Fanno Creek main stem, Pendleton Creek, Vermont Creek, Woods Creek, Ash Creek and Red Rock Creek, respectively.

Table 4-5 presents a summary of the number of culverts and storm pipes that are identified to have surcharging and roadway overflow problem in the Fanno Creek watershed. As shown in Table 4-5, surcharge problems under 2-year and/or 10-year storms were identified for more than half of the culverts and storm piped modeled in all major drainage basins expect Pendleton Creek basin. Fanno Creek main stem and Red Rock Creek have higher percentage of culverts that were predicted to have roadway flooding problems under different design storms than the rest of major drainage basins. In general, surcharged storm pipes or culverts are not considered flood hazards as they don't pose health and safety concerns. In fact, some culverts in the watershed were designed to function as an orifice to detention facilities or widened stream channel to provide flood storage.

Table 4-5: Summary of Capacity Deficiencies for Modeled Culverts and Storm Pipes in Watershed

	Number of Culverts Modeled	Number and Percent of Culverts Surcharged Under 2-yr & 10-yr Storm	Number and Percent of Culverts That Are Expected to Have Roadway Flooding Problems	Number of Storm Pipes Modeled	Number and Percent of Storm Pipes Surcharged Under 2-yr & 10-yr Storm
Fanno Creek Main Stem	71	49 (69%)	34 (48%)	15	9 (60%)
Pendleton Creek	25	8 (32%)	4 (16%)	35	4 (11%)
Vermont Creek	24	9 (38%)	6 (25%)	54	27 (50%)
Woods Creek	76	43 (57%)	12 (16%)	37	19 (70%)
Ash Creek	79	42 (53%)	17 (22%)	52	32 (62%)
Red Rock Creek	27	21 (78%)	12 (44%)	47	36 (77%)

5 Water Quality Calibration, Verification and Results

5.1 Quality Calibration/Verification Storm Selection

5.2 Calibration Results / Issues

6 Discussion & Conclusions

6.1 Appropriate Uses of Model

DHI's MIKE SHE and MIKE 11 models are comprehensive tools for analysis, planning and management of water resources and environmental problems requiring integrated surface water and groundwater analysis. However, the DHI models and their results should be carefully evaluated, reviewed, assessed, and compared against field data whenever possible in watershed decision making process. The modeling results for the Fanno Creek watershed should be used and interpreted with caution due to the model's inherent error in input and observed data, the approximate nature of model formulations, and uncertain in criteria for model acceptance or rejection. Like any other environmental model, continued testing and verification will help to improve the model performance and therefore make model a more useful and reliable tool.

Based on overview of Fanno Creek hydrodynamic model calibration and verification results, the modeling team recommends the MIKE SHE and MIKE 11 models developed for Fanno Creek main stem and tributaries be used for the following work:

- Evaluate conveyance capacity of major roadway crossings and storm pipes in the watershed and identify culverts and storm pipes, which are currently undersized for the appropriate design storm events as defined in City of Portland's Sewer Design Manual.
- Examine and identify places in modeled streams and other open conveyance systems that are prone to flood damages and erosion under relatively large storm events (i.e., storm events that are considered equal or more than a 2-year storm event).
- Provide flow and other hydrologic/hydraulic information in the watershed for ESA group.
- Predict flow conditions and other hydrologic/hydraulic parameters under future land use conditions and evaluate the relative impact on hydrodynamics of the watershed due to future development;
- Provide flow information for storm drainage system design and sizing in pres-design activities;
- Provide boundary conditions for more refined smaller scale models that will be developed for detailed capital projects design and evaluation.

Note that although the Fanno Creek modeling results can be used to estimate approximate flood damages from large storm events, caution should be taken when interpreting simulated water levels for modeled open waterways. The watershed models were limited in producing precise water levels for most open channel segments or identifying places where overbank flow may occur due to lack of survey data and information on channel floodplain configuration.

Cautions also need to be taken when analyzing velocity output from the models. Because MIKE 11 is one-dimensional model, the model does not account for any variation of the velocity distribution over the cross section. Thus simulated velocities may be lower than what would be expected for the main channel of such cross sections. Relying on simulated velocity information exclusively may sometimes under-estimate or over-estimate erosion potential depending on cross section area of interest.

6.2 Recommended next steps in model development

The following actions are recommended for next steps in Fanno Creek watershed model development:

- Collect detailed groundwater data in the watershed. The groundwater data would contribute to a better understanding of the dynamics and interactions between surface and groundwater within the watershed and also a better use of MIKE SHE model capabilities.
- Collect flow data on selected locations on Fanno Creek tributaries. The stream flow data can be used to calibrate tributary basin models.
- Survey critical roadway crossings, storm pipes and stream cross sections and floodplain that have missing information. These data will help to refine the hydraulic models and therefore produce better results.
- Continue to test and verify model results versus existing and new field information.
- Continue to improve model based on updated and new survey information or field data.
- Upgrade MIKE SHE and MIKE 11 model to the most current DHI version to take advantage of the improvements made by DHI in software and therefore improve model performance.
- Add more detail to refine the existing models or develop small-scale detailed models to provide support in capital projects design.

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environmental services
systems analysis

Technical Memorandum

To: Amin Wahab

From: Gregory Savage, P.E.; Binhong Wu, P.E.; Bill Owen, P.E.

Reviewed By:

CC:

Date: December 30, 2003

Project: Fanno/Tryon Watershed Plan

Subject: Tryon Creek Hydrodynamic and Water Quality Model Development

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Summary

This technical report summarizes the following work that has been performed by BES System Analysis group for the Tryon Creek watershed modeling:

1. Tryon Creek watershed model selection and modeling data collection;
2. Tryon Creek watershed hydrodynamic model development;
3. Tryon Creek watershed hydrodynamic model calibration and verification;
4. Tryon Creek watershed hydrodynamic model potential usage.

Information on Tryon Creek main stem water quality model development and calibration is currently not available in the report, although it is listed in the Table of Contents. The information on water quality model for Tryon Creek and its tributaries will be included once the water quality models are finalized and completed.

Table of Contents

1 Modeling Purpose & Objectives

The City of Portland (City), Bureau of Environmental Service (BES) initiated the development of the *Fanno/Tryon Creek Watershed Plan* in 2001 to address watershed issues within this southwest region of the City. The purpose of the watershed management plan is to complete and augment the work started in the *Fanno Creek Resource Management Plan (RMP) and the Upper Tryon Creek Corridor Assessment (UTCCA),* and recommended by the *BES Public Facilities Plan*. Specifically, this watershed plan will recommend a comprehensive, strategic set of projects and programs to improve water quality, fish and wildlife habitat, and watershed functions in the Portland's Fanno Creek and Tryon Creek Watersheds.

To accomplish its purpose, the *Fanno/Tryon Creek Watershed Plan* will address *Clean River Plan* priorities, and contribute substantially to the City's Clean Water Act and Endangered Species Act (ESA) compliance efforts. The watershed plan will guide key City programs and projects in the Fanno Creek and Tryon Creek watersheds including water quality and performance monitoring, stormwater Best Management Practices (BMPs), watershed re-vegetation, habitat restoration, and infrastructure projects. Finally, the watershed management plan will also provide a basis for development of the City's operating and capital budget to fund priority actions.

The BES project team requested that its Systems Analysis (SA) Section provide technical assistance to support the development of the *Fanno/Tryon Creek Watershed Plan*. As defined by the project Work Plan (August 30, 2001), the SA Section built a set of modeling tools to simulate hydrologic, hydraulic, upland pollutant loading, and in-stream water quality processes within this watershed. This Technical Memorandum summarizes the development, calibration and verification of the Tryon Creek basin model (including main stem and selected tributaries) system, which was developed in parallel with the Fanno Creek system watershed models, and its potential usage in the watershed plan. Additional information pertaining the mainstems and tributary modeling for the Fanno Creek watershed is available in related documents (DHI, 2002; CH2M HILL, 2002; and BES, 2002).

2 Model Selection and Data Collection

As part of the model selection process, the City reviewed a number of popular watershed models including EPA's SWMM and HSPF, and the U.S. Army Corps of Engineers' HEC programs. Based on the evaluations of the needs for the project and model performances, the project team decided that the Danish Hydraulics Institute's (DHI) MIKE SHE and MIKE 11 models were best suited for the project. MIKE SHE and MIKE 11 are integrated surface water and groundwater programs that can be used to simulate hydrologic, hydraulic, upland pollutant loading, and in-stream water quality processes within a watershed. MIKE SHE is a hydrologic program that converts precipitation falling onto the watershed into runoff. MIKE 11 is a hydraulic program that routes MIKE SHE generated runoff flows through a modeled stream system.

MIKE SHE is a physically based, dynamic, fully distributed hydrologic model that simulates all major hydrological processes occurring in the land phase of the hydrological cycle. The hydrological components in

MIKE SHE model operate in a coupled manner and include interception-evapotranspiration, infiltration, snow melt, overland flow, subsurface inter-flow, groundwater flow and river-aquifer exchange.

MIKE 11 is a 1-dimensional hydrodynamic contaminant transport model used for simulating flows and water quality in narrow water bodies of limited depth like estuaries, rivers, channels, and storm pipes that form either dendritic or looped networks systems. The 1-D structure of the MIKE 11 model assumes that the water bodies are vertically and laterally homogenous (viz., no stratification or lateral variations in flow conditions) and that significant variations in both hydrodynamics and water quality parameters exist only along the longitudinal axis of the system elements. This is a standard and fair assumption given that shallow and narrow water bodies like rivers and creeks are always "well-mixed" vertically and laterally, and exhibit no significant gradients in parameters such as temperature and contaminant concentration except along the stream's length.

MIKE SHE and MIKE 11 require numerous sets input data in order to perform the model simulation. The following subsections describe the data collection and data "pre-processing" procedure used to fulfill the model requirements which include elements such as meteorological and landuse inputs, soil parameters, runoff and groundwater computations, and routing through the drainage system.

2.1 Model Area and Boundary Conditions

The drainage basin for Tryon Creek was delineated using Geographic Information System (GIS) data sets that included topographic data overlaid with the storm drainage system. Portions of the Tryon Basin are located outside the City boundary (and extent of the City's data extents) so additional drainage system and topographical data were obtained from the City of Lake Oswego and Metro's RLIS GIS data set. The entire 4,290 acre (17.36 km^2) Tryon Creek drainage basin was modeled using the MIKE SHE/11 combination, and the extent of the drainage basin and the MIKE 11 model is illustrated in Figure 2-1.

The MIKE SHE model domain is defined within a discretized 180 by 205 element array of 100' x 100' square grids cells. Each grid cell is associated with a number of data layers that correspond to a number spatial variables used by the model which include: ground elevation (slope), soil type, imperviousness, vegetation type, landuse and other parameters. The grid size was chosen primarily based on basin characteristics and computational constraints in the model, and represents a balance of computational resolution needed to produce realistic results, and computational and data processing time limitations required in performing long-term simulations. The MIKE 11 component of the model consists of over 750 elements representing physical objects like stream cross-sections, culverts, storm drainage pipes and other hydraulic control structures. The stream network in MIKE 11 includes the mainstem of Tryon Creek, which is about 4.66 miles (7.5 km) and has an elevation drop of approximately 400 feet, along with 28 tributaries including Arnold Creek, Falling Creek and Nettle Creek. Due to the size of the entire system and the need to maintain reasonable model computational (simulation) times, not all storm drainage sub-systems consisting of 12" pipes were modeled. However, the MIKE 11 model includes second and third order streams and the areas not explicitly modeled in MIKE 11 are predominately impervious and the runoff flows are diverted from MIKE SHE to the nearest MIKE 11 coupling point. The MIKE model assumes that the flows from impervious surfaces have no storage or losses due to infiltration or evapotranspiration.

The boundary conditions for the basin models were set such that there would be no flow along the entire basin boundary, with the exception that a constant head boundary, allowing water to flow in and out through the model boundary, was set at the most downstream of each basin model.

2.2 Meteorological Data

Meteorological data sets are some of the primary inputs needed to run a physical-based hydrologic model. Mike SHE requires precipitation data, potential evapotranspiration (ET), and solar radiation data for the model to simulate both surface and groundwater effectively.

Precipitation Data

BES' Hydrologic Data Retrieval and Acquisition (HYDRA) system contains 5-minute rainfall data collected from meteorological stations operating throughout the City, including in and around the Tryon Creek watershed. Table 2-1 lists the three of rainfall gages in or near the Tryon Creek basin which have been in operation for various times during the period ranging from the mid-1970s to the present.

Table 2-1: Rain Gages Used in the Tryon Creek Watershed Model

BES HYDRA ID	Rain Gage Name	Mike SHE ID
006	Collins View	1
032	Vermont Hills	2
005	Sylvania	4

Figure 2-1 depicts the locations of these along with a meteorological station operated the National Weather Service (NWS) at the Portland International Airport. The spatial distribution over basin areas of point precipitation data was accomplished using Theissen polygons. Theissen polygons are formed by connecting lines between adjacent gages and then using perpendicular bisectors of these lines as boundaries for the spatial distribution of the particular gages' values. The key assumption of this method is that the rainfall for any point within a watershed is equal to the rainfall of the closest gage. Figure 2-2 also shows the Theissen polygons used in the MIKE SHE model. The precipitation gage data for these sites were converted to units of mm/hr and compiled into a specially formatted time-series file that is read by the MIKE-SHE model. Periods of record with missing data for the one particular gage were filled in by copying data from the closest gage in the watershed or averaging the values from the other watershed gages for the same time period.

Evapotranspiration Data

The potential evapotranspiration used in the Tryon Creek Mike SHE models was based on a 30-year average (1961-1990) of monthly pan evaporation measurements collected at the NWS Station at the Portland International Airport and provided by the Oregon Climate Service. The monthly potential evapotranspiration data that was used throughout the Tryon Creek watershed are shown in Table 2-3.

Table 2-3: Monthly Potential Evapotranspiration Values Used in MIKE SHE

Month	Millimeter/Hour	Inch/Month
January	0.031	0.908
February	0.051	1.349
March	0.078	2.285
April	0.120	3.402
May	0.175	5.126
June	0.210	5.953
July	0.259	7.586
August	0.233	6.825
September	0.168	4.762
October	0.084	2.460
November	0.039	1.106
December	0.026	0.762

Solar Radiation Data

Monthly solar radiation data (from 1999 through 2001) were obtained from the University of Oregon's Solar Radiation Monitoring Laboratory, Gladstone station (*http://solardat.uoregon.edu/*). A secondary source of solar radiation data was also available for the Tryon Creek watershed in the Tualatin Basin Total Maximum Daily Load report (ODEQ, 2001). More detailed information on solar radiation input is provided in Section 3.3.

Figure 2-1 Tryon Creek Watershed and Portland Area Climate Stations

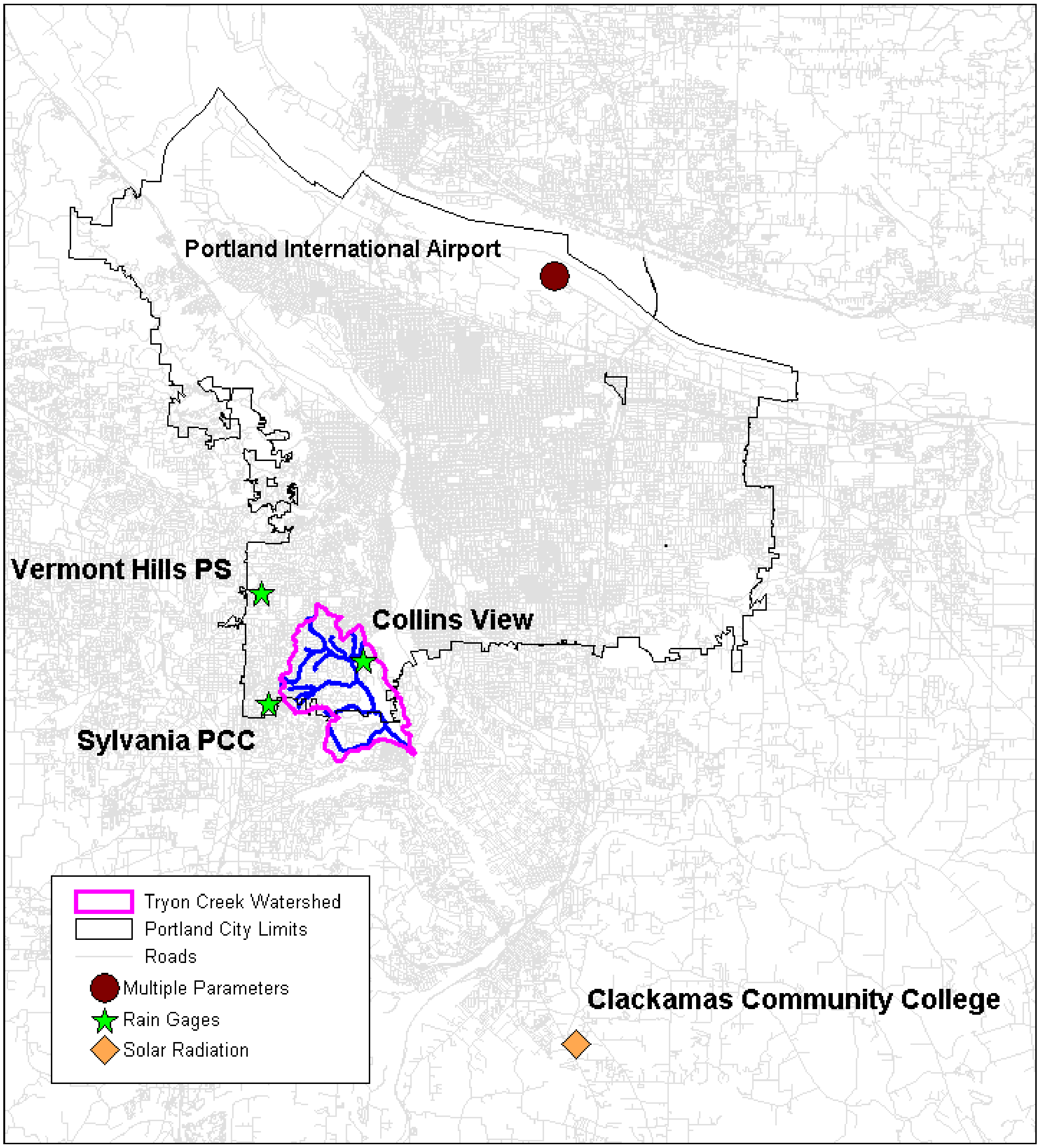

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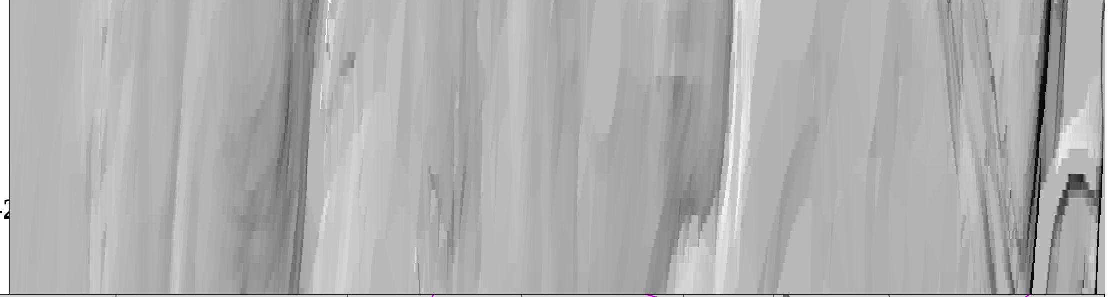
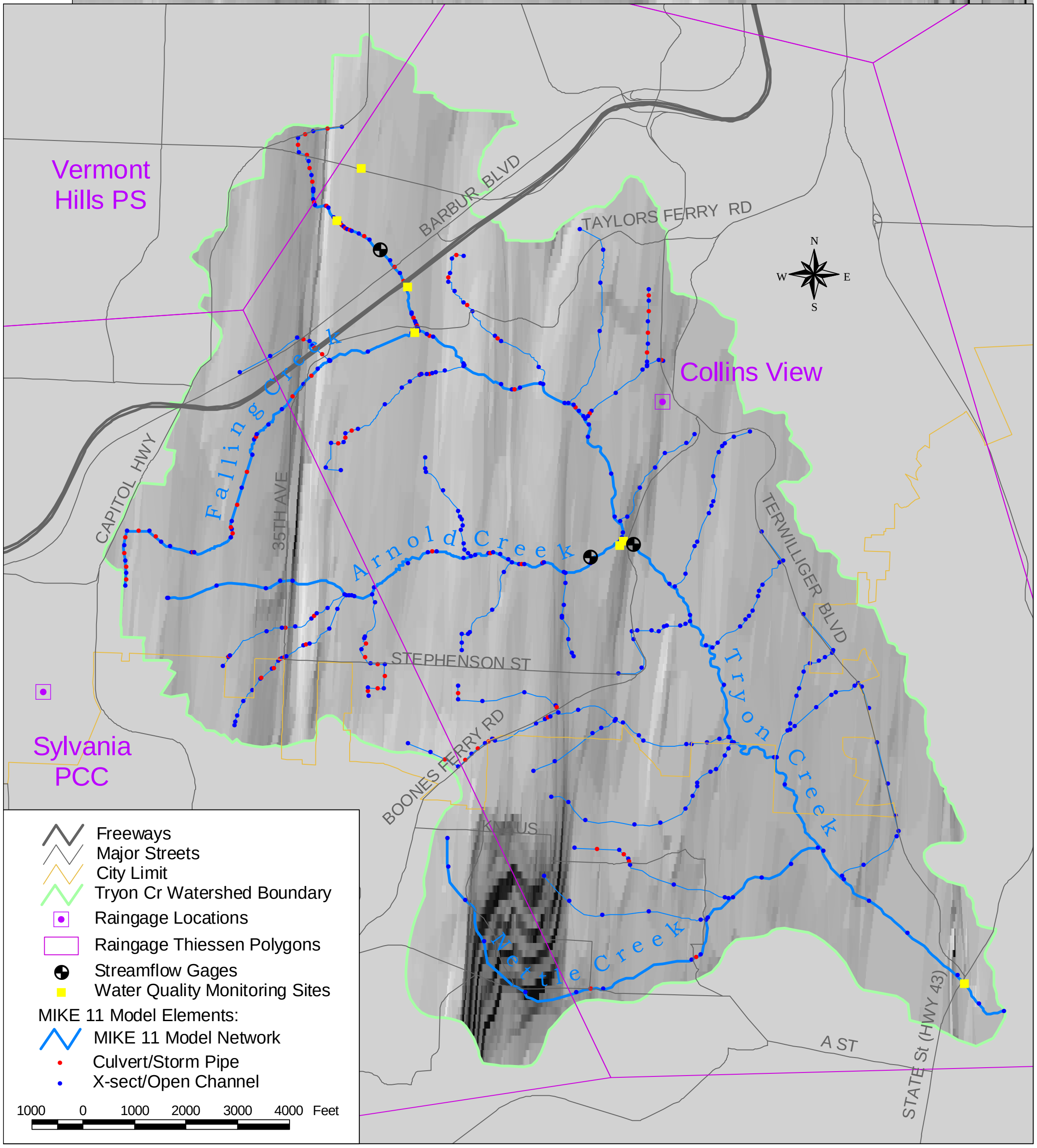
Figure 2-




Vermont Hills PS
Collins View
Sylvania PCC
BARBUR BLVD
TAYLORS FERRY RD
CAPITOL HWY
35TH AVE
Falling Creek
Arnold Creek
Tryon Creek
Nettle Creek
TERWILLIGER BLVD
STEPHENSON ST
BOONES FERRY RD
KERRUS
A ST
STATE St (HWY 43)
N
E
S
W
Freeways
Major Streets
City Limit
Tryon Cr Watershed Boundary
Raingage Locations
Raingage Thiessen Polygons
Streamflow Gages
Water Quality Monitoring Sites
MIKE 11 Model Elements:
MIKE 11 Model Network
Culvert/Storm Pipe
X-sect/Open Channel
1000
0
1000
2000
3000
4000
Feet

2.3 Surface Data

Various land surface data sets are used by the MIKE SHE model to simulate the hydrological processes of rainfall collection, infiltration and runoff. Major sources of information were collected from existing City and Metro GIS data sets (or coverages), and include land use, topographic, paved/imperious areas, and other basic watershed information. Multiple sources for the all the surface and systems data had to be utilized since approximately 30% of the Tryon watershed extends beyond the City limits and extent of data coverages. On a side note, the portion of the Tryon Creek watershed that exists within the City of Portland only accounts for about 3.3% of the City's total land area. More detailed information on Mike SHE model development is provided in Section 3.1.

2.4 Subsurface Data

Several sources of information on soil classifications with hydraulic parameters were available to develop model representations of the subsurface conditions. These included the following:

- Natural Resources Conservation Service's (NRCS') soil surveys (NRCS, 1983 & 1985)
- NRCS lab analysis of selected soil types in Multnomah County CS, 1985& 2001)
- Borehole data collected by the BES Material Testing Lab and the Oregon Department of Water Resources (Adolfson Associates, 2001), and
- Published literature (Freeze and Cherry, 1979).

Mike SHE Model subsurface data development details are provided in Section 3.1.

2.5 Stormwater Network

Surface water in the Tryon Creek watershed is conveyed through a network (not necessarily listed in order to occurrence) of curbs and gutters, stormwater pipes, drainage ditches, roadside swales, culverts, and natural creek channels. The principle data source for storm pipe network is the BES Facilities Inventory and Mapping Data which exist, along with most other types of spatial data, in the form of a GIS coverage. This data set contains information pertaining to pipe and culvert length; invert elevations, material, and other miscellaneous characteristics. The BES Facilities Inventory Database, also known as the "All_s" database, is being updated on a frequent basis. For purposes of this analysis, a snapshot of the GIS version of this data set was taken in October 2001, and was used as the initial drainage network in the model.

Even with the regular updates, by no means is the All_s database considered complete. In many cases, especially in the areas of Southwest Portland that were developed as County lands and later incorporated in to the City, the All_s database is incomplete and values for attributes like pipe size, material type and invert elevations do not exist. In many areas, up to 80% of the records for closed conduits are missing some form of attribute data. Several additional sources helped supplement the storm pipe data and drainage system databases. The 2001 Tryon Creek Assessment Survey and Data Collection report contains information on a number of roadway crossings and selected cross-sections within the mainstems of Arnold, Falling, Nettle and Tryon Creeks (W&H Pacific, 2001). As-built information obtained from Oregon Department of Transportation (ODOT) helped to fill data gaps on storm pipes along the I-5 corridor. For storm pipes and culverts that still have data gaps, estimates on size, length, inverts or material were made based on topographic data and best engineering adjustment.

Stormwater ditches and natural creek channels are included based upon topographic data and field surveys. The 2001 Tryon Creek field survey also detailed a number of open channel cross-sections adjacent to the major culverts in the watershed. Cross section data were also obtained from the existing 1- and 2-foot contour mapping data and 5-foot grid-cell Digital Elevation Model (DEM) data to fill-in any voids left by the 2001 survey.

2.6 Flow Gage Monitoring Data

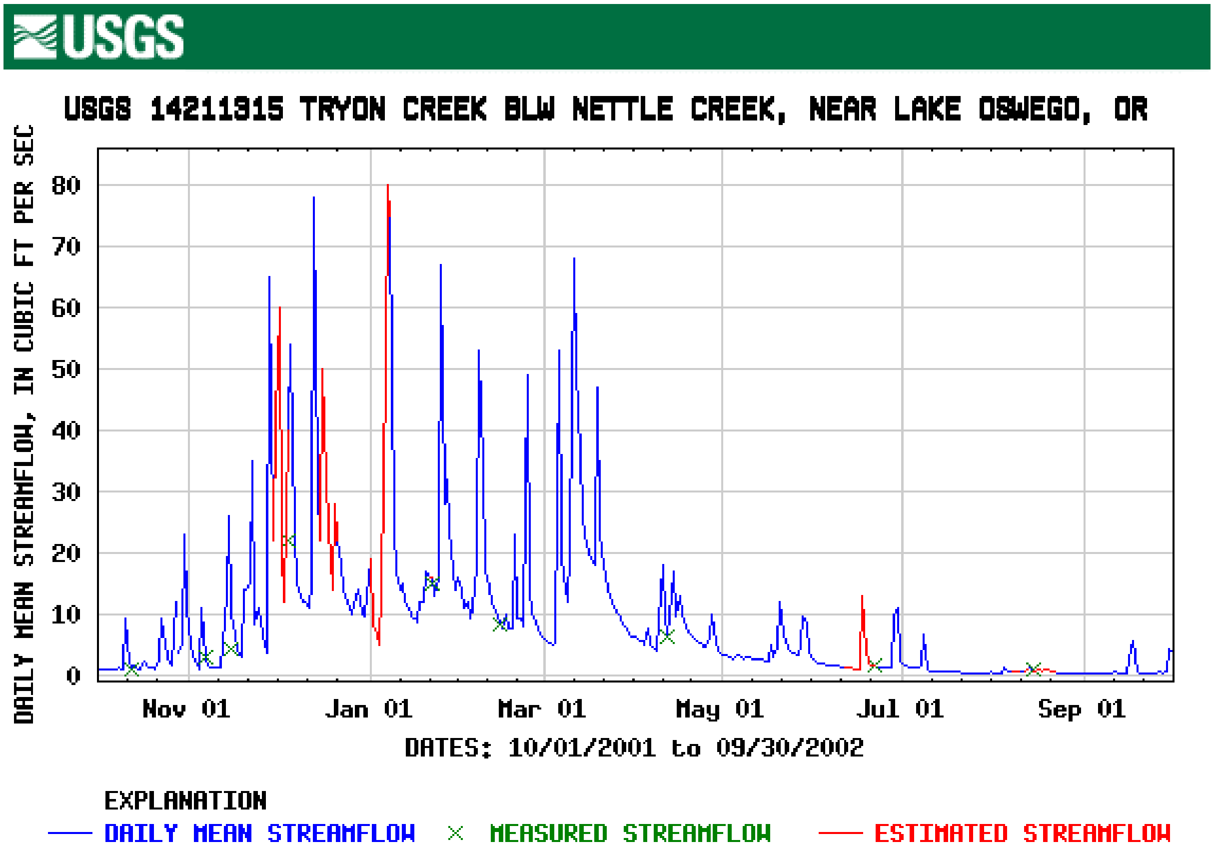
Continuous stream flow monitoring data within the Tryon Creek watershed are somewhat limited. The City of Portland installed two gages, one on Tryon Creek at Boones Ferry Road and the other on Arnold Creek at 11th, and the U.S. Geological Survey (USGS) also installed a stream flow gage on Tryon Creek right downstream from its confluence with Nettle Creek.. The periods of record for the sites are shown in Table 2-4. For the location of the gages, refer to Figure 2-2.

Table 2-4: Summary of Streamflow Gages within the Tryon Creek Basin

Gage Name	Period of Record	Collection Interval	No. of Records
Tryon Creek at Boones Ferry Rd	1995.08.31 to 1997.06.03	15 min.	53,094
Tryon Creek at Nettle Creek (USGS 14211315)	2001.08.02 to Present	15 min.	Active Gage
Arnold Creek at 11th	1995.09.27 to 1996.12.29	15 min.	44,046

The following figure, Figure 2-3, shows the USGS stream flow gage data for the 2001-02 water year. The typical over-all flow pattern with low dry-season baseflow and high peaks in response to rainfall events is evident.

Figure 2-3: USGS Tryon Creek Gage Data for 2001-02 Water Year



2.7 Water Quality Monitoring

BES has been monitoring the water quality of Tryon Creek and its tributaries for a number of periods starting in 1994. BES has monitored water quality at eight locations within the watershed (Figure 2-2). Two of eight sites were monitored weekly and the rest were monitored monthly. Water quality analyses included the parameters of interest for this modeling analysis: total phosphorus (TP), total suspended solids (TSS), *Escherichia coli* (E. coli), and water temperature. A summary of the water quality data available for model calibration and verification is presented in Table 2-5.

In addition to the grab samples collected at eight locations listed in Table 2-5, BES also operated a continuous temperature monitoring gage, with hourly readings, on Tryon Creek main stem at Boones Ferry Road from May 1998 to June 2002. The State also operated a daily peak stream temperature site within Tryon Creek State Park for the time period ranging from May through October for the years of 1998 to 2002.

BES also collected stormwater composite samples of land-use specific runoff at a number of sites in the Tryon Creek watershed that included monitoring of multi-family residential and transportation runoff. This information was useful in establishing Event Mean Concentrations (EMCs) used in the upland pollutant GIS grid loading model. More information pertaining to the development of this model is presented in Section 3.3.

Table 2-5: Tryon Creek Stream Flow and Water Quality Monitoring Sites

Site ID	Description	Period Start	Period End	Sampling Interval	Data Source	Creek	No. of Obs.	Parameters
TRYBF	Tryon Ck @ Boones Ferry	14-Nov-95	16-Jul-96	Monthly	-	Tryon	48	Flow
ARN11	Arnold Ck @ SW 11th Dr	12-Mar-01	-	Monthly	BES	Arnold	-	Flow, Temp, E. coli, TP, DO
TRYDO	Dolph Ct near I-5	3-Sep-75	20-Feb-77	Varies	USGS	Tryon	-	Flow, Temp, TP, DO
ARNBF	Arnold Ck @ Boones Ferry	14-Nov-95	16-Jul-96	-	-	Arnold	17	-
FAL26	Falling Ck @ 9310 SW 26th Ave	-	-	-	BES	Falling	0	-
TRYAC	Tryon Ck @ Arnold Ck confluence	14-Nov-95	11-Jun-97	Monthly	-	Tryon	17	-grab samples for conventional pollutants
TRYCOM	Commercial runoff sample, 8943 SW 26th Ave	1-Sep-01	-	Storm	BES	Tryon	0	-
TRYRES	Residential runoff sample, 3017 SW Multnomah Blvd	1-Sep-01	-	Storm	BES	Tryon	0	-
TRYSG	Small Tributary N of I-5, 3203 SW Spring Garden Rd	12-Sep-94	25-Jun-96	Weekly	-	Tryon	92	-
TRYWR	Tryon confluence w/ Willamette	14-Nov-95	11-Jun-97	Monthly	-	Tryon	4044	-

Notes:

1. Grad samples are collected weekly during TMDL period, i.e., May through October. Monthly grab samples are collected during rest of the year.
2. Hourly temperature data collected during TMDL period.

3 Model Development and Assumptions

Once the available information and data were collected, the next step in model development was to pre-process these data so that they can be used by MIKE SHE and MIKE 11. The general approach for developing the model was to select the appropriate data for different model components and translate them into some specially formatted data files for direct importation into the model. Some spatial data was formatted for subsequent importation to MIKE 11 or MIKE SHE using the DHI extension within the ArcView GIS program. Other data files developed as model inputs include time series files used to define temporally varying parameters such as rainfall, evapotranspiration and crop rotation (namely seasonal changes in tree foliage). Detailed information on hydrologic model (MIKE SHE), hydraulic model (MIKE 11) and water quality model (MIKE 11) development are discussed in following subsections.

3.1 Hydrology (MIKE SHE)

In a MIKE SHE model, all precipitation inputs in a watershed are accounted for by: runoff or overland flow in the surface zone, infiltration and groundwater recharge in the unsaturated zone, change in storage and interflow movement through the saturated zone, and evapotranspiration in conjunction with all zones located within tree root depth. Through the use of vegetation database and a number of other input parameters, the model also accounts for interception, depression storage and direct evaporation. The hydrological components or modules considered in the Tryon Creek MIKE-SHE model include the following:

- Catchment Definition
- Evapotranspiration
- 2-Dimensional overland flow
- 1-Dimensional unsaturated flow (vertical infiltration)
- Quasi 3-Dimensional saturated flow
- 1-Dimensional dynamic hydraulic model for simulating flow in rivers, channels, and other water bodies (MIKE 11) coupled with the saturated flow model to simulate aquifer/river exchange

The setup of the MIKE SHE modules is detailed in sections 3.1.1 through 3.1.5.

3.1.1 Catchment Definition

The basic catchment definition is comprised of a catchment or drainage basin delineation, horizontal discretization, surface topography and rainfall data. The initial delineation of the Tryon Creek drainage basin was taken from Metro's Regional Landuse Information System (RLIS) GIS data set that was derived from USGS maps with 10-ft contours. The delineation was further refined using overlays of the City's 2-ft contour and storm drainage system information (for the areas covered that are within the City limits – the extent of the data sets), in addition to some storm drainage system information provided by the City of Lake Oswego.

For the MIKE SHE model, the Tryon Creek drainage basin was discretized in a grid, or array, of 100-foot by 100-foot grid cells. Digital Elevation Models (DEM), based on the pre-defined, 100-ft model grid cell definitions, was created for the drainage basin utilizing the City's 2-ft contour data for the areas within the City merged with USGS 10-ft contour data for the remaining areas. A DEM is a raster data set (a uniform grid or array of cells) that represents the surface of the earth with the numeric value of a particular cell representing the land elevation at the cell's location. The surface DEM was then exported to a specially formatted MIKE SHE, ASCII text matrix file with a ".t2" extension. Other basin parameters in the model also utilize the "t2" file format with the same 100-ft grid cell spatial discretization.

Time-series of parameters such as rainfall intensity, evaporation rates, and crop rotations; are specified in a MIKE SHE ".t0" file. Multiple values within a ".t0" time-series may be spatially distributed over any portion of the catchment area using a grid code specification. The importance of this feature is that spatially varying rainfall, based upon multiple rain gages in and around the basin, can be defined for any given time step. Other time and spatially varying parameters like tree foliage are handled in a similar way. With respect to rain gages near the watershed, the distribution of the values for the gages were made using Thiessen polygons, as shown in Figure 2-2 and the corresponding model grid code assigned to each gage is shown in Table 2-1.

3.1.2 Surface Zone and Overland Flow

The surface zone components of the MIKE-SHE model simulate the behavior of rainfall collection and runoff (overland flow) and include parameters for surface topography, surface detention storage and surface runoff friction factors. No initial water depth was specified for the models but a surface storage value of 0.01 m (0.39 in) was globally specified for the watershed, representing rainfall that is captured and detained in numerous small depressions and not immediately converted to runoff. The surface storage term is a calibration parameter and is not so strictly defined as other model parameters such as topography or imperviousness.

The rate of overland sheet flow is a function of the surface's slope and the surface roughness factor “M”. The MIKE-SHE model internally computes the slope for each grid cell based upon the elevation of each cell its nearest neighbors. The model uses surface roughness factor “M”, which is the inverse of Manning's “n”, to account for the friction factor for overland flow. Overland Manning's n values were based on land use types and the values assigned to each land use are given in Table 3-1. Surface roughness factor “M” values were assigned to individual grids by performing a query on the land use and grid table files. If more than one “M” value occurred within a specific grid due to multiple land uses, the roughness factor “M” value that corresponded to the greatest land use area within that grid was assigned to that grid.

Table 3-1: Surface Roughness Factors for Different Land Use Types

Land Use Code	Land Use	Manning's n	Surface Roughness Factor “M”	Manning's n Source
COM	Commercial	0.25	4.0	CH2M HILL (1994)
MFR	Multi Family Residential	0.25	4.0	CH2M HILL (1994)
VAC	Vacant	0.035	28.6	Chow (1959) – short grass
SFR	Single Family Residential	0.25	4.0	CH2M HILL (1994)
TRN	Transportation	0.013	76.9	Chow (1959) – Concrete/Asphalt
FOR	Forest	0.1	10.0	Chow (1959) – heavy stands of timber
IND	Industrial	0.25	4.0	CH2M HILL (1994)
AGR	Agricultural	0.035	28.6	Chow (1959) – short grass

The overland flow component of MIKE-SHE also includes variables for overland-groundwater exchanges and channel flow routing. Full contact within the entire catchment for overland-groundwater exchange was specified in the model, and all the channels flows were routed through the MIKE-SHE-Mike 11 coupling, which utilizes Mike 11's more robust computational channel hydraulics. This coupling emulates the natural process where overland sheet flow is eventually concentrated into channel flows with its ultimate end, being the basin's outlet.

3.1.3 Unsaturated Zone and Soils

The MIKE SHE model includes modules for simulating surface and groundwater interactions and flux through an unsaturated zone (UZ) to and from the groundwater saturated zone (SZ). The parameters used for modeling UZ behavior were derived from Natural Resource Conservation Service (NRCS, formerly SCS) soil surveys, limited borehole data in the watershed, land use information and aerial photo data.

Soil data for the Tryon Creek watershed was taken from the NRCS Soil Survey Geographic database. The distribution of soil types in the Tryon Creek watershed is shown in Figure 3-1 and Table 3-2. Soil distribution was obtained by overlaying the grid coverage with NRCS soil coverage and defined by a soils type "t2" file. After analysis of soil data, an assumption was made that the soils were vertically homogenous for the first 60 inches (1.5 meters). This assumption was verified through random checks of all three NRCS GIS layers (i.e., Multnomah, Washington and Clackamas) throughout the watershed. In order to prevent the water table from dropping below the unsaturated zone soil column, a Xenocrepts basalt profile was added to each unsaturated zone soil column from 3 to 10 meters below land surface. The water-table elevation provides a boundary condition for the unsaturated zone module and is required for the numerical UZ solution. The vertical discretization was defined by the geological layers whose attributes were defined in the UZ soil property database.

The following parameters are specified in the UZ soil property database for each soil type:

- Soil Moisture at Saturation (θ_s, unitless)
- Soil moisture at effective saturation (θ_{eff}, unitless)
- Capillary pressure at filed capacity (pF_fc, pF unit)
- Capillary pressure at wilting point (pF_W, pF unit)
- Residual soil moisture content (θ_{res}, unitless)
- Exponent in hydraulic conductivity function (Expo, unitless)
- Saturated hydraulic conductivity (K_s, m/s)

NRCS laboratory data were used to determine UZ soil moisture retention data in the UZ soil database. Hydraulic conductivity for some soil types were obtained from a textbook titled "Groundwater" by Freeze and Cherry (1979). A global value of 10 was assigned to exponent in hydraulic conductivity function. Based on communications with NRCS Portland Office (Bill Owen, February 5, 2000) and information found in the NRCS soil survey in Washington and Clackamas counties, it was decided that soil properties for the following units were similar to those of Cornelius soil type: Kinton, Aloha, Woodburn, Quanatama, Cove, Verboort, Huberly, and Amity. Also Laurelwood, McBee and Bornstedt soil types all fall in a similar particle class family as Xerochrepts (i.e., silt loam/silty clay loam). Thus, their soil moisture retention curves can be taken from those of similar types. Table 3-3 presents input parameters in the UZ soil property database.

Figure 3-1 Tryon Creek Basin, Soil Types by MIKE SHE Identification

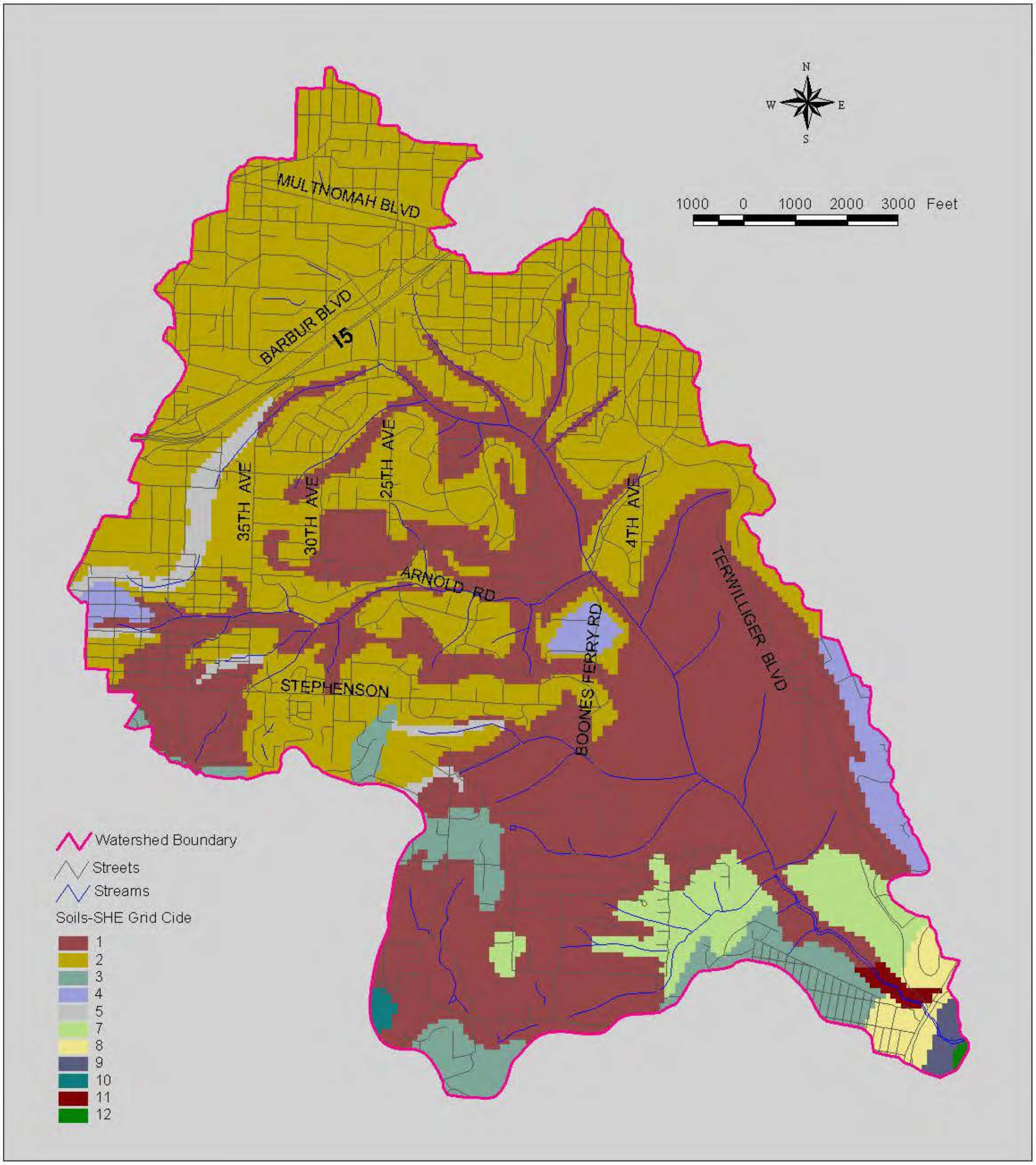


Table 3-2: Soil Types in the Tryon Creek Watershed

SCS Soil Unit No.	County	SCS Soil Unit Description	MIKE SHE ID
7 / 13	Multnomah & Washington / Clackamas	Cascade	1
8	Multnomah	Cascade-Urban land complex	2
10 / 11/ 23	Multnomah / Washington / Clackamas	Cornelius	3
11	Multnomah	Cornelius- Urban land complex	4
14 / 16	Multnomah / Washington	Delena silt loam	5
18	Multnomah	Goble-Urban land complex	6
48	Clackamas	Kinton silt loam	7
54	Clackamas	Laurelwood silt loam	8
56	Clackamas	McBee silty clay loam	9
8c	Clackamas	Bornstedt silt loam	10
46 / 92	Washington / Clackamas	Xerochrepts and Haploxerolls	11
93	Clackamas	Xerochrepts rock outcrop	12
21 / 19	Multnomah / Washington	Helvetica silt loam	13
1	Washington	Aloha silt loam	20
45	Washington	Woodburn silt loam	21
37	Washington	Quanatama silt loam	22
13	Washington	Cove silt loam	23
42	Washington	Verboort silty clay loam	24
22	Washington	Huberly silt loam	25
3	Clackamas	Amity silt loam	26

The simplified Richards' equation and automatic classification scheme were used in the MIKE SHE UZ module. A constant water table elevation of 0.7 meters below land surface was assigned to each unsaturated zone column. The 0.7-meter depth corresponds to the inferred elevation of the perched water table throughout much of the watershed due to the presence of a dense soil horizon with a permeability less than surrounding soil horizons (i.e., fragipan) 0.75 meters below land surface. The uniform depth to the fragipan was determined from a surface interpolation of mapped borehole data.

Table 3-3: Tryon Creek Watershed MIKE SHE Model UZ Soil Property Database

SHE DB Soil Name	Soil Unit Description/ NRCS ID	θ_s Soil moisture at saturation	θ_{eff} Soil moisture at effective saturation	K_s [m/s] Saturated Hydraulic Conductivity	pF_fc Capillary pressure at field capacity	pF_W Capillary pressure at wilting point	θ_s Residual soil moisture content
Bornsted (8c)	Bornsted silt loam/8c	0.587	0.587	9.17E-06	0.001	2.53	4.18
Cascade (7)	Cascade silt loam/7	0.587	0.587	9.17E-07	0.001	2.53	4.18
Cascade - Urban (8)	Cascade-Urban land complex/8-m	0.587	0.587	9.17E-07	0.001	2.53	4.18
Cascade fragipan	Cascade silt loam, fragipan/7f	0.470	0.470	4.23E-07	0.001	2.53	4.18
Cornelius (10)	Cornelius silt loam/10	0.510	0.510	9.17E-07	0.001	2.53	4.18
Cornelius fragipan	Cornelius silt loam, fragipan/11f	0.615	0.615	4.23E-07	0.001	2.53	4.18
Cornelius-Urban (11)	Cornelius-Urban land complex/11	0.510	0.510	9.17E-07	0.001	2.53	4.18
Delena (14)	Delena silt loam/14	0.472	0.472	2.12E-07	0.001	2.53	4.18
Delena fragipan	Delena silt loam, fragipan/14f	0.401	0.401	7.06E-08	0.001	2.53	4.18
Goble fragipan	Goble, fragipan/18f	0.386	0.386	4.23E-06	0.001	2.53	4.18
Goble-Urban (18)	Goble-Urban land complex/18	0.427	0.427	9.17E-06	0.001	2.53	4.18
Kinton (48)	Kinton silt loam/48	0.510	0.510	9.17E-07	0.001	2.53	4.18
Kinton hardpan	Kinton silt loam, hardpan/48f	0.615	0.615	4.23E-07	0.001	2.53	4.18
Laurelwood (54)	Laurelwood silt loam/54	0.587	0.587	2.12E-07	0.001	2.53	4.18
McBee (56)	McBee silty clay loam/56	0.587	0.587	7.08E-08	0.001	2.53	4.18
Xerochrepts (92)	Xerochrepts and Haploxerolls silt loam/92	0.587	0.587	4.23E-06	0.001	2.53	4.18
Xerochrepts-rock(93)	Xerochrepts rock outcrop/93	0.587	0.587	9.17E-07	0.001	2.53	4.18
Xerochrrepts basalt	Xerochrepts rock outcroping - lower basalt layer/93b	0.587	0.587	4.72E-14	0.001	2.53	4.18

The paved area option was selected in the Tryon Creek MIKE SHE UZ module. A "t2" file was created that defined the distribution of paved and unpaved areas throughout the basin. Impervious areas were identified based on street, driveway, building footprint and aerial photograph GIS overlays. In the MIKE SHE model, each grid cell is limited to being either 100% or 0% impervious. Cells containing both paved and unpaved areas were defined according to which condition made up the greater percentage of the cell’s area. In some cases, the "t2" files specifying paved areas were further refined using aerial photo overlays. Based on the total number of 19,167 modeled grid cells, there are 4,539 cells defined as being impervious (buildings, pavement, etc.) which yields an over-all percent imperviousness value of 23.7% for the entire basin.

3.1.4 Saturated Zone

The MIKE SHE model also includes an integrated module for simulating groundwater flows within the saturated zone (SZ) that interacts with the UZ module. The set up of SZ module includes five components: geology, vertical numerical discretization, initial conditions, boundary conditions and definition of degree of drainage. All SZ module input data for the Tryon Creek watershed model were developed based on geotechnical bore logs obtained from the Oregon Water Resources Department and existing BES bore log data sets.

Geology

The geology section of the SZ module is used to define the geologic layers within the model boundary. The model can be divided into a number of layers and each of these layers has assigned hydrologic values. Because of lack of data, a single layer saturated flow model was developed for the Tryon Creek model. The thickness of the saturated zone was based on borehole data located within the Tryon Creek watershed. Spatial distribution of the thickness for the saturated zone was developed using GIS and defined as a ".t2" for the model. Since only limited borehole data existed for the basin, a uniform depth of 5 meters was estimated based on a review of borehole data.

Below the wind blown silt soil deposits that cover the West Hills, basalt and basalt weathering products comprise the surficial aquifer in the watershed basin. The horizontal hydraulic conductivity of the saturated flow was set at a constant value of $1x10^{-6}$ m/s with horizontal to vertical hydraulic conductivity ratio of 10. The ratio of horizontal to vertical permeability is generally not known for most areas and a value of 10 is recommended by DHI in order to increase the vertical resistance to flow that is generally present in layered aquifer. The hydraulic conductivity used exceeds typical values for fractured and unfractured basalt (10^{-9} to 10^{-14} m/s) and represents a composite of basalt and basalt weathering products. In order to prevent water loss from the saturated zone, a so-called “impermeable bed” is added to the bottom of geologic layer. A very low hydraulic conductivity of $1x10^{-10}$ m/s was assigned for both horizontal and vertical hydraulic conductivities of this impermeable lower boundary layer. This level of conservatism is also justified on the grounds that the shallow interflow component with higher return flows to the stream network would be significantly greater due to the overall steepness of the terrain.

Vertical Discretization

There are different options in defining the vertical discretization in the saturated zone model and the option of geological layers was selected for all basin models. The model default value, i.e., a minimum thickness of 0.5 meters, was chosen for the computational layer for all models.

Initial Conditions

The initial conditions for the saturated zone represent the initial groundwater head elevation in the computational layer. The initial heads for Tryon Creek model was developed using an iterative process. The models were first set up to run for specific time period with an initial groundwater elevation of 1 or 2 meters below the ground surface. The depth to phreatic surface at the end of simulation time step at each model grid was retrieved from the model output file and converted into a "t2" file. This "t2" file was used to represent the initial groundwater heads at the beginning of a re-run of the same simulation.

Boundary Conditions

A no-flow, impermeable boundary that coincided with the basin's watershed boundary was assigned to the SZ "t2" file with the exception boundary segment near the basin outlet where a constant head, free flow boundary was assign

Drainage

Drain flow accounts for the interflow portion of water movement and captures the accumulative runoff effects of higher order tributaries consisting of smaller conduits and drainage ditches that are not explicitly modeled in the MIKE-11 network. Drain flow is estimated in MIKE SHE module through the use of a specified drainage level and drainage time constant. Drain flow is produced when the groundwater level in a grid rises above the grid's drainage level. The drainage level and time constant can either be constant or varied spatially in a MIKE SHE setup. A constant drain elevation of 0.15 meters below land surface and a drainage time constant of $1x10^{-4}$ sec^{-1} was used in the Tryon Creek MIKE SHE model. The values were derived from earlier main stem flow model calibration results.

3.1.5 Evapotranspiration

The evapotranspiration (ET) module of MIKE-SHE accounts for direct evaporation from the ground surface and transpiration from vegetation. The ET module uses meteorological and vegetative input data to predict the total evapotranspiration and net rainfall amounts resulting from the processes of:

- Interception of rainfall by the canopy
- Drainage from the canopy
- Evaporation from the canopy surface
- Evaporation from the soil surface
- Uptake of water by plant roots and its transpiration

The ET module interacts with the UZ module, providing net rainfall and evapotranspiration loss rates and using information on soil moisture conditions within the root zone. The ET module is dependent upon rainfall, vegetation root depth, moisture content in the unsaturated zone, and potential evapotranspiration rate. The potential evapotranspiration rate is specified in a time-series file that is derived from evaporation pan data taken from the Portland Airport meteorological station for a 30-year period of record dating from 1961-1990. A uniform value of potential evapotranspiration was used through the watershed. The monthly potential evapotranspiration values used in MIKE SHE models can be found in Table 2-3.

The Kristensen and Jensen method was used to simulate evapotranspiration in the Tryon Creek MIKE SHE model. The Kristensen and Jensen method is an empirical method to calculate evapotranspiration based on available soil moisture, rainfall, and root zone and vegetation parameters. More information on the Kristensen and Jensen method and its implementation in MIKE SHE can be found in the MIKE SHE Water Movement User Manual.

The annual range of vegetative properties is shown in Table 3-4 and was spatially distributed based on land uses in the watershed. Leaf area index is the cover of leaves over a unit area and is a dimensionless parameter. Root depth is the maximum depth of the vegetation root mass for a given vegetation type. The leaf area index and root zone depth for the transportation land use type were set to zero since vegetation for this land-use type is negligible. Leaf area index input data were obtained from a paper on Journal of Arboriculture (McPherson, 1998) titled "Structure and Sustainability of Sacramento's Urban Forest". Initial root depth data were obtained from the City of Portland's City Forester, who indicated that trees typically found in the Fanno-Tryon watersheds have moisture-absorbing roots extending 8 to 48 inches below the surface depending on vegetation type.

Table 3-4: Vegetation parameters used in the Tryon Creek MIKE SHE model

Land Use	Minimum Leaf Area Index	Maximum Leaf Area Index	Minimum Root Depth (m)	Maximum Root Depth (m)	Maximum Time	Kc
Urban	2	3	0.2	0.6	April-August	0.75
MFR	2	3	0.2	0.6	April-August	0.75
Vacant	1	5	0.2	1	March-May	0.75
SFR	2	3	0.2	0.6	April-August	0.75
Transportation	0	0	0	0	NA	0.75
Forest	3	7	0.4	1.2	March-June	0.75

NA – not applicable

Since the monthly potential evapotranspiration values were based on pan measurements, a coefficient Kc with a value of 0.75 to adjust estimated actual evaporation was used for all land use types. Pan evaporation is typically greater than the actual evaporation that would occur from the same water surface area in a very large lake (i.e., free surface evaporation). MIKE SHE required that potential evaporation from a given vegetation type be provided and uses the Kc parameter to scale the ET times series. A Kc value of 0.75 is a value that is commonly used when site-specific information is not available.

Seasonal variations (such as leaf-on and leaf-off conditions) in ET module for different vegetation types are represented by variations in the leaf I\area index and root depth. Seasonal variations of the parameters were obtained based on DHI's recommendations.

Other empirical parameters used to estimate plant transpiration in Kristensen and Jensen Method include the following:

- C_{int} = 0.05 meters, C_{int} is the depth of the interception storage for the vegetation type;
- C_1= 0.31, C_1 is a plant dependent empirical input parameter;
- C_2= 0.2, C_2 is soil parameter that controls the rate water can be extracted from the soil;
- C_3= 20, C_3 is an empirical input parameter that may depend on soil type and root density;
- AROOT =1, AROOT is a parameter that determines the vertical distribution of the root mass over the specified root depth.

More information on the above parameters can be found in the MIKE SHE Water Movement User Manual. The evapotranpiration parameters were not varied between the different land uses because site-specific information was not available.

3.2 Hydraulics

MIKE 11 is a standalone 1-D hydrodynamic model that includes water quality modeling capability. This model works in a coupled manner with the MIKE SHE hydrology model, and is used to route runoff flows, through networked systems of open channels (natural or artificial channels, and ditches) or closed conduits (pipes and culverts), and perform the in-stream contaminant transport and water quality modeling. MIKE 11 hydrodynamic (HD) module uses an implicit, finite difference scheme to solve the vertically integrated equations of conservation of continuity and momentum or the Saint Venant equations. The module can model sub-critical flow as well as supercritical flow conditions.

The MIKE 11 HD module set up is different from the traditional link-node type model (such as SWMM or XP-SWMM) or cross-section element model (such as HEC-2 or HEC-RAS). MIKE 11 HD module consists of points that are located at longitudinal stations called chainages. A chainage can be either a Q (discharge) point or an h (water level) point. Q points and h points are alternating computational elements that are automatically generated based on user requirements. Generally Q points are placed midway between neighboring h-points and at structures (i.e., culverts and weirs), while h points are located at channel cross sections, or at equidistant intervals between two neighboring cross sections if the distance between cross sections is greater than a maximum spacing required for numerical stability. Further details on how MIKE 11 solves the Saint Venant equations can be found in the MIKE 11 Reference Manual.

3.2.1 Flow Network

The flow network of the Tryon Creek MIKE 11 model consists of branches and chainages. The criteria applied for determining the extent of the modeled flow network was that 12-inch and larger pipes and culverts, and downstream channels, were modeled. This assumption produced typically second and some third order branches and occasional looped drainage networks within the models. The modeled points, or chainages, representing either h-points or Q-points along any particular branch, are sequentially numbered by their longitudinal distances from the uppermost point, in feet, and ending at the branch's outfall or confluence with a receiving stream. Usually "0" is assigned as the chainage number for the most upstream point on a main stem or a branch. All conveyance elements included in the model, whether it is an open channel, pipe, culvert or manhole, is identified by its branch and chainage. The naming convention used for the branches is that there is prefix given for the stream's mainstem or basin name followed by a chainage number of where it connected to the downstream branch. A higher order stream's name would be followed by second number corresponding the higher order stream's identification. For example: a small branch draining into tributary (at chainage 526) of the mainstem of a creek (at chainage 3065) would have the identification of "CREEKNAME_3065_526". There are some exceptions in model and these occur when there is a prominent tributary; in this case the tributary name is used.

Although all the Fanno-Tryon MIKE SHE/11 watershed models were developed based on the criteria to include all storm pipes and culverts that are 12-inch or larger, nearly all the third order tributaries in Tryon Creek that contain 12-inch or larger storm pipes or culverts, were ignored in developing the MIKE 11 model, but nevertheless are still modeled implicitly in the MIKE SHE component. The MIKE 11 network model is still pretty comprehensive, as shown in Figure 2-2, in spite of all the simplifications. The reasons for the necessary simplifications include:

- Data Limitations – Although the BES Facilities Inventory Database and supplementary field survey data and data from other agencies provided significant detail of the storm drainage network in the watershed, detailed information for certain storm pipes and roadway crossings were still incomplete. Therefore, some of these storm pipes and culverts were not included in the model due to lack of critical information such as pipe size or inverts.
- Computational Time – The number of branches were limited to decrease the number of calculation points to ensure reasonable run times for long-term simulations and multiple scenarios.

- Numerical Model Stability – Although modeling of situations where a number of reaches go dry during the simulation is possible since MIKE 11 substitutes the momentum equation with a zero flow equation for very low flow situations, the switch from the momentum equation to the zero flow equation is done gradually and depends on the water depth. Thus to ensure that the model is stable for low flow situations, the time step should be chosen small enough so that the change from dry riverbed to full flow is suitably resolved. Because of the above, having a number of small branches that tend to go dry during low flow conditions does not enhance the stability of a model set up if a reasonable run time step is desired.
- Calibration Issue – Since the data available for water quantity calibration consists of one discharge measurement throughout the whole watershed, the complexity of the model should be consistent with the amount and quality of data available for setting-up and calibration the model. Calibration was carried out with objective of tuning the parameters of a simple model so that the model can be used as a regional model to provide appropriate boundary conditions for more refined small-scale models.

3.2.2 Open Channels

The cross sections in the MIKE 11 model most often represent open channels describing natural streams or drainage ditches, but they are also used to define closed storm pipes. In the initial model set up, a number of closed cross sections were used to describe sections of drainage network consisting of closed conduits. Even though MIKE 11 facilitates implementing closed cross sections through the cross section database it was recommended by DHI for most of modeled closed pipes to use culvert description instead. The reason for this is that a culvert description uses the energy equation locally to model the flow whereas the flow through a closed conduit described by the use of cross sections is solved by the use of momentum equation. The momentum equation description does not take into account the local energy losses caused by contraction or expansion due to changes in storm pipe size and existence of manholes. To make sure that these local losses are incorporated, DHI recommended using culvert description as opposed to closed cross sections. The other benefit of using culvert description instead of closed conduit is related to the coupling between MIKE 11 and MIKE SHE. Flow from MIKE SHE is unable to get into closed cross sections defined in MIKE 11 and the use of culvert definition (a Q-point) requires upstream and downstream cross sections (h-points) which can also be manholes. These h-point cross section definitions act as linkage nodes where MIKE SHE runoff enters the MIKE 11 network for further routing.

Cross sections were defined for all selected locations on modeled streams and ditches. Additional cross sections were placed upstream, in close proximity (i.e., 0.5-3 m), of modeled culverts (and storm pipes modeled as culverts) to represent immediate upstream water level conditions. This was done also because all structural elements in a MIKE 11 model, like culverts, are only solved for flow and there is a need to estimate the water depth at the inlets of all culverts and manholes for the piped sections. The manholes between storm pipes were represented by short, narrow and rectangular cross sections.

The cross sections used in the MIKE 11 models to define creeks and ditches were obtained from a combination of surveyed data and interpreted topographic data. The 2001 Tryon Creek field survey data collected by W&H Pacific were used to develop cross section input data in the model where they were available. For certain locations on creeks or streams where no such data exist, the city's GIS data containing 2- foot and 10-foot contours were used to interpret stream cross sectional data. In some instances, invert data from field survey or BES stormwater database were not compatible with the cross section data developed based on topographic information. Under such circumstances, adjustments to interpreted cross section data were made based on best engineering judgment. When cross sections for modeled shallow ditches were unable to derive from mapped contour data, a uniform trapezoidal shape channel section for the purpose of simply conveying flows was assumed in the model.

Due to the lack of comprehensive stream field surveys, specific values for channel roughness were not assigned at all locations but a global value of 0.05 was used to represent the overall channel sections containing both the main channel and over-bank. The channel roughness coefficient of 0.05 usually represents streams that have trees and brush along banks and have gravel and cobbles in channel bottom (Chow 1959). In some cases, the overall channel roughness was multiplied by a scalar in channel sections with known characteristics.

3.2.3 Culvert/Pipe Data and Other Hydraulic Structures

Majority of storm pipe and roadway crossing input in the Tryon Creek MIKE 11 models were based on the BES Hansen Facility Management System and related GIS data sources. The BES Hansen database contains information pertaining to pipe and culvert length, invert elevations, material, and other characteristics. The BES Facilities Inventory Database is being updated on a frequent basis. For purposes of this analysis, a snapshot of the GIS version of this data set was taken in October 2001, and was used as the initial drainage network in the model. Several additional sources helped supplement the storm pipe data provided by the BES Facilities Inventory database. The 2001 Tryon Creek assessment survey control and data collection contains information on major roadway crossings along Tryon Creek mainstem, and Arnold and Falling Creeks. As-built information obtained from ODOT helped filling data gaps on storm pipes along I –5 corridors. For storm pipes and culverts that still have data gaps, estimates on size, length, inverts or material were made based on best engineering judgment. For example, size information could be estimated based on standard construction practices or interpolated between upstream and downstream segments; in the cases were pipe/culvert length data was missing in the attribute database, the pipe length was measured directly from the CAD and GIS maps. Missing invert information was usually filled by subtracting estimated soil cover and pipe diameter from ground level at upstream or downstream ends of a pipe segment or culvert. Soil cover for piped storm sewers was usually estimated based on nearby storm pipe information, and in cases where there is no pipe information available for nearby area, a typical 5-foot cover depth was assumed.

For the Tryon Creek main stem and many sections of its tributaries, roadway culverts create a constraint in the channel flow. In many cases, especially during high flow events, these constraints may result in a build up of the water level upstream of a culvert; and if the capacity of the culvert to convey flow is exceeded., then the water level will continue to rise until it reaches an overflow structure and bypasses, or overtops the roadway. To handle the cases where roadways were overtopped, a broad crested weir conforming to the geometry of the roadways was defined to convey flows downstream.

Weirs were also added to the models for the purposes of maintaining numeric stability of hydraulic computations. Like many other numeric models, MIKE 11 is prone to numerical instability problems when modeling channels with steep slopes or channels that have sudden changes in gradient in channel geometry. Sudden changes in the flow regime creates a condition that makes the model prone to numeric instability, especially when the solution scheme solves for conservation of momentum. In the model setup, broad-crested weirs were defined with the same geometry as the channel cross sections at locations (cross sections typically located on steep slopes) were numeric instabilities occurred during preliminary model runs. By using weirs, a solution scheme utilizing the more stable continuity equation helps force a solution at a point in the point in the model network that is prone to stability problems.

3.2.4 Detention ponds & Other Pollutant Reduction Facilities

The MIKE model does not contain special structure feature for detention ponds, however, such facilities can be modeled using cross section data combined with culverts or weirs. In the case of the detention facilities in the Fanno-Tryon systems that were defined within the models, multiple wide cross sections were used to the define the storage capacity of the facility while culverts and weirs were used to define the outlet flow control structures.

3.2.5 Energy Losses and Other Modeling Parameters

Manning's 'n' roughness and inlet head loss coefficients were defined for all culvert elements including the culverts that were substituted as pipes. Typical Manning's n-values for culverts and pipes were 0.013 for concrete storm pipes (CSP), 0.022 for corrugated metal pipes (CMP) and 0.011 for pipes made from plastics. A global entrance head loss coefficient of 0.5 and exit loss of 1 was assigned for all culverts. Since majority piped sections were straight and most open channels are characterized as having gradual lateral changes in directions, no head loss coefficients were specified for bends. The head loss associated with culverts in MIKE 11 model is strongly dominated by sudden expansions and contractions such as experienced at the inlet and outlet of a culvert. The simulated head loss also depends on the head loss coefficients specified.

4 Hydrodynamic Model Calibration, Verification and Results

4.1 Overview of Hydrodynamic Model Calibration and Verification

Calibration is a test of the model with known input and output information that is used to adjust or estimate factors for which data are not available. Hydrodynamic model calibration involves selecting individual storm events with matching rainfall and stream flow data and adjusting the model hydrologic and hydraulic inputs to reproduce the measured flow from the measured rainfall data. Model verification is in reality an extension of the calibration process. Its purpose is to assure that the calibrated model properly assesses all the variables and conditions that can affect model results. Although there are several approaches to validating a model, the most effective procedures is to use only a portion of the available record of observation data for calibration; once the final model inputs are developed through calibration, simulation is performed for the remaining period of observed data and goodness-of-fit between recorded and simulated data is reassessed.

As show above in table 2-4, stream flow data for Tryon Creek are available for limited periods of record at a couple of locations. USGS started to collect continuous stream flow data in 15-minute interval on Tryon Creek near the confluence with Nettle Creek in August of 2001. No groundwater time series data were available in the Tryon Creek watershed.

Since groundwater data were not available, the Tryon Creek MIKE SHE and MIKE 11 model was only calibrated with surface discharge data. The following steps were used in calibration of the main stem MIKE SHE model:

1. Adjust vegetation and evapotranspiration parameters until simulated evapotranspiration is within reasonable ranges.
2. Adjust impervious areas to make changes in the proportion of runoff and infiltration.
3. Adjust overland roughness factor M values (reciprocal of Manning's n values) to increase or decrease the timing of hydrograph peaks.
4. Adjust drainage elevations and time constants to control the height of peak events and the recession limb of hydrographs.

Io addition to changes made in the MIKE SHE model, the following adjustments were made in the main stem MIKE 11 model:

1. Channel Manning's M values (reciprocal of Manning's n values) were adjusted to increase or decrease residence times in channels.
2. Overflow structures were added in the model to represent roadway crossing and facilitate the flow passing over roadway during high flow events.

Both qualitative and quantitative measures were used to calibrate the Tryon Creek main stem hydrodynamic model based on stream flow data. These measures include the following:

- Water budget evaluation
- Qualitative comparison (i.e., graphical comparison) of simulated and observed hydrographs
- Cumulative flow volume comparison
- Statistical tests, including error statistics for peak and peak time, and correlation tests for peak flow

A literature on model calibration and acceptance criteria was also performed to help further quantify the performance and robustness of the Tryon Creek main stem hydrodynamic model. The outcome from the review is presented in 4.2.1.

In addition to the comparison between the modeled flow and measured flow data under real storm events, modeled results from various recurrence interval design storm events were also investigated. These additional checks are valuable due to the following reasons:

1. One of the watershed modeling goals is to evaluate the conveyance capacity of the existing stormwater drainage system and identify expected conveyance capacity problems for roadway crossings and stormwater pipes in the watershed. To achieve this goal, different recurrence interval design storm events, including the 2-year, 10-year, 25-year and 100-year design storms, were run through the model.

2. The design storms are not real storm events. The design storm distribution is based on the 24-hour SCS Type I-A distribution that applies to the Pacific Northwest. The total rainfall depth for the design storm was obtained from the Rainfall Intensity, Duration, Frequency Curves (IDF Curves) from the City of Portland's Sewer Design Manual.

The flow data for the gage located on the main stem of Tryon Creek at the Boones Ferry Road were used to calibrate the model because of its length and period of record, and that it included multiple storm events with extended periods of high and low flows. The calibration period was broken into two 50-day periods that preceded and followed the February 1996 flood event. Even though the operation of the gage was disrupted by the extreme 1996 event, it still provided useful events for calibration. The period immediately preceding the peak flood event was marked by a series of about a half dozen, heavy, back-to-back storms followed by a 5-day dry period leading into the flood event. The data record picks up on March 15, 1996 were there are a series of smaller events with 1- and 2-day dry periods followed by an extended dry period and then series of heavier storms leading up to a set larger events.

4.2 Flow Calibration Results/Issues

4.2.1 Tryon Creek Main Stem Hydrodynamic Model Calibration

The simulation period used for model calibration and verification ran from December 7, 1995 to May 1, 1996 and was based upon mainstem flow data on Tryon Creek at the Boones Ferry Road crossing. At this site, the collection of stream gage data for this time period was interrupted on February 6, during the Flood of 1996, and later resumed on March 13, 1996. The actual model calibration period was from ran for a 50-days from December 7, 1995 to January 26, 1996. This specific period is a reasonable time for calibration of the main stem hydrodynamic model since it contains a number of distinct storm events with periods of extended discharge as well as a number of dry periods between storms that ranged from a half day to eight days in length. In addition to the calibration period, the model run was compared, for verification purposes, against gage data that included the period from March 16 to May 1, 1996. The verification period was selected because it contained a number of small storms separated by a extended (2-3 days) dry periods along with a series of larger events of longer duration with significant discharge.

Figures 4-1 and 4-2 present the observed and simulated flows for Tryon Creek main stem at Boones Ferry Road for the calibration and verification periods. Table 4-1 shows model statistical test results for the calibration periods.

Table 4-1: Statistical Test Results for Tryon Creek Main Stem Hydrodynamic Model

Criteria	December to January 1995 Period	March to May 1996 Period	Period Averages
Daily Correlation Coefficient	0.948	0.954	0.951
Peak Error	15.7%	23.4%	19.5%
Peak Time Error (hrs)	1.26	1.92	1.59
Cumulative Volume Error	8.3%	7.4%	7.9%

As shown in Figures 4-1 and 4-2, the Tryon Creek main stem model is able to capture the variation in the observed record, although it tends to overestimates the larger peaks. The good fit shown in these figures are also reflected in the correlation test results in Table 4-1 where the daily average flow correlation coefficients are about 0.95 for both the calibration and verification periods. In general, the total runoff volumes of the simulated and observed data match well, and the average cumulative volume error is below 10% (Table 4-1). Except for the peak error, the main stem model is capable of adequately simulating most hydrological and hydraulic components of the watershed during the calibration and verification periods.

Figure 4-1. Comparison of Measured Flow and Model Simulated Flow from Dec. 1995 to Jan. 1996 for USGS Gage Tryon Creek at Boones Ferry Road

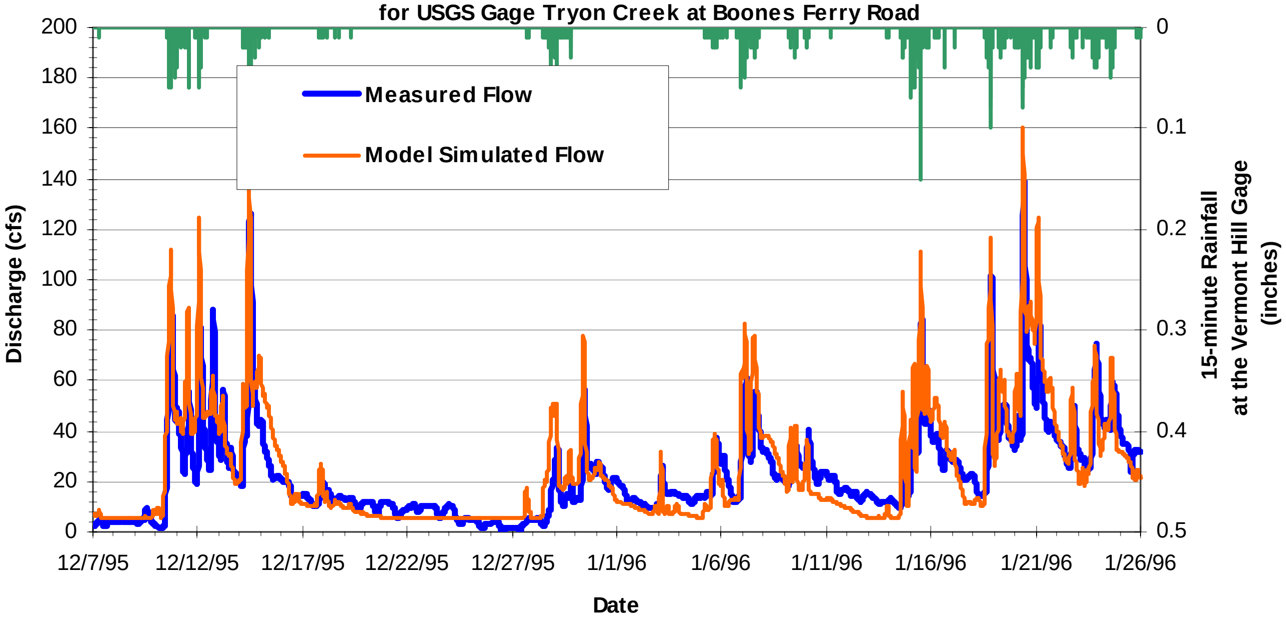
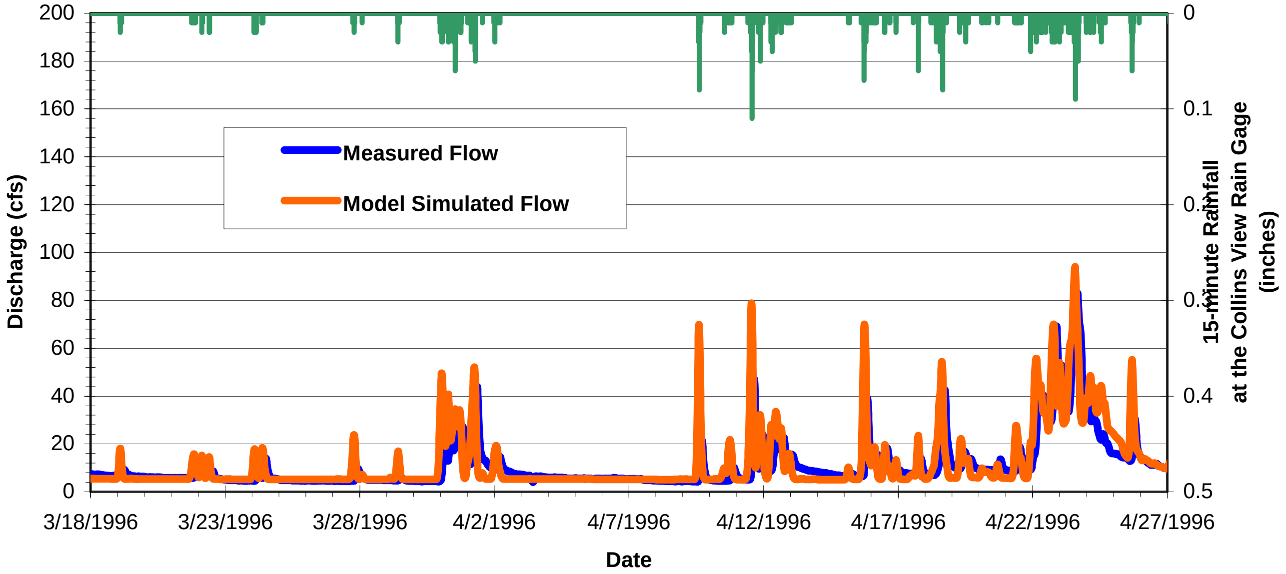


Figure 4-2. Flow Comparsons for Period of March 18-April 27, 1996 BES Gage Tryon Creek at Boones Ferry Road



A literature review on model calibration and acceptance criteria was performed to help quantify the performance of the model. Model performance expectations developed in several reports published by the Environmental Protection Agency (EPA) are provided below for comparison purpose. A Quality Assurance Project Plan developed for an EIS for the proposed Nicollet Mine in northern Wisconsin used the HSPF (Hydrological Simulation Program- Fortran) program and specified the following acceptability criteria:

"The targets for acceptable calibration and verification of monthly flows are a correlation coefficient greater than 0.85 and the coefficient of model-fit efficiency greater than 0.8." (EPA, 1998)

Table 4.2 lists general calibration/validation tolerance or targets that have been provided to model users as part of HSPF training workshops over the past 10 years. The values in the table attempt to provide some general guidance, in terms of the percentage mean errors, or differences between simulated and observed values, so that users can gage what level of agreement or accuracy may be expected from the model application.

Table 4-2: General Calibration/Validation Targets or Tolerances for HSPF Application (Donigian, 2002)

	Very Good	**Good**	**Fair**
Hydrology/Flow	<10	10 - 15	15 - 25
Sediment	<20	20 - 30	30 - 45
Water Temperature	<7	8 - 12	13 - 18
Water Quality/Nutrients	<15	15 - 25	25 - 35

Notes:
1. Percent variance (+/-) between observed and simulated values.
2. Relevant to monthly and annual values; storm peaks may differ more.
3. Dependent upon: quality and detail of input and calibration data; purpose of model application; availability of alternative assessment procedures; and resource availability.

For the Tryon Creek model, although there is some discrepancy in terms of instantaneous peak comparison, the averages parameters seems to be well within the tolerance ranges as shown in Table 4-2. As indicated in Table 4-1, the average daily flow showed a correlation coefficient of about 0.95 for all storm events during the verification periods. Also the cumulative runoff volume has an average error of about 8%. Based on the literature review, and the correlation of model results with monthly or annual stream gage values and not instantaneous ones, the model is within the acceptance criteria listed in Table 4-2.

Factors that may contribute to the relatively large discrepancies between the simulated and observed instantaneous peak flows can include uncertainties in the actual stream flow given that a stream gage physically measures stage and not flow. There is always some degree of error in a stage-discharge rating curve for any given site for a number of reasons including the fact that discharge measurements used to rate the gage are not collected continuously and the resultant the rating table developed generally has more calibration data in the "normal" flow zones as compared to the high and low flow zones. It is a normal practice that the stage-discharge rating curve or table will have to be extrapolated beyond the "fitted" or "calibrated" range to obtain a high or low flow value.

Model limitations and uncertainties in the model input data also produce error and uncertainty in the results. Although the model input was based on the best available information and substantial efforts have been taken to improve the quality of the input data of the model, there are still some uncertainties involved in some model input data. For example, highly resolved soil and groundwater information such as the spatial and temporal distribution of groundwater tables is not available. Certain aspects of the flow modeling are sensitive to this type of information, which is not available at this time to better refine this aspect of flow behavior. Also, although efforts were made to survey many key flow components of the watershed, time and budget did not allow for all flow components (viz.: open channels and conveyance structures like pipes and culverts) to be surveyed. As such, survey information is not always available for all modeled open channel sections and roadway crossings, and often there are discrepancies between the different data sources. These uncertainties and data gaps translate directly into uncertainties of the simulated flow calculated by the MIKE SHE and MIKE 11 models.

4.2.2 Tryon Creek Hydrodynamic Model Calibration

Another measure of model "goodness" is looking at how much runoff flow is generated from a set of storm events with a fixed volume of rainfall. Table 4-3 presents a set design storm generated flow results for the Tryon Creek basin expressed in terms of total event volumes for both rainfall and runoff, and ratio of these two. As shown in the table, although there are variations in model results in terms of unit runoff per acre and runoff coefficient among the basin models, the outputs from the model show a monotonic increase with storm volume,; which is to be expected

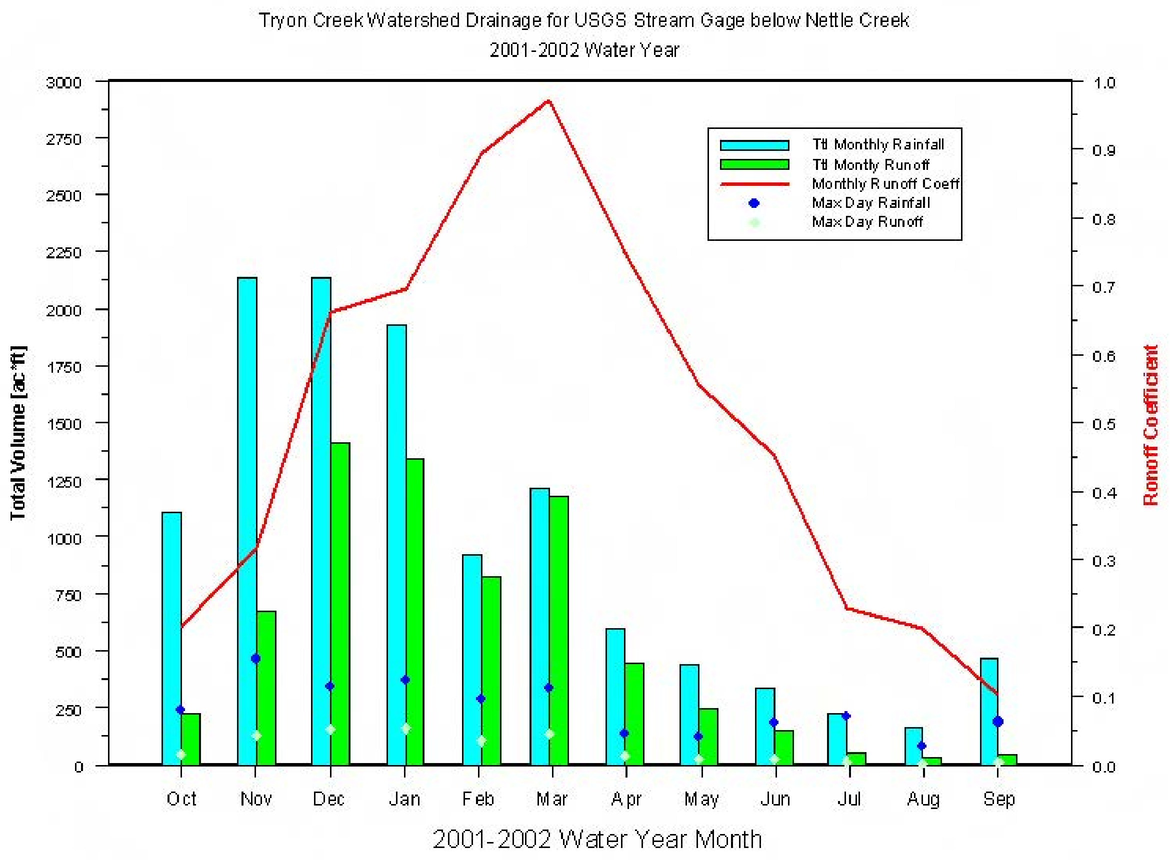
Table 4.3: Design Storm Flow Result for Tryon Creek Basin Model

			Tryon Creek Gage at Boones Ferry Road Basin Area = 4,290 acres				
Storm Event	Date	Rainfall (in.)	Modeled Peak Flow (cfs)	Rainfall Volume (Mgal.)	Total Model Flow Volume (Mgal.)	Modeled Flow Vol. per Acre (Mgal./ac.)	Runoff Coefficient
2-yr	12/1/- 12/2/96	2.53	290.5	294.7	160.9	0.038	0.54
10-yr	12/1/- 12/2/96	3.36	465.1	391.4	219.4	0.051	0.56
25-yr	12/1/- 12/2/96	3.84	587.0	447.3	305.0	0.071	0.68
100-yr	12/1/- 12/2/96	4.49	762.1	523.1	362.5	0.084	0.69

An initial review of the reported runoff coefficients may seem a bit high but further analysis of actual rainfall and stream gage data show that there is quite a bit of temporal variation in the coefficient with very high runoff values during the wet season.. Based on an analysis of the rainfall data from the PCC Sylvania rain gage (the closest gage with a complete record that coincided with the stream flow record) and the USGS Tryon Creek stream gage below Nettle Creek, for the 2001-2002 water year; it was found that the runoff coefficient varied from 0.10 to 0.97 and had a year average of 0.503. The 6-months with the highest rainfall (Oct-Mar) had an average runoff coefficient of 0.623 but the average value for six months (Dec-May) with the highest runoff coefficients was 0.755. The driest months (Apr-Sep) in terms of rainfall had an average runoff coefficient 0.382 whereas the months (Jun-Nov) with the lowest runoff coefficient had an average value of 0.250. Based on when the wettest months in the water year, and when the moths with the highest runoff coefficients occurred, it was found that there is about a 2-month lag time for the basin to reach saturated conditions. The same can be said for the time it takes for the basin to dry-out, by looking at lag time between the months with the lowest amount of rain and the lowest ratio of runoff.

The following figure, Figure 4-3, shows the monthly rainfall and runoff volumes along with the corresponding runoff coefficients. Also included on the figure are points that show the total rainfall and runoff volumes of the peak day for very given month. The display of the peak day can show the seasons where a few storms with either high intensities or high 24-hr volumes account for the total monthly rainfall versus times when any single day accounts for a smaller fraction of the total monthly rainfall. As is the case for the month of July, a single high intensity rainfall event accounted for nearly all the rainfall for the month, whereas for the month of December, the peak day only accounted for about 17% of the monthly total. Also of particular interest

Figure 4.3, Tryon Creek Monthly Precipitation and Runoff Volumes, and Runoff Coefficients



4.2.3 Tryon Creek Results for Design Storms

A

5 Water Quality

Water quality modeling or sampling data analysis has not been conducted at this time. The primary emphasis of the modeling effort for Tryon Creek has been the characterization of flows and flow conditions for use in basin characterization, fish passage analysis, and EDT habitat modeling input which included simulations of existing and pre-development conditions.

6 Discussion & Conclusions

6.1 Appropriate Uses of Model

DHI's MIKE SHE and MIKE 11 models are comprehensive tools for analysis, planning and management of water resources and environmental problems requiring integrated surface water and groundwater analysis. However, the DHI models and their results should be carefully evaluated, reviewed, assessed, and compared against field data whenever possible in watershed decision making process. The modeling results for the Tryon Creek watershed should be used and interpreted with caution due to the model's inherent error in input and observed data, the approximate nature of model formulations, certain simplifications of input data required for maintaining numeric stability during simulations, and uncertain in criteria for model acceptance or rejection. Like any other environmental model, continued testing and verification will help to improve the model performance and therefore make model a more useful and reliable tool.

Based on overview of Tryon Creek hydrodynamic model calibration and verification results, the modeling team recommends the MIKE SHE and MIKE 11 models developed for the Tryon Creek basin be used for the following work:

- Use the model generated flows to evaluate conveyance capacity of major roadway crossings and storm pipes in the watershed and identify culverts and storm pipes which are currently undersized for the appropriate design storm events as defined in City of Portland's Sewer Design Manual.
- Examine and identify places in modeled streams and other open conveyance systems that are prone to flood damages and erosion under relatively large storm events (i.e., storm events that are considered equal or more than a 2-year storm event).
- Provide flow and other hydrologic/hydraulic information in the watershed for ESA habitat modeling efforts.
- Predict flow conditions and other hydrologic/hydraulic parameters under future land use conditions and evaluate the relative impact on hydrodynamics of the watershed due to future development including the sizing of facilities and the selection of detention/stormwater management sites.
- Provide flow information for storm drainage system design and sizing in pres-design activities;
- Provide boundary conditions for more refined smaller scale models that will be developed for detailed capital projects design and evaluation.
- Identify reaches with higher velocities with a greater potential for channel instability.

It should be noted that although the modeling results can be used to estimate flood damages from large storm events, caution should be taken when interpreting simulated water levels for modeled open waterways. The watershed models were limited in producing precise water levels for most open channel segments or identifying places where overbank flow may occur due to lack of survey data and information on channel floodplain configuration.

Cautions also need to be taken when analyzing velocity output from the models. Because MIKE 11 is one-dimensional model, the model does not account for any variation of the velocity distribution over the cross section. Thus simulated velocities may be lower than what would be expected for the main channel of such cross sections. Relying on simulated velocity information exclusively may sometimes under-estimate or over-estimate erosion potential depending on the cross section's area of interest. A further discussion of flow velocity modeling and velocities within the Tryon Creek watershed can be found in a companion technical memorandum to this one on the subject.

6.2 Recommended next steps in model development

The following actions are recommended for next steps in the Tryon Creek watershed model development:

- Collect detailed groundwater data in the watershed and identify location of active springs. The groundwater data would contribute to a better understanding of the dynamics and interactions between surface and groundwater within the watershed and would also constitute a better use of MIKE SHE model capabilities.
- Survey critical roadway crossings, storm pipes and stream cross sections and floodplain that have missing information. These data will help to refine the hydraulic models and therefore produce better results.
- Continue to test and verify model results against existing and new field information.
- Continue to improve model based on updated and new survey information or field data.
- Upgrade MIKE SHE and MIKE 11 model to the most current DHI version to take advantage of the improvements made by DHI in software and therefore improve model performance.
- Add more detail to refine the existing models or develop small-scale detailed models to provide support in capital projects design.
- Collect more water quality data that would include continuous monitoring of temperature and TSS.
- Perform analysis of TSS samples to determine material types and sources such as: organic versus inorganic, in-stream versus upland, or natural versus anthropogenic.

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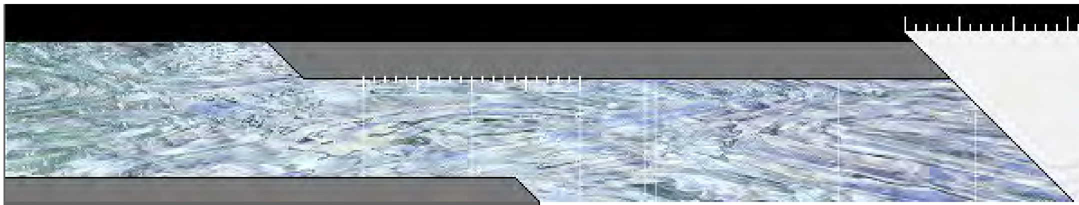

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Assessment of Habitat Potential in the Urban Streams and Rivers of Portland, Oregon

Analysis of Cutthroat Trout Habitat Potential and Limiting Factors for Fanno Creek

August 2005

Prepared for:
City of Portland,
Bureau of Environmental Services

Prepared by:
Mobrand-Jones and Stokes

Assessment of Habitat Potential in the Urban Streams and Rivers of Portland, Oregon

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Analysis of Cutthroat Trout Habitat Potential and Limiting Factors for Fanno Creek

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August 3, 2005

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1. Introduction and Scope

The City of Portland has undertaken an assessment of streams within the City's urban growth boundary in order to identify and prioritize stream restoration priorities and to inform management decisions by the City and other jurisdictions. This paper reports on the assessment of Fanno Creek in Southwest Portland and Washington County. Habitat can be assessed relative to a standard or to the performance of an indicator species. We have assessed habitat in Fanno Creek relative to the needs of cutthroat trout (*Oncorhynchus clarki*) a native fish species typical of small streams in western Oregon. We used cutthroat as an indicator of biological condition of Fanno Creek and believe that the assessment extends beyond cutthroat to address the needs of the larger biological community of Fanno Creek. This report provides the diagnosis of habitat conditions in Fanno Creek with respect to cutthroat trout, and identifies protection and restoration priorities and factors limiting the biological performance of cutthroat trout. This framework will be used by the City to evaluate specific restoration actions and relate them to habitat limitations identified in this assessment.

Fanno Creek has been extensively studied and monitored (City of Portland 1998) and the effects of urbanization are obvious and well documented. The purpose of this evaluation is to synthesize the available information to indicate restoration and protection priorities for Fanno Creek. As a result, the City has brought together existing information into a coherent, scientifically based framework that helps guide the City's restoration activities.

Our assessment treated Fanno Creek as a system and addressed habitat limitations on cutthroat throughout the watershed. However, because of physical barriers and jurisdictional interest, we divided the stream into upper and lower areas corresponding, respectively, to portions of the stream within the interest of the City of Portland and other jurisdictions (primarily Clean Water Services). Because of issues of time and scope, the assessment of lower Fanno Creek is less complete than the assessment of upper Fanno Creek. For example, we only included the Ash Creek tributary in lower Fanno and did not include Summer Creek and other tributaries.

2. Description of the Area

Fanno Creek originates in the Tualatin Mountains in Southwest Portland and flows southward through the Oregon cities of Portland, Beaverton, Tigard and Durham, where it enters the Tualatin River (Figure 1). The creek is approximately 15 miles long and has a drainage basin of 34 square miles (City of Portland 1998). Mean monthly discharge ranges from a low of 7 cubic feet per second (cfs) in August to 101 cfs in December (mean annual discharge = 44 cfs). Major tributaries within the City's Urban Services Boundary (USB) include Ash, Woods, Vermont, and Pendleton creeks. Upper reaches are in relatively steep, forested ravines. However, gradient throughout most of the stream is moderate to low. Soils within the watershed are characterized as highly erodable (City of Portland 1998).

Fanno Creek suffers from anthropogenic ills typical of urban streams in the Pacific Northwest (May et al. 1997a). Urban influences are significant throughout the watershed. Land use in the watershed is predominantly low-density residential and the stream winds through yards and around, and under, parking lots and shopping centers. The stream is intersected by and runs along side a number of major streets and highways. Fanno Creek is on the State of Oregon's 303(d) list due to high levels of phosphorous, nuisance algae, dissolved oxygen and temperature. The stream channel has been straightened and confined throughout its length while riparian vegetation along most of the stream has been removed or replaced by Himalayan blackberry and English ivy (City of Portland 1998).

Fish species in Fanno Creek include (in order of dominance) reticulate sculpin (*Cottus perplexus*), redside shiner (*Richardsonius balteatus*), cutthroat trout (*Oncorhynchus clarki*) and peamouth (*Mylocheilus caurinus*) (City of Portland 1998). Cutthroat trout spawning has been documented in upper Fanno Creek although the population is considered small (City of Portland 1998). Cutthroat life history in Fanno Creek has not been studies extensively, but it is believed that two life history forms exist: a migrant form that spawns in upper Fanno and then moves down into the Tualatin, and a resident form that spends its entire life in Fanno Creek (City of Portland 1998).

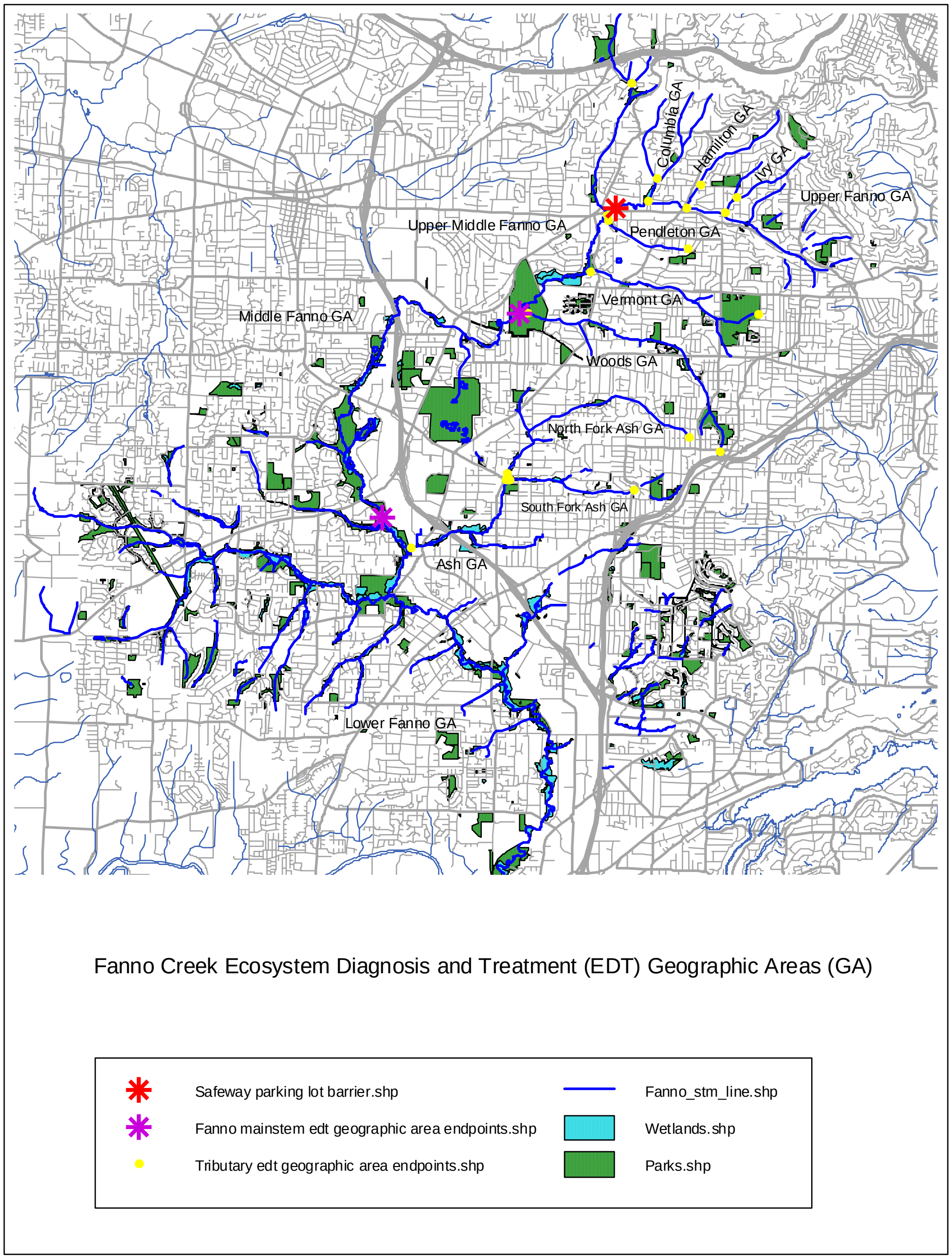

Figure 1. Fanno Creek vicinity map. Geographic areas are referred to in text discussion of results.

3. Methods

3.1 Assessment model

The condition of Fanno Creek was assessed from the perspective of cutthroat trout, which were used as an indicator of an environmental condition. Cutthroat can be thought of as a "biological probe" that was moved across the stream to assess the quality and quantity of habitat. Cutthroat are part of a biological community of aquatic and riparian species in Fanno Creek, the health of which is a function of processes and activities occurring throughout the watershed. Thus, while our assessment uses cutthroat trout as the metric of environmental condition of Fanno Creek, we believe it is indicative of the condition of the stream for the larger biological community and provides insights into the effects of land use on the aquatic community.

To relate the environmental condition in Fanno Creek to cutthroat performance, we used the Ecosystem Diagnosis and Treatment (EDT) model (Lestelle et al. 2004). EDT has been extensively used to assess habitat with respect to salmon species throughout the region including streams within the City of Portland (McConnaha 2003). Its use to assess habitat for a resident salmonid such as cutthroat, while presenting no theoretical difficulties, has required adaptation of the rating rules and procedures. This analysis represents the most complete analysis to date of an urban stream with respect to performance of cutthroat trout.

EDT rates the quality and quantity of habitat in a stream with respect to a fish species, in this case cutthroat trout. The procedure applies a set of species-habitat rules to a reach-level description of an environmental condition to estimate cutthroat performance. We used cutthroat specific rules to compute the biological carrying capacity, reflecting habitat quantity, productivity, reflecting habitat quality, and life history diversity for adult fish. Life history diversity is a measure of the "window of opportunity" for cutthroat or the area and time within Fanno Creek in which suitable conditions exist to support cutthroat trout. Productivity is the ratio between the number of adults spawning in one generation to the number of their surviving adult progeny in the next generation. In this report, productivity will be referred to as the return/spawner a term that is in common use in fisheries management although perhaps more appropriate to anadromous salmonids. Habitat is also characterized in terms of the equilibrium abundance of cutthroat trout, which is calculated from the EDT capacity and productivity and provides a useful summary metric.

An important consideration in interpreting EDT results is that habitat is evaluated in terms of adult, spawning-age cutthroat. The actual abundance of cutthroat present in the stream is larger than the EDT estimate of abundance but will include many juvenile life stages.

To define change in Fanno Creek, we rated the stream under two conditions. The current condition is based on available empirical information on conditions within the stream. This was contrasted to a reference condition that characterizes the intrinsic potential of the stream to support cutthroat trout and is roughly equivalent to the pre-development historical condition. The reference condition was constructed from historical maps and by reference to salmonid habitat benchmarks for western Washington/Oregon streams (Peterson et al. 1992).

3.2 Data Sources

The EDT assessment of Fanno Creek is based on existing information collected from a variety of sources. The Resource Management Plan developed by the City of Portland (City of Portland 1998) provided background information and filled gaps around more detailed analyses of water quality and other factors. Information was collected a reach level with respect to 43 environmental attributes (defined in Lestelle 2004) listed in Appendix 1. Measurements for these 43 attributes are combined in EDT to assess species performance relative to the 11 habitat attributes discussed in the results below. As discussed previously, we defined two environmental conditions in Fanno Creek, a current condition based on empirical data and a reference condition based on historical accounts and regional benchmarks (Peterson et al. 1992).

Stream reaches were defined by the Oregon Department of Fish and Wildlife (ODFW) based on valley form, tributaries, or other features (Table 1). In EDT, obstructions, both natural (waterfalls) and artificial (culverts and dams), are included as "reaches" having a length of zero. The current condition was based on existing data sources. Data for Ash, Woods, Vermont and mainstem Fanno Creek upstream from its confluence with Vermont Creek came from the ODFW Aquatic Inventory Project (AIP) surveys (Moore et al. 1997). The AIP data was also used to identify dams and culverts, all of which were incorporated as obstruction reaches. Fish passage at each culvert was rated based on the comments, such as outfall drop height, contained within the AIP dataset. If there were no comments about a culvert, it was assumed to be fully passable. Beaver dams were also assumed to be fully passable and were not designated as obstruction reaches.

Significant portions of the project area were not surveyed as part of AIP, particularly in lower Fanno. For mainstem Fanno Creek from its confluence with the Tualatin upstream to Vermont Creek and Sylvan Creek, habitat, wetted stream widths, bankfull widths, large woody debris and fine sediment attributes were rated from the Tualatin Watershed 2000 Rapid Stream Assessment Technique dataset (Clean Water Services unpublished data). Pendleton Creek was rated based on qualitative observations noted in the Fanno Creek Resource Management Plan (City of Portland 1998).

To summarize the results, reaches were grouped into Geographic Areas that represented distinct valley segments, tributaries, or other major delineations of the stream (Appendix 2). In this report, results are reported at the Geographic Area scale; reach scale results, however, are provided in Appendix 3.

Information depicting conditions for the current and the historic condition was compiled at the reach scale. Most primary data sources and information were identified and assembled in consultation with City staff. In addition to the literature review, a field reconnaissance was conducted to confirm data and reach delineations.

Table 1. Stream miles and reaches defined in EDT for Fanno Creek.

Stream	Total Stream Miles	Total Reaches (incl. obstructions)	Number of obstruction reaches
Fanno Creek	15.4	52	11
Ash Creek	5.6	75	33
Woods Creek	3.0	44	18
Vermont Creek	2.3	29	9
Pendleton Creek	0.9	5	2
Sylvan Creek	2.3	9	2
Upper Fanno tributaries	2.3	21	8

Flow attribute ratings were based on flow modeling data (MGS Engineering 2001) and the area covered with impervious surfaces within each watershed (City of Portland 1998). Flow patterns were established from 1993-2002 mean daily flow data collected at the USGS gage station on Fanno Creek at SW 56th Ave.

Maximum monthly temperature ratings and patterns were generated from hourly temperature data collected from May through October at Fanno Creek at SW 56th Ave (1998-2004) and Woods Creek at Hideaway Park (1999-2004) by BES. Other streams were scaled to the ratings developed for these two streams based on instantaneous temperature data (Aroner 2000).

Water quality was rated based on Aroner (2000). This included alkalinity, dissolved oxygen, nutrient enrichment, and metals in the water column. Ratings for pollutants characterized the typical condition in the stream and did not address specific point sources or pulsed inputs such as might occur after a storm event.

Aerial photographs and topographical maps were consulted for natural confinement and adjacent landuse. Map Terrain Navigator and Geographic

Information System (GIS) coverages were used to determine reach lengths and gradients, in the absence of other data sources.

3.3 Population Description

Fanno Creek was assessed in regard to its potential to support non-anadromous cutthroat trout. Cutthroat are native to Fanno Creek and the Tualatin basin (Friesen and Ward 1996) and are typical of similar small streams throughout the Pacific Northwest. Cutthroat are sensitive indicators of environmental conditions and are often used as diagnostic species for pollutants and water quality conditions (May et al. 1997a). However, cutthroat are intolerant of competition from other salmonids (Trotter 1997) and predominate in areas where anadromous salmonids are blocked or excluded by environmental conditions. As a result, their abundance relative to coho salmon is often used as an indicator of urbanization or other high-impact land use (May et al. 1997b).

Cutthroat trout, especially non-anadromous populations, display a complex life history (Trotter 1997). This can include forms identified as “resident” that spawn, rear and mature within a limited area of the stream, and “migrants” that may exhibit extended upstream and downstream movement (Hilerbrand 2004). Little is known about the specifics of cutthroat life history in Fanno Creek. Because of this we developed a life history hypothesis based on published accounts of cutthroat trout behavior (Hickman 1982, Trotter 1997, Rosenfeld 2002, Hilerbrand 2004). Our resulting life history hypothesis, summarized in Table 2, describes multiple age classes and includes the potential for both the resident and migrant life histories. Cutthroat were assumed to spawn from week 5 (beginning January 29) to week 13 (ending April 1); egg incubation was assumed to last 3-6 weeks. We evaluated habitat with respect to the resident life history that spends its entire life within Fanno Creek and displays limited movement within the stream. It is likely that a riverine form exists as well that may spawn in Fanno and mature in the Tualatin (City of Portland 1998).

Habitat was assessed for cutthroat at a population level. These populations do not necessarily have a genetic basis but instead represent spawning aggregations that are used to define areas for habitat assessment. Within Fanno Creek, two cutthroat trout areas or populations were designated. The first area, Lower Fanno, included all reaches in Fanno Creek from its confluence with the Tualatin River upstream to the confluence with Woods Creek and all reaches in Ash Creek (note that there are other tributaries in lower Fanno that were not included in the assessment). The second area, Upper Fanno, encompassed all reaches in Fanno Creek from its confluence with Woods Creek to the upper limits of cutthroat habitat, and included Woods, Vermont, Pendleton, Sylvan, Columbia, Hamilton and Ivy creeks.

Table 2. Description of cutthroat population hypothesis used in habitat assessment of Fanno Creek.

Age	% Mature	Fecundity (eggs/female)	% Females	Eggs per spawner
2	47	120	25%	30
3	43	180	50%	90
4	5	400	75%	300

4. Assessment

4.1 Population Potential

EDT was used to estimate the capacity, productivity, life history diversity and equilibrium abundance of cutthroat trout in upper Fanno Creek and separately in lower Fanno Creek. In this discussion, equilibrium abundance has been used as a summary measure of species performance as a function of habitat quantity and quality. Measures of species performance were compared to the estimates under the reference condition to provide an overall measure of the impact of urbanization on Fanno Creek.

It is important to emphasize that the EDT estimates of species performance relate to adult fish and do not include non-spawning or immature life stages. In other words, the estimates of potential cutthroat abundance are not population estimates. A true census of cutthroat in Fanno Creek is undoubtedly larger than indicated here but would include many juvenile and non-spawning fish.

4.1.1 Upper Fanno Creek

Upper Fanno Creek is the portion of the Fanno Creek drainage upstream of and including Woods Creek. It consists of the upper 4.1 miles of the mainstem Fanno Creek and tributaries including Woods, Pendleton, Sylvan creeks and several smaller tributaries (total of 15.3 stream miles). In this analysis, the mainstem was divided into two geographic areas by the long culvert under the Safeway parking lot at Beaverton-Hillsdale Highway, which was assumed to be an impassible barrier to cutthroat.

The equilibrium abundance of adult cutthroat trout in upper Fanno Creek under current habitat conditions was estimated to be around 390 fish (Table 3). This translates to a density of 25.5 adult cutthroat per mile in upper Fanno. The current estimated abundance is an 85 percent reduction in cutthroat trout potential relative to the reference condition and can be related to habitat change in upper Fanno Creek. Current productivity of cutthroat in upper Fanno was estimated to be 2.4 returns/spawner, which is a 75 percent reduction from the historic level. The life history diversity of cutthroat is 14 percent of that estimated in the historic condition. This indicates a considerable narrowing, both spatially and temporally, of the "window of opportunity" within which suitable conditions exist in Fanno Creek for cutthroat trout. These changes reflect the effects of habitat change resulting from urbanization and land use change in the Fanno Creek watershed.

Table 3. Estimated potential of habitat in the Upper Fanno Creek watershed to support adult, spawning cutthroat trout.

Population	Scenario	Diversity index	Productivity (return/spawner)	Adult Capacity	Adult Abundance
Upper Fanno Cutthroat	Current without harvest	14%	2.4	671	393
	Reference potential	100%	10.1	2,797	2,519

4.1.2 Lower Fanno Creek

Lower Fanno Creek consists of the 11-mile mainstem below Woods Creek and the Ash Creek Drainage (total of 16.5 stream miles). Several significant tributaries in lower Fanno were not included in this assessment because of project scope.

The equilibrium abundance of cutthroat trout in lower Fanno Creek under current habitat conditions was estimated to be around 650 adults (Table 4). This is an average density of 39.4 adult cutthroat per mile in lower Fanno Creek. The estimated current abundance is an 83 percent reduction in cutthroat trout potential as a result of habitat limitations in lower Fanno Creek. Current productivity was estimated to be 2.3 returns/spawner, which is an 80 percent reduction from the historic level indicating a considerable loss in potential survival as a result of habitat quality. EDT life history diversity was 17 percent of that in the reference condition as a result of restrictions in habitat along the stream and within a typical year.

Table 4. Estimated potential of habitat in the Lower Fanno Creek watershed to support cutthroat trout.

Population	Scenario	Diversity index	Productivity (return/spawner)	Adult Capacity	Adult Abundance
Lower Fanno Cutthroat	Current without harvest	17%	2.3	1,153	650
	Reference potential	100%	11.1	4,162	3,786

4.2 Protection-Restoration Priorities

Spatial priorities[1] for habitat protection and restoration were addressed using EDT to examine how cutthroat potential changed as current conditions in areas were degraded or restored. Here we report priorities only at the Geographic Area scale but note that reach level priorities within each area are available. Areas that, when degraded within the model, resulted in large changes in population performance, had high protection value for the current potential of the system. Areas with a high protection value can, and in this case do, have significant habitat degradation but are key to the maintenance of the current cutthroat population. In a like manner, the restored reference conditions were substituted in each area to assess the restoration potential. Those areas that showed large increases in population performance when restored were indicated as priorities for restoration.

4.2.1 Upper Fanno Creek

For upper Fanno Creek (Woods Creek and above), the top three areas for protection were Vermont Creek, Woods Creek, and the mainstem section above Beaverton-Hillsdale Highway (Safeway parking lot, Figure 2). This means that these areas, although degraded relative to the reference condition, had the best current conditions in the upper portion of Fanno Creek for cutthroat trout, and that further degradation of these areas would have a significant impact on the current potential of the area for cutthroat trout. On the other hand, the top three areas for restoration in upper Fanno were the mainstem above Safeway, Woods Creek and the mainstem below Safeway down to Woods Creek (Figure 2). Sylvan Creek showed significant restoration potential as well.

4.2.2 Lower Fanno Creek

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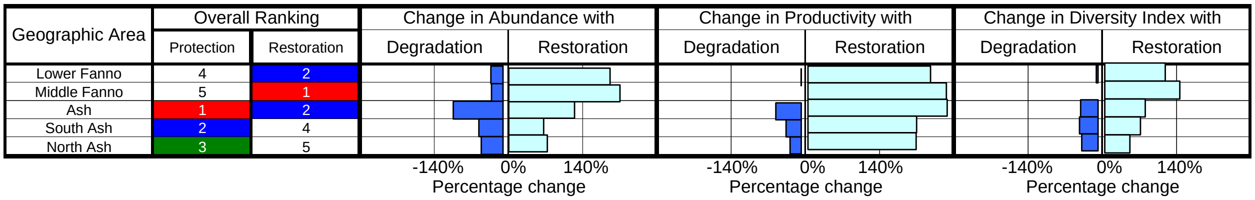
[1] Priorities only address our estimation of cutthroat habitat and do not include social, economic or other biological factors and do not necessarily represent priorities of the City of Portland or other entities.

Lower Fanno Creek-Resident Cutthroat Trout Assessment

Relative Importance Of Geographic Areas For Protection and Restoration Measures



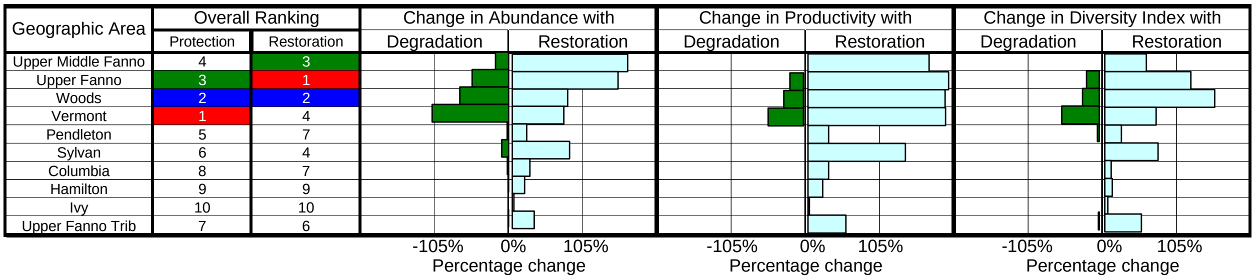
Geographic Area	Overall Ranking	
	Protection	Restoration
Lower Fanno	4	2
Middle Fanno	5	1
Ash	1	2
South Ash	2	4
North Ash	3	5

Figure 3. Restoration and protection rankings for geographic areas within lower Fanno Creek

In lower Fanno Creek, protection priorities for current habitat were confined to Ash Creek, bearing in mind that not all tributaries in lower Fanno Creek are included in this analysis (Figure 3). For restoration, the middle Fanno section had the highest ranking followed by lower Fanno and Ash Creek mainstem, which were tied.

Upper Fanno Creek-Resident Cutthroat Trout Assessment

Relative Importance Of Geographic Areas For Protection and Restoration Measures



Geographic Area	Overall Ranking	
	Protection	Restoration
Upper Middle Fanno	4	3
Upper Fanno	3	1
Woods	2	2
Vermont	1	4
Pendleton	5	7
Sylvan	6	4
Columbia	8	7
Hamilton	9	9
Ivy	10	10
Upper Fanno Trib	7	6

Figure 2. Restoration and protection rankings for geographic areas within upper Fanno Creek

4.3 Limiting Factors

Limiting factors were analyzed by substituting in the model the restored reference condition for each attribute for the current condition and examining the model response. Attributes were ranked in regard to the change in cutthroat performance as each attribute was restored in the model. Here we discuss limiting factors at the geographic area scale. Similar reach level results are provided in Appendix 3. The geographic area scale provides a strategic examination of habitat limitations across upper and lower Fanno Creek while the reach scale focuses on specific locations of habitat limitations.

At each scale, the effect of EDT attributes on cutthroat trout was ranked within a geographic area or reach. For convenience, the top three limiting factors for each geographic area or reach were color-coded. In the figures below, the limiting factors are ranked *within* each geographic area, i.e. across a row. A limiting factor may be ranked high within a geographic area that has relatively limited restoration potential and hence be less important overall compared to a factor with a lower rank in a reach with high restoration potential.

4.3.1 Upper Fanno Area

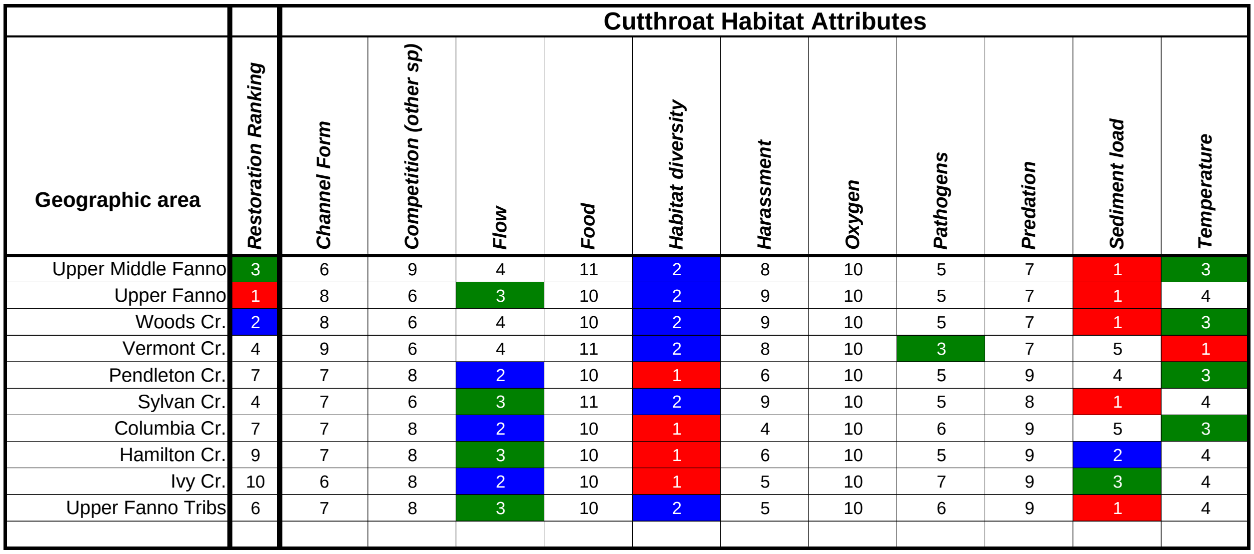
In the upper Fanno area (above Woods Creek) major factors limiting cutthroat abundance were sediment, habitat diversity, high summer water temperature and flow (Figure 4). Within the top ranked restoration areas, Fanno mainstem and Woods Creek, major habitat limiting factors were sediment, habitat diversity and summer water temperature. These three habitat attributes were pervasive problems throughout Fanno Creek and are typical of habitat limitations in urban streams (May et al. 1997a). Sediment, which includes turbidity and deposited sediment, is derived from in-stream processes and street runoff affects success of egg incubation and other life stages. Excessive amounts of fine sediment has also been show to affect the composition of the benthic insect community and impairs salmonid production (Suttle et al. 2005). Habitat diversity is a function of the amount of large wood in the stream that provides cover and controls channel form and habitat development. Large wood is nearly totally lacking in Fanno Creek and is a major habitat limitation.

Habitat structure and diversity is an important stream characteristic for cutthroat and other fish species and is a common limiting factor in urban streams (Booth et al. 1996). Habitat diversity provides cover and structure for juvenile and adult life stages and substrate for food sources such as insects. The habitat diversity attribute in EDT is a function of the amount of large wood and channel structure. The identification of habitat diversity as a key limiting factor throughout upper Fanno reflects the extremely low levels of woody debris and the simplified and confined channel structure.

Flow, both summer low flow as well as stream "flashiness", was a limiting factor especially in the tributaries. Hydrologic modeling indicated that Upper Fanno Creek peak flows have increased approximately 210 percent from predevelopment and the discharge has increased from ~55 cubic feet per second per square mile of drainage area (cfs/sqmi) to ~117 cfs/sqmi (MGS Engineering 2001). A stream is said to be flashy if it responds quickly to storm events. It occurs because precipitation is prevented from entering the water table and instead is transferred rapidly to the stream by overland flow across impervious surfaces. Urbanization of the Fanno Creek watershed has greatly increased impervious surfaces. The mapped impervious area (roofs and impervious substrates) of upper Fanno Creek was estimated as 29% (City of Portland 1998).

4.3.2 Lower Fanno Creek

In lower Fanno Creek (downstream of Woods Creek) major factors limiting cutthroat potential are sediment load, water temperature and habitat diversity (Figure 5). Again, the significant limiting effect of habitat diversity reflects the near total lack of large wood in Fanno Creek. Temperature in lower Fanno Creek was high enough in some areas to potentially produce a pathogen problem for cutthroat trout.



		Cutthroat Habitat Attributes										
Geographic area	Restoration Ranking	Channel Form	Competition (other sp)	Flow	Food	Habitat diversity	Harassment	Oxygen	Pathogens	Predation	Sediment load	Temperature
Upper Middle Fanno	3	6	9	4	11	2	8	10	5	7	1	3
Upper Fanno	1	8	6	3	10	2	9	10	5	7	1	4
Woods Cr.	2	8	6	4	10	2	9	10	5	7	1	3
Vermont Cr.	4	9	6	4	11	2	8	10	3	7	5	1
Pendleton Cr.	7	7	8	2	10	1	6	10	5	9	4	3
Sylvan Cr.	4	7	6	3	11	2	9	10	5	8	1	4
Columbia Cr.	7	7	8	2	10	1	4	10	6	9	5	3
Hamilton Cr.	9	7	8	3	10	1	6	10	5	9	2	4
Ivy Cr.	10	6	8	2	10	1	5	10	7	9	3	4
Upper Fanno Tribs	6	7	8	3	10	2	5	10	6	9	1	4

Figure 4. Habitat attribute rankings for Upper Fanno Creek cutthroat trout by Geographic Area.

Geographic area	Restoration Ranking	Coho Habitat Attributes										
		Channel Form	*Competition (other sp)*	*Flow*	*Food*	*Habitat diversity*	*Harassment*	*Oxygen*	*Pathogens*	*Predation*	*Sediment load*	*Temperature*
Lower Fanno	2	8	9	5	11	3	7	10	4	6	1	2
Middle Fanno	1	7	9	5	11	2	8	10	4	6	1	3
Ash	3	6	7	4	11	2	8	10	5	9	1	3
South Ash	4	5	6	3	10	2	4	10	9	8	1	7
North Ash	5	8	6	4	11	3	9	10	5	7	1	2

Figure 5. Habitat attribute ranking for lower Fanno Creek cutthroat trout by Geographic area.

4.4 Culverts and blockages to fish migration

Culverts and blockages in Fanno Creek are treated separately from other factors because of how they interact with the cutthroat life history. In contrast to anadromous fish, for which culverts can block completion of the life history, cutthroat do not necessarily require clear passage in order to complete their life history. In fact, because of the limiting effect of competition with other salmonids on cutthroat, especially anadromous coho and steelhead, blockages can even benefit cutthroat production (Trotter 1997). This is not to say that blockages and culverts are "good" but rather that they are perceived differently for resident cutthroat than for anadromous salmonids. Passage impediments and blockages caused by culverts likely isolate population elements and prevent normal distribution of life stages within the watershed.

Most culverts in Fanno Creek have not been rated for fish passage. We estimated the impact of culverts on fish movement where data existed; however, where data was lacking we had to assume no effect. This is likely not the case and personal observation of culverts in Fanno Creek lead to the conclusion that most have at least some impact of fish movement within the stream. To the extent that culverts do affect fish movement, we have underestimated their impact.

In Table 5, we summarize the statistics for culverts and blockages in Fanno Creek that could affect cutthroat potential. Blockages other than culverts include dams constructed to create ponds. Throughout Fanno Creek, we included a total of 83 culverts. Ash Creek has the most of any section of the creek included in this analysis. However, there are likely many additional culverts in tributaries that we did not include, especially in the lower Fanno area. Each culvert has a length that may seem minor but collectively represents a significant reduction in length and area of habitat in Fanno Creek. In fact, over a mile of Fanno Creek is devoted to culverts, which provide little or no habitat value. Ash Creek alone has 0.4 miles of culverts.

Table 5. Culverts and blockages in Fanno Creek

Area	Number	Length (ft.)
Upper Fanno mainstem	11	1,801
Woods Creek	18	1,042
Vermont Creek	9	765
Upper Fanno Tributaries	12	1,358
Ash Creek	33	2,163
Total	83	5,328

4.5 Pollutants

Perhaps a surprising result of the limiting factors analysis is that pollutants do not appear as an important factor anywhere in Fanno Creek. Urban streams often have a multitude of pollutant issues that affect salmonids and other species (May et al. 1997a) and, indeed, Fanno Creek is a 303(D) listed stream. One reason why pollutants does not come up as a significant limiting attribute in this analysis is that we define the Pollutant attribute in terms of chemical inputs to the stream such as heavy metals, pesticides or other substances. Other attributes of water quality (including those in the 303(D) listing) such as flow, temperature and turbidity are treated as separate attributes (for example, Figure 5).

Although chemical pollutants did not appear as a major limiting factor for cutthroat in Fanno Creek, it would be premature to assume that pollutants were not a potential problem in Fanno Creek. In fact, Aroner (2000) reported levels of copper, lead and zinc during the 1990's that potentially exceeded his threshold of impact on aquatic life, although levels of arsenic, cadmium, chromium and zinc were below his impact criteria. He also found lower values of iron during summer months and an increase in levels in the fall suggesting a wash-off process.

Although Aroner (2000) provides a detailed examination of pollutants in Fanno Creek from 1990-99, significant development of the Fanno Creek watershed has occurred since that time that could increase pollutant levels. There is a need to regularly monitor water quality, particularly in rapidly developing areas where conditions can change quickly. Aroner also did not assess the stream with regard to pesticides and other chemicals that are significant detriments in other Portland streams (Tanner and Lee 2004). Water quality monitoring should also be address pollutant dynamics including timing and pathways for pollutants. Metals and other pollutants in urban streams can appear sporadically or peak with "first flush" storm events (Pitt et al. 1995). The question of whether the first big fall storms wash off metals and other pollutants from streets into the creek is also unresolved and should be investigated.

Conclusions and Recommendations

1. The study has identified and prioritized restoration and protection priorities at both geographic area and reach scales that can guide organization of restoration efforts.
2. Specific limiting factors for cutthroat have been identified at course and reach scales that can be addressed through restoration and management actions.
3. An analytical framework for restoration and management of habitat in Fanno Creek has been created based on empirical data and existing scientific knowledge.
   a. The analytical framework can be used to evaluate restoration actions across the Fanno Creek drainage.
   b. The framework also provides structure and guidance for environmental monitoring and evaluation of restoration efforts.
4. The assessment has demonstrated the extent of habitat alteration and the remaining potential for cutthroat trout.
   a. Human-caused habitat changes have appreciably diminished the potential of Fanno Creek to produce cutthroat trout.
   b. Throughout Fanno Creek, habitat potential has been decreased by loss of Habitat Diversity, change in Flow, increased Temperature and increased Sediment.
5. Suggestions for improvements and refinements that would increase the value of the assessment:
   a. Water quality—systematic reporting of pollutant levels including pesticides and other chemicals.
   b. Pollutant sources and relation to storm events
   b. Fish passage impacts at culverts and blockages
   c. Inclusion of tributaries in lower Fanno Creek
   d. Expansion of study to include Tualatin River and connectivity to cutthroat in Fanno Creek.

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Appendix 1
Environmental Attributes used to describe Fanno Creek in Ecosystem Diagnosis and Treatment

Hydrologic Characteristics		
AttrCode	AttributeName	Attribute Definition
FlwHigh	Flow - change in interannual variability in high flows	The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Evidence of change in peak flow can be empirical where sufficiently long data series exists, can be based on indicator metrics (such as TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development. Relative change in peak annual discharge here is based on changes in the peak annual flow expected on average once every two years (Q2yr).
FlwLow	Flow - changes in interannual variability in low flows	The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Evidence of change in low flow can be empirically-based where sufficiently long data series exists, or known through flow regulation practices, or inferred from patterns corresponding to watershed development. Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.
FlwDielVar	Flow - Intra daily (diel) variation	Average diel variation in flow level during a season or month. This attribute is informative for rivers with hydroelectric projects or in heavily urbanized drainages where storm runoff causes rapid changes in flow.
FlwIntraAnn	Flow - intra-annual flow pattern	The average extent of intra-annual flow variation during the wet season -- a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with % total impervious area and road density, but is attenuated as drainage area increases. Evidence for change can be empirically derived using flow data (e.g., using the metric TQmean, see Konrad [2000]), or inferred from patterns corresponding to watershed development.
HydroRegime-Natural	Hydrologic regime - natural	The natural flow regime within the reach of interest. Flow regime typically refers to the seasonal pattern of flow over a year; here it is inferred by identification of flow sources. This applies to an unregulated river or to the pre-regulation state of a regulated river.
HydroRegime-Reg	Hydrologic regime - regulated	The change in the natural hydrograph caused by the operation of flow regulation facilities (e.g., hydroelectric, flood storage, domestic water supply, recreation, or irrigation supply) in a watershed. Definition does not take into account daily flow fluctuations (See Flow-Intra-daily variation attribute).

Stream Corridor Structure		
AttrCode	AttributeName	Attribute Definition
ChLngth	Channel length	Length of the primary channel contained with the stream reach -- Note: this attribute will not be given by a categories but rather will be a point estimate. Length of channel is given for the main channel only--multiple channels do not add length.
WidthMx	Channel month Maximum width (ft)	Average width of the wetted channel during peak flow month (average monthly conditions). If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.
WidthMn	Channel month Minimum width (ft)	Average width of the wetted channel. If the stream is braided or contains multiple channels, then the width would represent the sum of the wetted widths along a transect that extends across all channels. Note: Categories are not to be used for calculation of wetted surface area; categories here are used to designate relative stream size.

Grad	Gradient	Average gradient of the main channel of the reach over its entire length. Note: Categorical levels are shown here but values are required to be input as point estimates for each reach.
Confine	Confinement - natural	The extent that the valley floodplain of the reach is confined by natural features. It is determined as the ratio between the width of the valley floodplain and the bankful channel width. Note: this attribute addresses the natural (pristine) state of valley confinement only.
ConfineHydro	Confinement - Hydromodifications	The extent that man-made structures within or adjacent to the stream channel constrict flow (as at bridges) or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment (associated with the process called "headcutting"). Flow access to the floodplain can be partially or wholly cutoff due to channel incision. Note: Setback levees are to be treated differently than narrow-channel or riverfront levees--consider the extent of the setback and its effect on flow and bed dynamics and micro-habitat features along the stream margin in reach to arrive at rating conclusion. Reference condition for this attribute is the natural, undeveloped state.
HbPls	Habitat type - primary pools	Percentage of the wetted channel surface area comprising pools, excluding beaver ponds
HbPlTails	Habitat type - pool tailouts	Percentage of the wetted channel surface area comprising pool tailouts.
HbBckPls	Habitat type - backwater pools	Percentage of the wetted channel surface area comprising backwater pools.
HbBvrPnds	Habitat type - beaver ponds	Percentage of the wetted channel surface area comprising beaver ponds. Note: these are pools located in the main or side channels, not part of off-channel habitat.
HbGlide	Habitat type - Glides	Percentage of the wetted channel surface area comprising glides. Note: There is a general lack of consensus regarding the definition of glides (Hawkins et al. 1993), despite a a commonly held view that it remains important to recognize a habitat type that is intermediate between pool and riffle. The definition applied here is from the ODFW habiat survey manual (Moore et al. 1997): an area with generally uniform depth and flow with no surface turbulence, generally in reaches of <1% gradient. Glides may have some small scour areas but are distinguished from pools by their overall homogeneity and lack of structure. They are generally deeper than riffles with few major flow obstructions and low habitat complexity.
HbLrgCbl	Habitat type - large cobble/boulder riffles	Percentage of the wetted channel surface area comprising large cobble/boulder riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et a. (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).
HbSmlCbl	Habitat type - small cobble/gravel riffles	Percentage of the wetted channel surface area comprising small cobble/gravel riffles. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et a. (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).
HbOfChFctr	Habitat type - off-channel habitat factor	A multiplier used to estimate the amount of off-channel habitat based on the wetted surface area of the all combined in-channel habitat.
Obstr	Obstructions to fish migration	Obstructions to fish passage by physical barriers (not dewatered channels or hinderances to migration caused by pollutants or lack of oxygen). Note: Rating here is used as a flag in the database. The nature of the obstruction is required to be defined more carefully in a follow-up form.
Wdrwl	Water withdrawals	The number and relative size of water withdrawals in the stream reach.
BdScour	Bed scour	Average depth of bed scour in salmonid spawning areas (i.e., in pool-tailouts and small cobble-gravel riffles) during the annual peak flow event over approximately a 10-year period. The range of annual scour depth over the period could vary substantially. Particle sizes of substrate modified from Platts et al. (1983) based on information in Gordon et a. (1991): gravel (0.2 to 2.9 inch diameter), small cobble (2.9 to 5 inch diameter), large cobble (5 to 11.9 inch diameter), boulder (>11.9 inch diameter).

Icing	Icing	Average extent (magnitude and frequency) of icing events over a 10-year period. Icing events can have severe effects on the biota and the physical structure of the stream in the short-term. It is recognized that icing events can under some conditions have long-term beneficial effects to habitat structure.
RipFunc	Riparian function	A measure of riparian function that has been altered within the reach.
WdDeb	Wood	The amount of wood (large woody debris or LWD) within the reach. Dimensions of what constitutes LWD are defined here as pieces >0.1 m diameter and >2 m in length. Numbers and volumes of LWD corresponding to index levels are based on Peterson et al. (1992), May et al. (1997), Hyatt and Naiman (2001), and Collins et al. (2002). Note: channel widths here refer to average wetted width during the high flow month (< bank full), consistent with the metric used to define high flow channel width. Ranges for index values are based on LWD pieces/CW and presence of jams (on larger channels). Reference to "large" pieces in index values uses the standard TFW definition as those > 50 cm diameter at midpoint.
Emb	Embeddedness	The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays. Embeddedness is determined by examining the extent (as an average %) that cobble and gravel particles on the substrate surface are buried by fine sediments. This attribute only applies to riffle and tailout habitat units and only where cobble or gravel substrates occur.
FnSedi	Fine sediment	Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles. Definition of "fine sediment" here depends on the particle size of primary concern in the watershed of interest. In areas where sand size particles are not of major interest, as they are in the Idaho Batholith, the effect of fine sediment on egg to fry survival is primarily associated with particles <1mm (e.g., as measured by particles <0.85 mm). Sand size particles (e.g., <6 mm) can be the principal concern when excessive accumulations occur in the upper stratum of the stream bed (Kondolf 2000). See guidelines on possible benefits accrued due to gravel cleaning by spawning salmonids.
Turb	Turbidity	The severity of suspended sediment (SS) episodes within the stream reach. (Note: this attribute, which was originally called turbidity and still retains that name for continuity, is more correctly thought of as SS, which affects turbidity.) SS is sometimes characterized using turbidity but is more accurately described through suspended solids, hence the latter is to be used in rating this attribute. Turbidity is an optical property of water where suspended, including very fine particles such as clays and colloids, and some dissolved materials cause light to be scattered; it is expressed typically in nephelometric turbidity units (NTU). Suspended solids represents the actual measure of mineral and organic particles transported in the water column, either expressed as total suspended solids (TSS) or suspended sediment concentration (SSC)—both as mg/l. Technically, turbidity is not SS but the two are usually well correlated. If only NTUs are available, an approximation of SS can be obtained through relationships that correlate the two. The metric applied here is the Scale of Severity (SEV) Index taken from Newcombe and Jensen (1996), derived from: SEV = a + b(lnX) + c(lnY) , where, X = duration in hours, Y = mg/l, a = 1.0642 , b = 0.6068, and c = 0.7384. Duration is the number of hours out of month (with highest SS typically) when that concentration or higher normally occurs. Concentration would be represented by grab samples reported by USGS. See rating guidelines.

Water Quality

AttrCode	AttributeName	Attribute Definition
Alka	Alkalinity	Alkalinity, or acid neutralizing capacity (ANC), measured as milliequivalents per liter or mg/l of either HCO3 or CaCO3.
DisOxy	Dissolved oxygen	Average dissolved oxygen within the water column for the specified time interval.
MetSedSls	Metals/Pollutants - in sediments/soils	The extent of heavy metals and miscellaneous toxic pollutants within the stream sediments and/or soils adjacent to the stream channel.

MetWatCol	Metals - in water column	The extent of dissolved heavy metals within the water column.
MscToxWat	Miscellaneous toxic pollutants - water column	The extent of miscellaneous toxic pollutants (other than heavy metals) within the water column.
NutEnrch	Nutrient enrichment	The extent of nutrient enrichment (most often by either nitrogen or phosporous or both) from anthropogenic activities. Nitrogen and phosphorous are the primary macro-nutrients that enrich streams and cause build ups of algae. These conditions, in addition to leading to other adverse conditions, such as low DO can be indicative of conditions that are unhealthy for salmonids.Note: care needs to be applied when considering periphyton composition since relatively large mats of green filamentous algae can occu in Pacific Northwest streams with no nutrient enrichment when exposed to sunlight.
TmpMonMx	Temperature - daily maximum (by month)	Maximum water temperatures within the stream reach reach during a month.
TmpMonMn	Temperature - daily minimum (by month)	Minimum water temperatures within the stream reach reach during a month.
TmpSptVar	Temperature - spatial variation	The extent of water temperature variation within the reach as influenced by inputs of groundwater.

Biological Community

AttrCode	AttributeName	Attribute Definition
FshComRch	Fish community richness	Measure of the richness of the fish community (no. of fish taxa, i.e., species).
FshPath	Fish pathogens	The presence of pathogenic organisms (relative abundance and species present) having potential for affecting survival of stream fishes.
FSpIntro	Fish species introductions	Measure of the richness of the fish community (no. of fish taxa). Taxa here refers to species.
Harass	Harassment	The relative extent of poaching and/or harassment of fish within the stream reach.
HatFOutp	Hatchery fish outplants	The magnitude of hatchery fish outplants made into the drainage over the past 10 years. Note: Enter specific hatchery release numbers if the data input tool allows. "Drainage" here is defined loosely as being approximately the size that encompasses the spawning distribution of recognized populations in the watershed.
PredRisk	Predation risk	Level of predation risk on fish species due to presence of top level carnivores or unusual concentrations of other fish eating species. This is a classification of per-capita predation risk, in terms of the likelihood, magnitude and frequency of exposure to potential predators (assuming other habitat factors are constant). NOTE: This attribute is being updated to distinguish risk posed to small bodied fish (<10 in) from that to large bodied fish (>10 in).
SalmCarcass	Salmon Carcasses	Relative abundance of anadromous salmonid carcasses within watershed that can serve as nutrient sources for juvenile salmonid production and other organisms. Relative abundance is expressed here as the density of salmon carcasses within subdrainages (or areas) of the watershed, such as the lower mainstem vs the upper mainstem, or in mainstem areas vs major tributary drainages.
BenComRch	Benthos diversity and production	Measure of the diversity and production of the benthic macroinvertebrate community. Three types of measures are given (choose one): a simple EPT count, Benthic Index of Biological Integrity (B-IBI)—a multimetric approach (Karr and Chu 1999), or a multivariate approach using the BORIS (Benthic evaluation of ORegon RIverS) model (Canale 1999). B-IBI rating definitions from Morley (2000) as modified from Karr et al. (1986). BORIS score definitions based on ODEQ protocols, after Barbour et al. (1994).

Appendix 2. Fanno Creek Ecosystem Diagnosis and Treatment Reach Structure

Geographic Area	Cutthroat Population		Reach Name	Reach Description	RM at DS end	Reach Length (mi)	Gradient
Lower Fanno	L		Fanno01	Fanno Creek from Tualatin River to end of RSAT Reach FL10	0.0	0.758	0.00%
Lower Fanno	L		Fanno02	Fanno Creek RSAT Reach FL09	0.8	0.658	0.00%
Lower Fanno	L		Fanno03	Fanno Creek RSAT Reach FL08 (includes Ball Creek confluence (LB))	1.4	0.598	0.00%
Lower Fanno	L		Fanno04	Fanno Creek RSAT Reach FL12	2.0	0.664	0.00%
Lower Fanno	L		Fanno05	Fanno Creek RSAT Reach FL06 (includes Red Rock Creek confluence (LB))	2.7	0.775	0.00%
Lower Fanno	L		Fanno06	Fanno Creek RSAT Reach FL11	3.5	1.018	0.00%
Lower Fanno	L		Fanno07	Fanno Creek RSAT Reach FL01 to Derry Dell Creek (RB)	4.5	0.763	0.00%
Lower Fanno	L		Fanno08	Fanno Creek RSAT Reach FU01 (includes Summer Creek confluence (RB))	5.2	0.492	0.00%
Lower Fanno	L		Fanno09a	Fanno Creek RSAT Reach FU02 to Ash Creek (LB)	5.7	0.610	0.00%
Middle Fanno	L		Fanno09b	Fanno Creek RSAT Reach FU02 from Ash Creek (LB) to Hiteon Creek (RB)	6.3	0.100	0.00%
Middle Fanno	L		Fanno10	Fanno Creek RSAT Reach FU03	6.4	0.651	0.00%
Middle Fanno	L		Fanno11	Fanno Creek RSAT Reach FU06	7.1	0.521	0.00%
Middle Fanno	L		Fanno12	Fanno Creek RSAT Reach FU07	7.6	0.694	0.00%
Middle Fanno	L		Fanno13	Fanno Creek RSAT Reach FU16	8.3	0.584	0.00%
Middle Fanno	L		Fanno14	Fanno Creek RSAT Reach FU08	8.9	0.752	0.00%
Middle Fanno	L		Fanno15	Fanno Creek RSAT Reach FU09	9.6	0.507	0.00%

Middle Fanno	L		Fanno16_A	Fanno Creek RSAT Reach FU17 to Woods Creek (LB)	10.1	0.762	0.00%
Upper Middle Fanno		U	Fanno16_B	Fanno Creek RSAT Reach FU17 from Woods Creek (LB) to Vermont Creek (LB)	10.9	1.000	0.00%
Upper Middle Fanno		U	Fanno21_01_A	Fanno Creek from Vermont Creek to Pendleton Creek	11.9	0.615	0.10%
Upper Middle Fanno		U	Fanno21_01_B	Fanno Creek from Pendleton Creek to Sylvan Creek	12.5	0.002	0.10%
Upper Middle Fanno		U	Fanno21_01_C	Fanno Creek from Sylvan Creek to the Beaverton Hillsdale HWY	12.5	0.002	0.10%
Upper Fanno		U	Fanno21_02(obstrcc)	Fanno Creek culvert - BVTN. HILLSDALE HWY;2.4M METAL	12.5		
Upper Fanno		U	Fanno21_03_A	Fanno Creek Beaverton Hillsdale Culvert Length Reach	12.5	0.114	1.20%
Upper Fanno		U	Fanno21_03_B	Fanno Creek from upstream end of BVTN. HILLSDALE HWY culvert to Pendleton(Fanno21.03) and PRIVATE DRIVEWAY culver	12.6	0.072	1.20%
Upper Fanno		U	Fanno21_04(obstrcc)	Fanno Creek PRIVATE DRIVEWAY culvert 1.9M METAL	12.7		
Upper Fanno		U	Fanno21_05	Fanno Creek from Private driveway culvert to parking lot culvert	12.7	0.091	0.60%
Upper Fanno		U	Fanno21_06(obstrcc)	Fanno Creek parking lot culvert	12.8		
Upper Fanno		U	Fanno21_07	Fanno Creek from parking lot culvert to Columbia(Fanno21.07) (upper end of AIP Reach 1)	12.8	0.124	0.30%
Upper Fanno		U	Fanno22_01	Fanno Creek from Columbia(Fanno21.07) to SW Shattuck Rd (beginning of AIP reach 2)	12.9	0.415	0.40%
Upper Fanno		U	Fanno22_02(obstrcc)	Fanno Creek SW Shattuck Rd box	13.3		

				culvert			
Upper Fanno		U	Fanno22_03	Fanno Creek from SW Shattuck Rd box culvert to unnamed tributary Trib(Fanno22.03)	13.3	0.062	0.70%
Upper Fanno		U	Fanno23_01	Fanno Creek from Trib(Fanno22.03) to SW 45th Ave culvert (beginning of AIP Reach 3)	13.4	0.543	0.60%
Upper Fanno		U	Fanno23_02(obstrcc)	Fanno Creek SW 45th Ave culvert	13.9		
Upper Fanno		U	Fanno23_03	Fanno Creek from SW 45th Ave culvert to Ivy(Fanno23.03) (end of AIP Reach 3)	13.9	0.028	1.80%
Upper Fanno		U	Fanno24_01	Fanno Creek from Ivy(Fanno23.03) confluence to SW 43rd Ave (beginning of AIP Reach 4)	14.0	0.146	0.50%
Upper Fanno		U	Fanno24_02(obstrcc)	Fanno Creek SW 43rd Ave culvert	14.1		
Upper Fanno		U	Fanno24_03	Fanno Creek from SW 43rd Ave culvert to unnamed tributary Trib(Fanno24.03) (end of AIP Reach 4)	14.1	0.236	0.70%
Upper Fanno		U	Fanno25_01	Fanno Creek from Trib(Fanno24.03) to SW 39th Dr culvert (beginning of AIP Reach 5)	14.4	0.028	0.30%
Upper Fanno		U	Fanno25_02(obstrcc)	Fanno Creek SW 39th Dr culvert	14.4		
Upper Fanno		U	Fanno25_03	Fanno Creek from SW 39th Dr culvert to unnamed tributary Trib(Fanno25.03)	14.4	0.073	0.70%
Upper Fanno		U	Fanno25_04	Fanno Creek from Trib(Fanno25.03) to SW 35th Ave	14.5	0.306	1.50%
Upper Fanno		U	Fanno25_05(obstrcc)	Fanno Creek SW 35th Ave culvert	14.8		
Upper Fanno		U	Fanno25_06	Fanno Creek from SW 35th Ave to Beaverton Hillsdale HWY	14.8	0.135	0.80%
Upper Fanno		U	Fanno25_07(obstrcc)	Fanno Creek Beaverton Hillsdale HWY culvert	14.9		

Upper Fanno		U	Fanno25_08	Fanno Creek from Beaverton Hillsdale HWY to SW 30th	14.9	0.052	1.60%
Upper Fanno		U	Fanno25_09(obstrcc)	Fanno Creek SW 30th culvert	15.0		
Upper Fanno		U	Fanno25_10	Fanno Creek from SW 30th culvert to unnamed tributary Trib(Fanno25.10) (upper end of AIP Reach 5)	15.0	0.083	1.20%
Upper Fanno		U	Fanno26_01	Fanno Creek from Trib(Fanno25.10) to private driveway culvert	15.0	0.008	1.20%
Upper Fanno		U	Fanno26_02(obstrcc)	Fanno Creek private driveway culvert	15.0		
Upper Fanno		U	Fanno26_03	Fanno Creek from private driveway culvert to unnamed tributary Trib(26.03)	15.0	0.030	0.60%
Upper Fanno		U	Fanno26_04	Fanno Creek from unnamed tributary Trib(Fanno26.03) to unmapped tributary Trib(Fanno26.04)	15.1	0.209	4.50%
Upper Fanno		U	Fanno26_05	Fanno Creek from Trib(Fanno26.04) to upper extent of AIP survey	15.3	0.145	7.00%
Ash	L		Ash1_01	Ash Creek From Fanno Creek to culvert	0.0	0.031	0.10%
Ash	L		Ash1_02(obstrcc)	Ash Creek culvert	0.0		
Ash	L		Ash1_03	Ash Creek from culvert to culvert at SW 95th and HWY217	0.0	0.746	0.10%
Ash	L		Ash1_04(obstrcc)	Ash Creek culvert at SW 95th and HWY217	0.8		
Ash	L		Ash1_05	Ash Creek from culvert at SW 95th and HWY217 to old IRR Dam	0.8	0.303	0.20%
Ash	L		Ash1_06(obstrdam)	Ash Creek old IRR Dam	1.1		
Ash	L		Ash1_07	Ash Creek from old IRR Dam to SW Locust box culvert	1.1	0.317	0.30%
Ash	L		Ash1_08(obstrcc)	Ash Creek SW Locust box culvert	1.4		
Ash	L		Ash1_09	Ash Creek from SW Locust box culvert to	1.4	0.257	0.50%

				SW 80th culvert			
Ash	L		Ash1_10(obstrcc)	Ash Creek SW 80th culvert	1.7		
Ash	L		Ash1_11	Ash Creek from SW 80th culvert to North Ash	1.7	0.017	0.20%
South Ash	L		AshS2_01	South Ash Creek from North Ash to private driveway culvert (beginning of AIP Reach 2)	1.7	0.009	1.50%
South Ash	L		AshS2_02(obstrcc)	South Ash Creek private driveway culvert	1.7		
South Ash	L		AshS2_03	South Ash Creek from private driveway culvert SW 82nd culvert	1.7	0.098	0.70%
South Ash	L		AshS2_04(obstrcc)	South Ash Creek SW 82nd culvert	1.8		
South Ash	L		AshS2_05	South Ash Creek from SW 82nd culvert to SW 80th culvert	1.8	0.154	0.20%
South Ash	L		AshS2_06(obstrcc)	South Ash Creek SW 80th culvert	1.9		
South Ash	L		AshS2_07	South Ash Creek from SW 80th culvert to dry reach	1.9	0.196	0.60%
South Ash	L		AshS2_08(obstrDry)	South Ash Creek seasonally dry reach	2.1		
South Ash	L		AshS2_09	South Ash Creek seasonally dry reach	2.1	0.002	1.00%
South Ash	L		AshS2_10	South Ash Creek from seasonally dry reach to culvert	2.1	0.164	0.30%
South Ash	L		AshS2_11(obstrcc)	South Ash Creek culvert	2.3		
South Ash	L		AshS2_12	South Ash Creek from culvert to end of AIP Reach 2	2.3	0.003	0.50%
South Ash	L		AshS3_01	South Ash Creek from culvert to (beginning of AIP Reach3) dry reach	2.3	0.125	0.60%
South Ash	L		AshS3_02(ObstrDry)	South Ash Creek dry reach (obstr)	2.4		
South Ash	L		AshS3_03	South Ash Creek dry reach	2.4	0.003	9.00%

South Ash	L		AshS3_04	South Ash Creek from dry reach to backyard dam	2.4	0.220	2.00%
South Ash	L		AshS3_05(obstrdam)	South Ash Creek backyard dam	2.6		
South Ash	L		AshS3_06	South Ash Creek from backyard dam to SW Ventura Dr culvert	2.6	0.026	4.40%
South Ash	L		AshS3_07(obstrcc)	South Ash Creek SW Ventura Dr culvert	2.7		
South Ash	L		AshS3_08	South Ash Creek from SW Ventura Dr culvert to step structure	2.7	0.029	4.70%
South Ash	L		AshS3_09(obstrss)	South Ash Creek step structure 0.2m high	2.7		
South Ash	L		AshS3_10	South Ash Creek from step structure to unmapped tributary (Trib(Ash3.10)	2.7	0.090	6.60%
South Ash	L		AshS3_11	South Ash Creek from Trib(Ash3.10) to culvert at county boundary	2.8	0.021	9.60%
South Ash	L		AshS3_12(obstrcc)	South Ash Creek culvert at county boundary	2.8		
South Ash	L		AshS3_13	South Ash Creek from culvert at county boundary to step structure	2.8	0.093	3.00%
South Ash	L		AshS3_14(obstrss)	South Ash Creek step structure 0.5 m high	2.9		
South Ash	L		AshS3_15	South Ash Creek from step structure to exposed sewer pipe obstruction	2.9	0.080	3.20%
South Ash	L		AshS3_16(obstrss)	South Ash Creek exposed sewer pipe obstruction	3.0		
South Ash	L		AshS3_16b	South Ash Creek from exposed sewer pipe obstruction to SW Lauradel culvert	3.0	0.070	3.20%
South Ash	L		AshS3_17(obstrcc)	South Ash Creek SW Lauradel culvert	3.1		
South Ash	L		AshS3_18	South Ash Creek from SW Lauradel culvert to SW 62nd culvert	3.1	0.045	3.30%
South Ash	L		AshS3_19(obstrcc)	South Ash Creek SW 62nd culvert	3.1		

South Ash	L		AshS3_20	South Ash Creek from SW 62nd culvert to walking path culvert	3.1	0.092	9.70%
South Ash	L		AshS3_21(obstrcc)	South Ash Creek walking path culvert	3.2		
South Ash	L		AshS3_22	South Ash Creek from walking path culvert to vertical culvert	3.2	0.175	4.00%
South Ash	L		AshS3_23(obstrcc)	South Ash Creek vertical culvert	3.4		
South Ash	L		AshS3_24	South Ash Creek from vertical culvert to culvert	3.4	0.004	0.50%
South Ash	L		AshS3_25(obstrcc)	South Ash Creek culvert	3.4		
South Ash	L		AshS3_26	South Ash Creek from culvert to the end of AIP Reach 3	3.4	0.022	10.50%
South Ash	L		Trib(Ash3_10)-01	Trib(Ash3.10) from Ash Creek to upper extent of AIP survey	0.0	0.010	6.00%
North Ash	L		AshN1_01	North Ash Creek from Ash Creek to private driveway culvert	0.0	0.006	0.50%
North Ash	L		AshN1_02(obstrcc)	North Ash Creek private driveway culvert	0.0		
North Ash	L		AshN1_03	North Ash Creek from private driveway culvert to concrete slide and dam	0.0	0.056	0.50%
North Ash	L		AshN1_04(obstrdam)	North Ash Creek concrete slide and dam	0.1		
North Ash	L		AshN1_05	North Ash Creek from concrete slide and dam to SW Cedarcrest	0.1	0.181	0.30%
North Ash	L		AshN1_06(obstrcc)	North Ash Creek SW Cedarcrest	0.2		
North Ash	L		AshN1_07	North Ash Creek from SW Cedarcrest to SW 80th	0.2	0.480	0.30%
North Ash	L		AshN1_08(obstrcc)	North Ash Creek SW 80th	0.7		
North Ash	L		AshN1_09	North Ash Creekfrom SW 80th to private driveway culvert	0.7	0.124	0.70%
North Ash	L		AshN1_10(obstrcc)	North Ash Creek private driveway culvert	0.8		

North Ash	L		AshN1_11	North Ash Creek fom private driveway culvert to SW 74th culvert	0.8	0.238	0.80%
North Ash	L		AshN1_12(obstrcc)	North Ash Creek SW 74th culvert	1.1		
North Ash	L		AshN1_13	North Ash Creek from SW 74th culvert to old driveway	1.1	0.097	0.70%
North Ash	L		AshN1_14(obstrcc)	North Ash Creek old driveway	1.2		
North Ash	L		AshN1_15	North Ash Creek from old driveway to SW Dolph	1.2	0.512	0.90%
North Ash	L		AshN1_16(obstrcc)	North Ash Creek SW Dolph	1.7		
North Ash	L		AshN1_17	North Ash Creek from SW Dolph to end of AIP Reach 1	1.7	0.105	1.10%
North Ash	L		AshN2_01	North Ash Creek from beginning of AIP Reach 2 to SW Orchid Dr	1.8	0.070	1.60%
North Ash	L		AshN2_02(obstrcc)	North Ash Creek SW Orchid Dr	1.9		
North Ash	L		AshN2_03	North Ash Creek from SW Orchid Dr to exposed sewer pipe crossing	1.9	0.026	2.60%
North Ash	L		AshN2_04(obstrss)	North Ash exposed sewer pipe crossing	1.9		
North Ash	L		AshN2_05	North Ash from exposed sewer pipe crossing to SW Lancaster	1.9	0.172	2.70%
North Ash	L		AshN2_06(obstrcc)	North Ash SW Lancaster	2.1		
North Ash	L		AshN2_07	North Ash from SW Lancaster to SW 55th	2.1	0.121	11.60%
Woods		U	Woods1_00	Woods Creek from Fanno Creek to golf course dam	0.0	0.024	0.50%
Woods		U	Woods1_01(obstrdam)	Woods Creek golf course dam (beginning of AIP Reach 1)	0.0		
Woods		U	Woods1_02	Woods Creek golf course pond (beginning of AIP Reach 1)	0.0	0.067	0.00%
Woods		U	Woods1_03(obstrcc)	Woods Creek golf cart	0.1		

				path culvert			
Woods		U	Woods1_04	Woods Creek from golf cart path culvert to culvert	0.1	0.039	0.40%
Woods		U	Woods1_05(obstrcc)	Woods Creek culvert	0.1		
Woods		U	Woods1_06	Woods Creek from culvert to culvert	0.1	0.066	0.30%
Woods		U	Woods1_07(obstrcc)	Woods Creek culvert	0.2		
Woods		U	Woods1_08	Woods Creek from culvert to culvert	0.2	0.018	0.20%
Woods		U	Woods1_09(obstrcc)	Woods Creek culvert	0.2		
Woods		U	Woods1_10	Woods Creek from culvert to walking path culvert	0.2	0.165	0.10%
Woods		U	Woods1_11(obstrcc)	Woods Creek walking path culvert	0.4		
Woods		U	Woods1_12	Woods Creek from walking path culvert to fish ladder	0.4	0.013	1.10%
Woods		U	Woods1_13(obstrfshldr)	Woods Creek fish ladder	0.4		
Woods		U	Woods1_14	Woods Creek from fish ladder to SW Oleson Rd	0.4	0.248	0.50%
Woods		U	Woods1_15(obstrcc)	Woods Creek SW Oleson Rd culvert	0.6		
Woods		U	Woods1_16	Woods Creek from SW Oleson Rd culvert to park driveway culvert	0.6	0.025	1.70%
Woods		U	Woods1_17(obstrcc)	Woods Creek park driveway culvert	0.7		
Woods		U	Woods1_18	Woods Creek from park driveway culvert to unmapped tributary (Trib(Woods1.18) at SW Canby	0.7	0.704	0.50%
Woods		U	Woods1_19	Woods Creek from unmapped tributary (Trib(Woods1.18) at SW Canby to SW 60th Ave culvert	1.4	0.044	1.50%
Woods		U	Woods1_20(obstrcc)	Woods Creek SW 60th Ave culvert	1.4		
Woods		U	Woods1_21	Woods Creek from SW 60th Ave culvert to step structure obstruction	1.4	0.076	1.10%
Woods		U	Woods1_22(obstrss)	Woods Creek step structure	1.5		

Woods		U	Woods1_23	Woods Creek from step structure to private driveway	1.5	0.003	0.80%
Woods		U	Woods1_24(obstrcc)	Woods Creek private driveway culvert	1.5		
Woods		U	Woods1_25	Woods Creek from private driveway culvert to end of AIP Reach 1	1.5	0.329	0.80%
Woods		U	Woods2_01	Woods Creek from beginning of AIP Reach 2 to SW Multnomah box culvert	1.8	0.100	2.50%
Woods		U	Woods2_02(obstrcc)	Woods Creek SW Multnomah box culvert	1.9		
Woods		U	Woods2_03	Woods Creek from SW Multnomah box culvert to unmapped tributary Trib(Woods2.03)	1.9	0.353	1.80%
Woods		U	Woods2_04	Woods Creek from unmapped tributary Trib(Woods2.03) to SW Garden Home	2.3	0.019	1.70%
Woods		U	Woods2_05(obstrcc)	Woods Creek SW Garden Home culvert	2.3		
Woods		U	Woods2_06	Woods Creek from SW Garden Home culvert to dry reach	2.3	0.160	3.20%
Woods		U	Woods2_07(obstrdry)	Woods Creek dry reach obstruction	2.5		
Woods		U	Woods2_08	Woods Creek dry reach	2.5	0.003	2.50%
Woods		U	Woods2_09	Woods Creek from dry reach to SW 45th	2.5	0.013	2.50%
Woods		U	Woods2_10(obstrcc)	Woods Creek SW 45th	2.5		
Woods		U	Woods2_11	Woods Creek from SW 45th to unnamed tributary (Trib(Woods2.11))	2.5	0.064	3.00%
Woods		U	Woods2_12	Woods Creek from unnamed tributary (Trib(Woods2.11)) to SW Taylor's Ferry culvert	2.5	0.390	7.60%
Woods		U	Woods2_13(obstrcc)	Woods Creek SW Taylor's Ferry culvert	2.9		
Woods		U	Woods2_14	Woods Creek from SW Taylor's Ferry culvert	2.9	0.047	0.90%

				to upper extent of AIP survey			
Woods		U	Trib(Woods1_18)-01(obstrcc)	Trib(Woods1.18) from Woods Creek to SW Canby culvert	0.0		
Woods		U	Trib(Woods1_18)-02	Trib(Woods1.18) from SW Canby culvert to upper extent of AIP survey	0.0	0.015	1.30%
Woods		U	Trib(Woods2_03)-01	Trib(Woods2.03) from Woods Creek to upper extent of AIP survey	0.0	0.008	6.00%
Woods		U	Trib(Woods2_11)-01	Trib(Woods2.11) from Woods Creek to upper extent of AIP survey	0.0	0.009	12.00%
Vermont		U	VT1_01	Vermont Creek AIP Reach1 from Fanno Creek to SW Oleson Rd culvert	0.0	0.134	0.40%
Vermont		U	VT1_02(obstrcc)	Vermont Creek SW Oleson Rd culvert	0.1		
Vermont		U	VT1_03	Vermont Creek from SW Oleson Rd culvert to private driveway	0.1	0.202	0.50%
Vermont		U	VT1_04(obstrcc)	Vermont Creek private driveway culvert	0.3		
Vermont		U	VT1_05	Vermont Creek from private driveway to SW Shattuck Rd	0.3	0.126	0.50%
Vermont		U	VT1_06(obstrcc)	Vermont Creek SW Shattuck Rd culvert	0.5		
Vermont		U	VT1_07	Vermont Creek from SW Shattuck Rd to private driveway	0.5	0.088	0.00%
Vermont		U	VT1_08(obstrcc)	Vermont Creek private driveway culvert	0.6		
Vermont		U	VT1_09	Vermont Creek from private driveway to walking path near SW 55th Dr	0.6	0.320	1.00%
Vermont		U	VT1_10(obstrcc)	Vermont Creek walking path near SW 55th Dr culvert	0.9		
Vermont		U	VT1_11	Vermont Creek from walking path near SW 55th Dr to SW Vermont Ave	0.9	0.262	1.00%
Vermont		U	VT1_12(obstrcc)	Vermont Creek SW Vermont Ave culvert	1.1		

Vermont		U	VT1_13	Vermont Creek from SW Vermont Ave to unmapped tributary Trib(VT1.13)	1.1	0.348	0.70%
Vermont		U	VT1_14	Vermont Creek from unmapped Trib(VT1.13) to unnamed Trib(VT1.14) (upstream end of AIP Reach 1)	1.5	0.116	0.60%
Vermont		U	VT2_01	Vermont Creek from unnamed Trib(VT1.14) to SW 45th Ave (beginning of AIP Reach 2)	1.6	0.036	0.80%
Vermont		U	VT2_02(obstrcc)	Vermont Creek SW 45th Ave	1.6		
Vermont		U	VT2_03	Vermont Creek from SW 45th Ave to unmapped tributary Trib(VT2.03)	1.6	0.064	0.90%
Vermont		U	VT2_04	Vermont Creek from unmapped tributary Trib(VT2.03) to unnamed Trib(VT2.04)	1.7	0.127	2.20%
Vermont		U	VT2_05	Vermont Creek from unnamed Trib(VT2.04) to unmapped Trib(VT2.05)	1.8	0.016	2.20%
Vermont		U	VT2_06	Vermont Creek from unmapped Trib(VT2.05) to upper extent of AIP survey	1.8	0.433	3.50%
Vermont		U	Trib(VT1_13)-01	Trib(VT1.13) from Vermont Creek to culvert for apartment parking lot	0.0	0.003	1.00%
Vermont		U	Trib(VT1_13)-02(obstrcc)	Trib(VT1.13) culvert for apartment parking lot	0.0		
Vermont		U	Trib(VT1_13)-03	Trib(VT1.13) from apartment parking lot to upper extent of AIP survey	0.0	0.012	3.50%
Vermont		U	Trib(VT1_14)-01	Trib(VT1.14) from Vermont Creek to private driveway	0.0	0.008	0.80%
Vermont		U	Trib(VT1_14)-02(obstrcc)	Trib(VT1.14) private driveway	0.0		
Vermont		U	Trib(VT1_14)-03	Trib(VT1.14) from private driveway to	0.0	0.015	0.50%

				upper extent of AIP survey			
Vermont		U	Trib(VT2_03)-01	Trib(VT2.03) from Vermont Creek to upper extent of AIP survey	0.0	0.008	7.00%
Vermont		U	Trib(VT2_04)-01	Trib(VT2.04) from Vermont Creek to upper extent of AIP survey	0.0	0.009	4.00%
Vermont		U	Trib(VT2_05)-01	Trib(VT2.05) from Vermont Creek to upper extent of AIP survey	0.0	0.013	7.00%
Pendleton		U	Pendleton(Fanno21_01A)-01(obstrcc)	Pendleton(Fanno21.03) culvert 0.4M METAL 1.0M DROP at Fanno Creek confluence	0.0		
Pendleton		U	Pendleton(Fanno21_01A)-02	Trib(Fanno21.03) culvert reach (upper extent of AIP survey)	0.0	0.057	1.00%
Pendleton		U	Pendleton(Fanno21_01A)-03	Pendleton Creek from culvert to SW Shattuck Rd	0.1	0.493	1.00%
Pendleton		U	Pendleton(Fanno21_01A)-04(obstr)	Pendleton Creek SW Shattuck Rd	0.6		
Pendleton		U	Pendleton(Fanno21_01A)-05	Pendleton Creek from SW Shattuck Rd to end	0.6	0.310	1.00%
Sylvan		U	Sylvan_01	Sylvan Creek from Fanno Creek to end of RSAT reach 4	0.0	0.284	1.30%
Sylvan		U	Sylvan_02	Sylvan Creek RSAT reach 5	0.3	0.379	0.90%
Sylvan		U	Sylvan_03	Sylvan Creek RSAT reach 6	0.7	0.341	2.50%
Sylvan		U	Sylvan03_B(obstr)	Sylvan Creek culvert obstruction	1.0		
Sylvan		U	Sylvan_04	Sylvan Creek RSAT reach 7	1.0	0.473	2.50%
Sylvan		U	Sylvan_05	Sylvan Creek RSAT reach 3	1.5	0.284	3.00%
Sylvan		U	Sylvan05_B(obstr)	Sylvan Creek culvert obstruction	1.8		
Sylvan		U	Sylvan_06	Sylvan Creek RSAT reach 2	1.8	0.265	4.50%
Sylvan		U	Sylvan_07	Sylvan Creek tributary reach	0.0	0.227	3.00%
Columbia		U	Columbia(Fanno21_07)-01	Columbia Creek from Fanno Creek to upper extent	0.0	0.600	4.50%

Hamilton		U	Hamilton(Fanno22_03)-01	Trib(Fanno22.03) from Fanno Creek to upper extent	0.0	0.500	1.50%
Ivy		U	Ivy(Fanno23_03)-01(obstrcc)	Ivy(Fanno23.03) private driveway culvert at Fanno Creek confluence	0.0	0.220	2.00%
Ivy		U	Ivy(Fanno23_03)-02	Ivy(Fanno23.03) from culvert to upper extent	0.2	0.000	
Upper Fanno Trib		U	Trib(Fanno24_03)-01	Trib(Fanno24.03) from Fanno Creek to SW 39th Dr culvert	0.0	0.012	0.40%
Upper Fanno Trib		U	Trib(Fanno24_03)-02(obstrcc)	Trib(Fanno24.03) SW 39th Dr culvert	0.0		
Upper Fanno Trib		U	Trib(Fanno24_03)-03	Trib(Fanno24.03) from SW 39th Dr culvert to sediment capture structure	0.0	0.015	3.00%
Upper Fanno Trib		U	Trib(Fanno24_03)-04(obstrdam)	Trib(Fanno24.03) sediment capture structure	0.0		
Upper Fanno Trib		U	Trib(Fanno24_03)-05	Trib(Fanno24.03) from sediment capture structure to upper extent of AIP survey	0.0	0.008	3.00%
Upper Fanno Trib		U	Trib(Fanno25_03)-01	Trib(Fanno25.03) from Fanno Creek to upper extent of AIP survey	0.0	0.220	4.00%
Upper Fanno Trib		U	Trib(Fanno25_10)-01(obstrcc)	Trib(Fanno25.10) Beaverton Hills culvert at Fanno Creek confluence	0.0		
Upper Fanno Trib		U	Trib(Fanno25_10)-02	Trib(Fanno25.10) from Beaverton Hills culvert to private parking lot	0.0	0.111	1.90%
Upper Fanno Trib		U	Trib(Fanno25_10)-03(obstrcc)	Trib(Fanno25.10) private parking lot	0.1		
Upper Fanno Trib		U	Trib(Fanno25_10)-04	Trib(Fanno25.10) from private parking lot to walking path	0.1	0.249	1.60%
Upper Fanno Trib		U	Trib(Fanno25_10)-05(obstrcc)	Trib(Fanno25.10) walking path	0.4		
Upper Fanno Trib		U	Trib(Fanno25_10)-06	Trib(Fanno25.10) from walking path to culvert	0.4	0.055	2.00%
Upper Fanno Trib		U	Trib(Fanno25_10)-07(obstrcc)	Trib(Fanno25.10) culvert	0.4		
Upper Fanno Trib		U	Trib(Fanno25_10)-08	Trib(Fanno25.10) culvert glide	0.4	0.038	3.50%

Upper Fanno Trib		U	Trib(Fanno26_03)-01(obstrcc)	Trib(Fanno26.03) parking lot culvert at Fanno Creek confluence	0.0		
Upper Fanno Trib		U	Trib(Fanno26_03)-02	Trib(Fanno26.03) from parking lot culvert to upper extent of AIP survey	0.0	0.045	7.90%
Upper Fanno Trib		U	Trib(Fanno26_04)-01	Trib(Fanno26.04) from Fanno Creek to upper extent of AIP survey	0.0	0.220	10.00%

Appendix 3. Reach level limiting factor results

Upper Fanno Creek Cutthroat Trout Habitat Restoration Potential

Upper Fanno Creek Mainstem

The limiting factors for cutthroat trout potential in upper Fanno Creek mainstem are displayed in Table 1 by reach.   Sediment load, Habitat diversity, Flow, and Temperature are pervasive limiting factors throughout the upper Fanno Creek watershed (Table 1). In the Upper Middle Fanno geographic area, the priority area for restoration is Fanno16_B, the section of Fanno Creek between Woods and Vermont creeks. In this reach, the most limiting factors in decreasing order of importance are sediment load, habitat diversity and temperature.

In the Upper Fanno geographic area, Fanno23_01 (from unnamed tributary to the SW 45th St. culvert), Fanno21_07 (from Safeway parking lot to Columbia Creek), Fanno25_01 (from unnamed tributary to the SW 39th Dr. culvert), and Fanno22_01 (from Columbia Creek to SW Shattuck Road) reaches have the highest restoration potential (Table 1). Sediment load, Habitat diversity, Flow, and Temperature are the primary limiting factors in these four reaches (Table 1). Habitat diversity usually reflects the lack of large wood structure in a creek. Temperatures have increased due to lack of forested cover and reduced summer flows. Sediment loads have increased due to flashy flows and increased surface runoff. The lack of habitat complexity has also eliminated alternating areas of scour and deposition.

Table 1. Limiting habitat attributes for cutthroat trout in Fanno Creek above its confluence with Woods Creek. Sediment load, Habitat diversity, Flow, and Temperature are pervasive limiting factors throughout the upper watershed. In the Upper Middle Fanno, the priority area for restoration is Fanno16_B. In the Upper Fanno, Fanno23_01, Fanno21_07, Fanno25_01, and Fanno22_01 have the highest restoration potential.

			Cutthroat Habitat Attributes: Upper Fanno Mainstem											
Geographic Area	Reach	Restoration Ranking	Channel Form	Pollutants	Competition (other sp)	Flow	Food	Habitat diversity	Harassment	Oxygen	Pathogens	Predation	Sediment load	Temperature
	Woods Creek													
Upper Middle Fanno	Fanno16_B	1	6	11	9	5	11	2	7	10	4	8	1	3
	Fanno21_01_A	2	6	10	7	3	10	2	9	10	5	8	1	4
	Fanno21_01_B	3	7	10	8	3	10	1	9	10	4	6	5	2
	Fanno21_01_C	3	4	9	5	2	9	1	8	9	9	6	3	7
	Safeway Parkinglot													
Upper Fanno	Fanno21_03_A	13	7	10	8	2	10	1	6	10	5	9	3	4
	Fanno21_03_B	7	6	10	7	3	10	1	9	10	5	8	2	4
	Fanno21_05	6	8	10	6	3	10	1	9	10	5	7	2	4
	Fanno21_07	2	6	10	7	3	10	2	9	10	5	8	1	4
	Fanno22_01	3	8	9	6	4	9	2	9	9	5	7	1	3
	Fanno22_03	16	8	10	6	3	10	1	9	10	5	6	2	4
	Fanno23_01	1	8	8	6	5	8	3	8	8	4	7	1	2
	Fanno23_03	9	7	10	8	2	10	1	5	10	6	9	3	4
	Fanno24_01	15	8	9	6	3	9	2	9	9	5	7	1	4
	Fanno24_03	5	8	9	6	3	9	2	9	9	5	7	1	4
	Fanno25_01	3	6	10	7	3	10	1	9	10	5	8	2	4
	Fanno25_03	8	6	10	7	3	10	1	9	10	5	8	2	4
	Fanno25_04	11	8	9	6	2	9	4	9	9	5	7	1	3
	Fanno25_06	10	7	10	6	3	10	2	9	10	5	8	1	4
	Fanno25_08	12	7	10	6	2	10	1	9	10	5	8	3	4
	Fanno25_10	17	9	10	6	3	10	1	7	10	5	8	2	4
	Fanno26_01	19	7	10	8	2	10	1	4	10	6	9	3	5
	Fanno26_03	13	6	10	7	3	10	1	8	10	5	9	2	4
	Fanno26_04	[illegible]	8	9	6	3	[illegible]	2	9	9	5	7	1	4

Woods Creek

The limiting factors for cutthroat trout potential in Woods Creek are displayed in Table 2 by reach. Sediment load and Habitat diversity, followed by Flow and Temperature, are pervasive limiting factors throughout Woods Creek (Table 2). The priority areas for restoration in Woods Creek are Woods1_18 (from the park driveway culvert to unmapped tributary (Trib(Woods1.18) at SW Canby Ave.), Woods1_00 (from Fanno Creek confluence to the golf course dam), and Woods1_25.

Sediment load is the most limiting factor to cutthroat potential in these three reaches as well as the majority of lower Woods Creek. Sediment loads have increased due to flashy flows and increased surface runoff. The lack of habitat complexity has also eliminated alternating areas of scour and deposition. Habitat diversity usually reflects the lack of large wood structure in a creek.

Flow is limiting to cutthroat due to extremely flashy fall/winter flows, and decreased summer flows. Woods Creek watershed is flashy due to impervious substrates and channelization. The mapped impervious area (roofs and impervious substrates) of Woods Creek was estimated as 28% (City of Portland, Bureau of Environmental Services 1998). Modeling indicated that Woods Creek peak flows have increased approximately 220% from predevelopment and the discharge has increased from ~65 cfs/sqmi to ~130 cfs/sqmi (MGS Engineering Consultants, Inc. 2001).

Temperatures have increased due to lack of forested cover and reduced summer flows. While pathogens are indicated as being the third most limiting factor in Woods1_25, pathogens are not actually any more limiting in this reach than anywhere else in Fanno Creek. It was assumed that *Ceratomyxa shasta*, the causative agent of ceratomyxosis, which is known to occur in the Willamette basin was also present at low levels throughout the Fanno Creek watershed. However, the incidence of this disease is known to increase with increasing water temperatures. In Table 2, pathogens are identified as a limiting factor due to increased water temperatures.

Table 2. Limiting habitat attributes for cutthroat trout in Woods Creek. Sediment load and Habitat diversity, followed by Flow and Temperature, are pervasive limiting factors throughout Woods Creek. The priority areas for restoration are Woods1_18, Woods1_00, and Woods1_25.

			Cutthroat Habitat Attributes: Woods Creek											
Geographic Area	Reach	Restoration Ranking	Channel Form	Pollutants	Competition (other sp)	Flow	Food	Habitat diversity	Harassment	Oxygen	Pathogens	Predation	Sediment load	Temperature
Woods Creek	Woods1_00	2	6	10	7	5	10	2	9	10	4	8	1	3
	Woods1_02	8	6	10	9	4	10	2	8	10	5	7	1	3
	Woods1_04	6	7	10	8	3	10	2	4	10	6	9	1	5
	Woods1_06	7	7	10	8	3	10	2	5	10	6	9	1	4
	Woods1_08	13	7	10	8	3	10	2	4	10	6	9	1	5
	Woods1_10	22	6	10	7	3	10	2	9	10	5	8	1	4
	Woods1_12	10	7	10	8	3	10	2	4	10	6	9	1	5
	Woods1_14	4	8	9	6	5	9	4	9	9	3	7	1	2
	Woods1_16	19	7	10	8	3	10	2	4	10	6	9	1	5
	Woods1_18	1	8	8	5	4	8	7	8	8	3	6	1	2
	Woods1_19	11	7	10	8	3	10	2	6	10	5	9	1	4
	Woods1_21	12	6	10	8	3	10	2	7	10	5	9	1	4
	Woods1_23	23	3	9	5	2	9	1	4	9	9	7	6	8
	Woods1_25	3	8	8	5	4	8	7	8	8	3	6	1	2
	Woods2_01	14	6	10	8	3	10	2	7	10	5	9	1	4
	Woods2_03	8	8	8	6	3	8	5	8	8	4	7	1	2
	Woods2_04	5	6	10	7	2	10	1	9	10	5	8	4	3
	Woods2_06	18	8	8	5	2	8	7	8	8	4	6	3	1
	Woods2_08	23	5	10	6	1	10	2	9	10	4	8	7	3
	Woods2_09	17	6	10	7	2	10	1	8	10	5	9	4	3
	Woods2_11	16	9	10	7	1	10	2	6	10	5	8	4	3
	Woods2_12	20	9	9	6	1	9	2	8	9	5	7	4	2
	Woods2_14	15	4	10	7	2	10	1	8	10	6	9	5	3
	Trib(Woods1_18)-02	21	7	10	8	3	10	2	5	10	6	9	1	4

Vermont Creek

The limiting factors for cutthroat trout potential in Vermont Creek are displayed in Table 3 by reach. Temperature, Flow, Habitat diversity, and Pathogens are pervasive limiting factors throughout Vermont Creek (Table 3). Sediment Load is limiting in a few Vermont Creek reaches while Harassment and Channel form are limiting in some of the tributaries to Vermont Creek. Harassment refers to the close proximity of the stream to human activities and the effects of waders, dogs and so on. The priority areas for restoration in Vermont Creek are VT1_13 (from SW Vermont Ave to unmapped tributary Trib(VT1.13)), VT1_11 (from walking path near SW 55th Dr to SW Vermont Ave), and VT1_01 (from Fanno Creek confluence to SW Oleson Rd).

Flow is limiting to cutthroat due to extremely flashy fall/winter flows, and decreased summer flows. Vermont Creek watershed is flashy due to impervious substrates and channelization. The mapped impervious area (roofs and impervious substrates) of Vermont Creek was estimated as 25.5% (City of Portland, Bureau of Environmental Services 1998).

Temperatures have increased due to lack of forested cover and reduced summer flows. Sediment loads have increased due to flashy flows and increased surface runoff. The lack of habitat complexity has also eliminated alternating areas of scour and deposition. Habitat diversity usually reflects the lack of large wood structure in a creek.

While pathogens are indicated as being the second or third most limiting factor in several Vermont Creek reaches, pathogens are not actually any more limiting in these reaches than anywhere else in Fanno Creek. It was assumed that *Ceratomyxa shasta*, the causative agent of ceratomyxosis, which is known to occur in the Willamette basin, was also present at low levels throughout the Fanno Creek watershed. However, the incidence of this disease is known to increase with increasing water temperatures. In Table 3, pathogens are identified as a limiting factor due to increased water temperatures.

Table 3. Limiting habitat attributes for cutthroat trout in Vermont Creek. Temperature, Flow, Habitat diversity, and Pathogens are pervasive limiting factors throughout Vermont Creek. Sediment Load is limiting in a few Vermont Creek reaches while Harassment and Channel form are limiting in some of the tributaries to Vermont Creek. The priority areas for restoration are VT1_13, VT1_11, and VT1_01.

			Cutthroat Habitat Attributes: Vermont Creek												
Geographic Area	Reach	Restoration Ranking	Channel Form	Pollutants	Competition (other sp)	Flow	Food	Habitat diversity	Harassment	Oxygen	Pathogens	Predation	Sediment load	Temperature
Vermont Creek	VT1_01	3	5	11	7	4	11	1	8	10	3	9	6	2
	VT1_03	8	8	11	6	3	11	4	9	10	2	7	5	1
	VT1_05	5	5	11	8	3	11	4	7	10	2	9	6	1
	VT1_07	17	5	11	7	3	11	2	9	10	8	6	4	1
	VT1_09	16	8	11	7	2	11	5	6	10	9	4	3	1
	VT1_11	2	8	11	7	3	11	1	6	10	4	8	5	2
	VT1_13	1	9	10	6	5	10	4	10	8	2	7	3	1
	VT1_14	4	9	9	5	4	9	7	9	8	2	6	3	1
	VT2_01	13	9	11	6	4	11	3	8	10	2	7	5	1
	VT2_03	7	8	11	7	2	11	5	4	10	3	9	6	1
	VT2_04	10	9	9	6	3	9	4	9	8	2	7	5	1
	VT2_05	11	9	9	5	3	9	7	9	8	2	6	4	1
	VT2_06	5	10	10	7	2	10	3	5	9	4	8	6	1
	Trib(VT1_13)-01	18	3	8	5	2	8	1	4	8	8	7	6	8
	Trib(VT1_13)-03	15	6	10	7	2	10	1	3	10	5	9	8	4
	Trib(VT1_14)-01	9	5	10	6	2	10	1	7	10	4	9	8	3
	Trib(VT1_14)-03	12	6	10	7	2	10	1	3	10	5	8	9	4
	Trib(VT2_04)-01	14	5	10	6	2	10	1	9	10	4	8	7	3

Upper Fanno Creek Tributaries

The limiting factors for cutthroat trout potential in upper Fanno Creek tributaries are displayed in Table 4 by reach. Sediment load, Habitat diversity, and Flow are pervasive limiting factors throughout the upper Fanno Creek tributaries (Table 4). In Pendleton Creek, the priority area for restoration is reach Pendleton(Fanno21_01A)-05, the section of Pendleton Creek above SW Shattuck Rd. In this reach, the most limiting factors in decreasing order of importance are Habitat diversity, Flow, and Temperature.

In Sylvan Creek, Sylvan_04 (RM 1.0-1.5), Sylvan_02 (RM 0.3-0.7), Sylvan_03 (RM 0.7-1.0) and Sylvan_01 (RM0-0.3) have the highest restoration potential (Table 4) in decreasing order. Sediment load, Habitat diversity, Flow, and Temperature are the primary limiting factors in these four Sylvan Creek reaches, as well as the smaller tributary reaches (Table 4). Habitat diversity usually reflects the lack of large wood structure in a creek. Sediment loads have increased due to flashy flows and increased surface runoff. The lack of habitat complexity has also eliminated alternating areas of scour and deposition. Temperatures have increased due to lack of forested cover and reduced summer flows.

Fanno Creek watershed is flashy due to impervious substrates and channelization. The mapped impervious area (roofs and impervious substrates) was estimated as 29% of upper Fanno Creek and 26.5% of Pendleton Creek watershed (City of Portland, BES 1998).

Table 4. Limiting habitat attributes for cutthroat trout in Upper Fanno Creek tributaries. Sediment load, Habitat diversity, and Flow are pervasive limiting factors throughout the upper Fanno Creek tributaries. In Pendleton Creek, the priority area for restoration is Pendleton(Fanno21_01A)-05. In Sylvan Creek, the lower 1.5 miles have the highest restoration potential. Columbia and Hamilton creeks have the highest restoration potential of the smaller tributaries.

			Cutthroat Habitat Attributes: Upper Fanno Tributaries											
Geographic Area	Reach	Restoration Ranking	Channel Form	Pollutants	Competition (other sp)	Flow	Food	Habitat diversity	Harassment	Oxygen	Pathogens	Predation	Sediment load	Temperature
Pendleton Creek	Pendleton(Fanno21_03)-02	3	7	10	8	2	10	1	3	10	6	9	5	4
	Pendleton(Fanno21_03)-03	2	8	10	6	3	10	1	9	10	5	7	4	2
	Pendleton(Fanno21_03)-05	1	7	10	8	2	10	1	4	10	6	9	5	3
Sylvan Creek	Sylvan01	3	9	11	7	3	11	5	6	10	4	8	1	2
	Sylvan_02	2	8	11	7	5	11	2	6	10	4	8	1	3
	Sylvan_03	3	6	11	7	3	11	2	9	10	5	8	1	4
	Sylvan_04	1	6	11	6	3	11	2	9	10	5	8	1	4
	Sylvan_05	6	8	10	6	3	10	2	10	9	5	7	1	4
	Sylvan_06	7	7	11	6	3	11	1	9	10	5	8	2	4
	Sylvan_07	5	6	11	8	2	11	1	7	10	5	9	3	4
Smaller Tributaries	Columbia(Fanno21_07)-01	1	7	10	8	2	10	1	4	10	6	9	5	3
	Hamilton(Fanno22_03)-01	2	7	10	8	3	10	1	6	10	5	9	2	4
	Ivy(Fanno23_03)-02	11	6	10	8	2	10	1	5	10	7	9	3	4
	Trib(Fanno24_03)-01	3	6	10	7	3	10	1	9	10	5	8	2	4
	Trib(Fanno24_03)-03	10	6	10	8	2	10	1	4	10	7	9	3	5
	Trib(Fanno24_03)-05	6	7	10	8	3	10	1	5	10	6	9	2	4
	Trib(Fanno25_03)-01	4	7	10	8	3	10	2	5	10	6	9	1	4
	Trib(Fanno25_10)-02	5	6	10	8	2	10	1	7	10	5	9	3	4
	Trib(Fanno25_10)-04	8	6	10	8	3	10	1	7	10	5	9	2	4
	Trib(Fanno25_10)-06	9	7	10	8	3	10	2	6	10	5	9	1	4
	Trib(Fanno25_10)-08	13	6	10	8	2	10	1	4	10	7	9	3	5
	Trib(Fanno26_03)-02	12	6	10	8	2	10	1	5	10	7	9	3	4
	Trib(Fanno26_04)-01	7	7	10	8	3	10	1	5	10	6	9	2	4

Lower Fanno Creek Cutthroat Trout Habitat Restoration Potential

Lower Fanno Creek Mainstem

The limiting factors for cutthroat trout potential in lower Fanno Creek mainstem are displayed in Table 5 by reach. Sediment load, Habitat diversity, and Temperature are pervasive limiting factors throughout the lower Fanno Creek watershed (Table 5). In the Lower Fanno geographic area, Fanno06 (RM 3.5-4.5), Fanno14 (RM 8.9-9.7), and Fanno16_A (from RM 10.1 to RM 10.9 at Woods Creek confluence) have the highest restoration potential (Table 5).

Sediment load, Habitat diversity, and Temperature are the primary limiting factors in these three reaches (Table 5). Habitat diversity usually reflects the lack of large wood structure in a creek. Temperatures have increased due to lack of forested cover and reduced summer flows. Sediment loads have increased due to flashy flows and increased surface runoff. The lack of habitat complexity has also eliminated alternating areas of scour and deposition.

Flow is limiting to cutthroat due to extremely flashy fall/winter flows, and decreased summer flows. The lower Fanno Creek watershed is flashy due to impervious substrates and channelization. Modeling indicated that lower Fanno Creek peak flows have increased approximately 225% from predevelopment and the discharge has increased from ~32 cfs/sqmi to ~72 cfs/sqmi (MGS Engineering Consultants, Inc. 2001). Middle Fanno Creek peak flows have increased approximately 390% from predevelopment and the discharge has increased from ~20 cfs/sqmi to ~85 cfs/sqmi (MGS Engineering Consultants, Inc. 2001).

Table 5. Limiting habitat attributes for cutthroat trout in the Lower Fanno Creek mainstem. Sediment load, Habitat diversity, and Temperature are pervasive limiting factors throughout lower Fanno Creek. Fanno06 (RM 3.5-4.5), Fanno14 (RM 8.9-9.7), and Fanno16_A (RM 10.1-RM 10.9) have the highest restoration potential.

			Cutthroat Habitat Attributes: Lower Fanno Mainstem											
Geographic Area	Reach	Restoration Ranking	Channel Form	Pollutants	Competition (other sp)	Flow	Food	Habitat diversity	Harassment	Oxygen	Pathogens	Predation	Sediment load	Temperature
Lower Fanno	Fanno01	17	7	10	8	2	10	5	10	9	6	3	4	1
	Fanno02	16	6	11	9	3	11	2	7	10	8	5	4	1
	Fanno03	12	9	11	7	6	11	4	8	10	2	5	3	1
	Fanno04	4	8	11	9	5	11	2	7	10	4	6	1	3
	Fanno05	13	8	11	7	6	11	3	9	10	2	5	4	1
	Fanno06	1	8	11	9	5	11	2	7	10	4	6	1	3
	Fanno07	14	8	11	8	5	11	3	7	10	2	6	4	1
	Fanno08	7	8	11	9	5	11	2	6	10	4	7	1	3
	Fanno09a	9	8	11	9	5	11	2	6	10	4	7	1	3
	Fanno09b	11	8	11	9	5	11	2	6	10	4	7	1	3
	Fanno10	5	7	11	9	5	11	2	8	10	4	6	1	3
	Fanno11	7	7	11	8	5	11	2	9	10	4	6	1	3
	Fanno12	15	8	11	9	5	11	2	7	10	3	6	4	1
	Fanno13	6	7	11	9	5	11	2	6	10	4	8	1	3
	Fanno14	2	7	11	9	5	11	2	8	10	4	6	1	3
	Fanno15	10	6	11	8	5	11	2	9	10	4	7	1	3
	Fanno16_A	3	6	11	9	5	11	2	7	10	4	8	1	3

Ash Creek

The limiting factors for cutthroat trout potential in Ash Creek are displayed in Table 6 by reach. In the portion of Ash Creek below the confluence of the North and South forks, the highest restoration potential occurs in the lower 1.1 miles. The most limiting factors in decreasing order of importance are habitat diversity, temperature, flow and sediment load.

In South Ash Creek, AshS2_05 (from SW 82nd Ave to SW 80^{th} Ave), AshS2_07 (from SW 80th Ave. to dry reach at RM 2.1), and AshS2_10 (RM 2.1-2.3) had the highest restoration potential (Table 6). Sediment load, Habitat diversity, and Flow are the most limiting factors in decreasing order of importance for each of the three reaches. Habitat diversity usually reflects the lack of large wood structure in a creek. It is important to note South Ash Creek was the only stream analyzed in which Temperature was not determined to be a limiting factor to cutthroat potential.

In North Ash Creek, the highest restoration potential occurs in AshN1_15 (from RM 1.2 to SW Dolph Rd. at RM 1.7), AshN1_05 (from concrete slide and dam at RM 0.1 to SW Cedarcrest Dr.) and AshN1_17 (from SW Dolph Rd. to RM 1.8) (Table 6). Within these reaches, Sediment load, Temperature, Pathogens and Flow are the most limiting factors.

Sediment loads have increased due to flashy flows and increased surface runoff. The lack of habitat complexity has also eliminated alternating areas of scour and deposition. Temperatures have increased due to lack of forested cover and reduced summer flows.

Flow is limiting to cutthroat due to extremely flashy fall/winter flows, and decreased summer flows. The Ash Creek watershed is flashy due to impervious substrates and channelization. Modeling indicated that Woods Creek peak flows have increased approximately 345% from predevelopment and the discharge has increased from ~37 cfs/sqmi to ~125 cfs/sqmi (MGS Engineering Consultants, Inc. 2001).

While pathogens are indicated as being the third most limiting factor in several North Ash Creek reaches, pathogens are not actually any more limiting in these reaches than anywhere else in Fanno Creek. It was assumed that *Ceratomyxa shasta*, the causative agent of ceratomyxosis, which is known to occur in the Willamette basin was also present at low levels throughout the Fanno Creek watershed. However, the incidence of this disease is known to increase with increasing water temperatures. In Table 6, pathogens are identified as a limiting factor due to elevated water temperatures.

Table 6. Limiting habitat attributes for cutthroat trout in Ash Creek. Habitat diversity, Flow, Sediment load, and Temperature are the primary limiting factors in the watershed. In Ash Creek, the highest restoration potential occurs in the lower 1.1 miles. In South Ash Creek, AshS2_05, AshS2_07, and AshS2_10 have the highest restoration potential. In North Ash Creek, the highest restoration potential occurs in AshN1_15, AshN1_05, and AshN1_17.

			Cutthroat Habitat Attributes: Ash Creek											
Geographic Area	Reach	Restoration Ranking	Channel Form	Pollutants	Competition (other sp)	Flow	Food	Habitat diversity	Harassment	Oxygen	Pathogens	Predation	Sediment load	Temperature
Ash Creek	Ash1_01	2	6	11	7	3	11	1	9	10	4	8	5	2
	Ash1_03	1	5	11	7	3	11	1	8	10	4	9	6	2
	Ash1_05	3	7	11	8	3	11	2	5	10	6	9	1	4
	Ash1_07	4	6	10	7	2	10	1	8	10	4	9	5	3
	Ash1_09	5	8	10	6	4	10	2	9	10	5	7	1	3
	Ash1_11	6	5	10	8	2	10	1	7	10	6	9	3	4
South Ash Creek	AshS2_01	7	5	10	6	1	10	2	3	10	8	8	4	7
	AshS2_03	6	4	10	5	3	10	2	6	10	8	8	1	7
	AshS2_05	1	6	9	4	3	9	2	9	9	7	7	1	5
	AshS2_07	2	8	10	4	3	10	2	9	10	6	6	1	5
	AshS2_09	19	7	8	4	2	8	3	5	8	8	6	1	8
	AshS2_10	3	5	10	6	3	10	2	4	10	8	8	1	7
	AshS2_12	19	3	10	5	2	10	1	4	10	9	7	8	6
	AshS3_01	5	4	10	6	3	10	2	5	10	8	8	1	7
	AshS3_03	19	7	7	3	1	7	2	5	7	7	4	6	7
	AshS3_04	9	4	10	5	1	10	2	3	10	7	7	9	6
	AshS3_06	12	8	10	4	1	10	2	9	10	6	6	3	5
	AshS3_08	10	4	10	5	2	10	1	3	10	7	7	9	6
	AshS3_10	18	3	10	4	2	10	1	6	10	7	7	9	5
	AshS3_11	19	4	10	3	2	10	1	8	10	6	6	9	5
	AshS3_13	4	5	10	4	1	10	2	3	10	7	7	9	6
	AshS3_15	14	8	9	3	1	9	2	9	9	5	5	7	4
	AshS3_16b	16	4	10	5	2	10	1	3	10	7	7	9	6
	AshS3_18	13	5	10	6	2	10	3	4	10	8	8	1	7
	AshS3_20	8	4	10	6	2	10	1	3	10	8	8	5	7
	AshS3_22	11	5	10	4	1	10	2	3	10	7	7	9	6
	AshS3_24	19	3	8	5	2	8	1	4	8	8	6	7	8
	AshS3_26	17	5	10	6	3	10	2	4	10	8	8	1	7
	Trib(Ash3_10)-01	15	4	10	5	3	10	2	7	10	8	8	1	6
North Ash Creek	AshN1_01	13	5	11	6	1	11	3	8	10	4	7	9	2
	AshN1_03	10	6	11	8	4	11	3	7	10	5	9	1	2
	AshN1_05	2	8	10	6	3	10	4	10	9	5	7	1	2
	AshN1_07	4	8	10	6	5	10	4	10	9	3	7	1	2
	AshN1_09	7	9	10	5	4	10	7	10	8	3	6	1	2
	AshN1_11	9	7	11	6	3	11	4	9	10	4	8	1	2
	AshN1_13	8	8	10	6	4	10	5	10	9	3	7	2	1
	AshN1_15	1	9	10	5	4	10	7	10	8	3	6	1	2
	AshN1_17	3	9	10	5	4	10	7	10	8	3	6	1	2
	AshN2_01	5	9	11	7	3	11	5	6	10	4	8	1	2
	AshN2_03	6	7	11	8	2	11	1	4	10	6	9	5	3
	AshN2_05	12	9	10	6	2	10	4	10	8	5	7	1	3
	AshN2_07	11	7	11	8	2	11	1	5	10	6	9	4	3

APPENDIX J:

Summary of the 2001 ODFW Fanno Tributary Study

IBI Summary

From 1999-2001, the Oregon Department of Fish and Wildlife completed fish surveys in three reaches of mainstem Fanno Creek and Ash Creek (tributary to Fanno Creek) in summery, fall, winter and spring. From this data, they derived Index of Biotic Integrity (IBI) scores – these summary results are presented in Table 1.

Table 9. IBI Scores for Upper Fanno Creek - IBI Scores: < 50 - severely impaired; 51-75 - moderately impaired; > 75 - acceptable (ODFW 2002).

	Reach	Summer	Fall	Winter	Spring	Mean
Fanno Creek	Lower	42.7	30.7	NS	51.7	41.7
	Middle	46.0	37.0	49.1	49.2	45.3
	Upper	47.5	40.6	41.1	50.2	44.9
Ash Creek	Lower	39.7	25.2	14.6	29.2	27.2
	Middle	30.5	32.2	33.3	32.2	32.1
	Upper	41.1	43.9	39.4	43.9	42.1

Based on fish communities observed, biotic integrity is severely impaired in Upper Fanno Creek in the summer, fall, and winter, and marginally impaired in the spring. The mean score for Upper Fanno Creek was 45, with scores ranging from 40.6 in the fall to 50.2 in the spring. Although these scores are low, they are higher than previous observations made by ODFW from 1993 thru 1995.

IBI scores show that Upper Ash Creek is severely impaired year-round, with a mean score of 42.1. Scores ranged from 39.4 in winter to 43.9 in fall and spring. Ash Creek IBI scores showed a dramatic 77 percent increase in biotic integrity from the 1993-1995 summer surveys (from 23.2 to 41.1).

In order of abundance, four fish species were identified in the 1999-2001 sampling:

- reticulate sculpin (*Cottus perplexus*)
- redside shiner (*Richardsonius balteatus*)
- cutthroat trout (*Onchorynchus clarki*)
- lamprey (*lampetra sp).*

Each is native to Oregon and commonly found in small headwater streams. Interestingly, reticulate sculpin, redside shiner and cutthroat trout are considered tolerant, intermediate, and intolerant to pollution, temperature, and warm water in the Willamette basin (Hughes and Gammon 1987). The physiological needs of sculpin species are generally similar to those of salmonids, and the presence of sculpin indicates the availability of unembedded cobble substrate that is required for cavity nesting and refuge. Mebane (2002) found that sculpin age classes declined with increasing proportions of fine sediment.

In addition to these fish species, western brook lamprey and Pacific lamprey (along with unidentified lamprey) were observed. Many consider the Willamette River Basin to be one of the last strongholds for lamprey in the Pacific Northwest

Mosquito fish (*Gambusia affinis*) were the only non-native fish observed in Upper Fanno Creek. ODFW likewise found large mouth bass (*Micropterus salmoides*) in lower Fanno Creek, and common carp (*cyprinus carpio*), pumpkinseed (*Lepomis gibbosus*), and yellow perch *(Perca flavescens*) at the confluence of Fanno Creek and the Tualatin River. Large mouth bass, pumpkinseed, and common carp are tolerant species (and yellow perch are intermediate species) in regard to water quality condition. In addition, common carp are omnivorous, exceptionally tolerant of warm, turbid, silty water, and indicators of seriously degraded habitat conditions (Mebane et al. 2003).

Target Fish Species

Species population observations in Fanno Creek are based on ODFW fish distribution maps (ODFW 2002), ODFW habitat surveys (ODFW 2002b), and surveys conducted in 1994 by Harza. Additional anecdotal information was documented during habitat and environmental surveys and was used to better understand fish community structure. Of the four viable salmonid parameters considered (abundance, productivity, spatial structure, and diversity), this characterization evaluates only spatial structure (or distribution) and presence/absence. Abundance, productivity, and diversity cannot be confidently evaluated with existing data. **Therefore, the following characterization of salmonid fish communities is not comprehensive and is considered preliminary.** Fish sampling surveys that span the entire creek and tributaries will be needed to further evaluate seasonal and spatial distributions and additional presence/absence.

Fish surveys show that salmonids occupy Upper Fanno Creek year-round (ODFW 2002b; DEQ, 2000). Although large numbers are not regularly observed, coho, steelhead and cutthroat have been documented (in the past five reproductive cycles) throughout different areas of mainstem Fanno Creek during all or parts of their freshwater life stage (ODFW 2002). During ODFW 2002 surveys, cutthroat trout were most abundant of all salmonid communities observed, followed by unidentified trout and steelhead (rainbow). Salmonids were captured in spring, summer, fall, and winter, indicating use during all or parts of their freshwater life stage. Total catch was highest in winter and spring.

Benthic Macroinvertebrates

Benthic macroinvertebrates were surveyed in 1993 using a modified rapid bioassessment protocol (Plafkin 1989; Wisseman 1996). Data showed that benthic communities were low in diversity and abundance. Lack of suitable substrate**,** particularly cobble and gravel-size particles, and the preponderance of silt substrate limit periphyton production, which in turn limits the food base for “scraper” organisms such as snails and caddis flies (Brown and Caldwell 1998). Poor macroinvertebrate production may significantly impair the current carrying capacity of this system for salmonids and other cold-water species.

APPENDIX K:
Summary of the 2001 ODFW Tryon Tributary Study

LOWER TRYON

Confluence Reach

The confluence reach of Tryon Creek is moderately impaired for stream health (based on stream IBI) in the spring and summer and is moderately impaired in fall (ODFW 2001 and ODFW 2002). As shown below, species richness is highest in the fall.

	Season		
Species	**Spring**	**Summer**	**Fall**
Chinook		X	X
Coho	X	X	X
Steelhead	X		X
Cutthroat	X	X	X

* Note, field surveys were not conducted in the winter

Juvenile coho were present in the lower canyon reach (Tryon 1), but were not observed in any other stream segment of the subbasin. During 2001 – 2002 field surveys, coho were observed during all three-sample seasons (spring, summer, and fall periods), indicating that they use (and/or rear in) this lower confluence reach year-round. Juveniles that occupy this lower confluence area are probably progeny of coho that inhabit other Willamette Basin tributaries, primarily the Clackamas River, Johnson Creek, and the Tualatin River. Hence, the confluence reach continues to function as off-channel rearing and refuge habitat to Willamette Basin coho. Coho were least abundant in the fall.

Lower Canyon Reach

Biotic integrity in the lower canyon reach is severely impaired in spring and summer, and moderately impaired in fall (ODFW 2002). Field data show that cutthroat trout were the predominant species encountered in spring, summer, and fall. Steelhead were observed in the fall and coho were not encountered during any sampling periods.

	Season		
Species	**Spring**	**Summer**	**Fall**
Chinook	NA	NA	NA
Coho			
Steelhead			X
Cutthroat	X	X	X

NA – Not Applicable. Chinook did not historically populate Tryon Creek

Presence of coho in the lower confluence reach, but not in the lower canyon reach suggests that coho can not ascend HWY 43 culvert; this culvert is steep and long, and drop height at the culvert outlet is high, making it relatively impassable except during very opportune flow conditions. Note higher stream flows raise the water surface elevation, decreasing the jump height into the culvert outlet. Adult coho return to spawn in the fall, just after fall rains commence. During this period, stream flows are just beginning to raise, but are not yet at an elevation that allows access into or through HWY 43 culvert. Because of the lower surface water elevations, and lower stream flows, coho are not able to either jump into the culvert and / or navigate through it. The result is that coho no longer populate Tryon Creek subbasin. Conversely, winter-run steelhead return to spawn in December, January, and February, when stream flows are higher and likely provide more opportunities to navigate above the culvert. As a result, winter steelhead continue to spawn and rear in Tryon Creek, at least up to Boones Ferry Rd (approximately RM 2.5) which is completely impassable to all migratory fish (moving upstream).

Middle and Upper Park Reach

Biotic integrity in the middle and upper park reach is considered severely impaired in spring, summer, and fall (and presumably in winter if it been sampled) (ODFW 2002). Field surveys found cutthroat trout in spring, summer and fall, and steelhead in the summer. Chinook and coho were not observed.

	Season		
Species	**Spring**	**Summer**	**Fall**
Chinook	NA	NA	NA
Coho			
Steelhead		X	
Cutthroat	X	X	X

NA – Not Applicable. Chinook did not historically populate Tryon Creek

MIDDLE TRYON CREEK

Biotic integrity in Middle Tryon Creek is severely impaired in spring, summer, and fall (and presumably in winter if it had been sampled). Field surveys found cutthroat trout in spring, summer and fall (ODFW 2002). Chinook, coho, and steelhead were not observed.

	Season		
Species	**Spring**	**Summer**	**Fall**
Chinook	NA	NA	NA
Coho			
Steelhead			
Cutthroat	X	X	X

NA – Not Applicable. Chinook did not historically populate Tryon Creek

BASIN SUMMARY

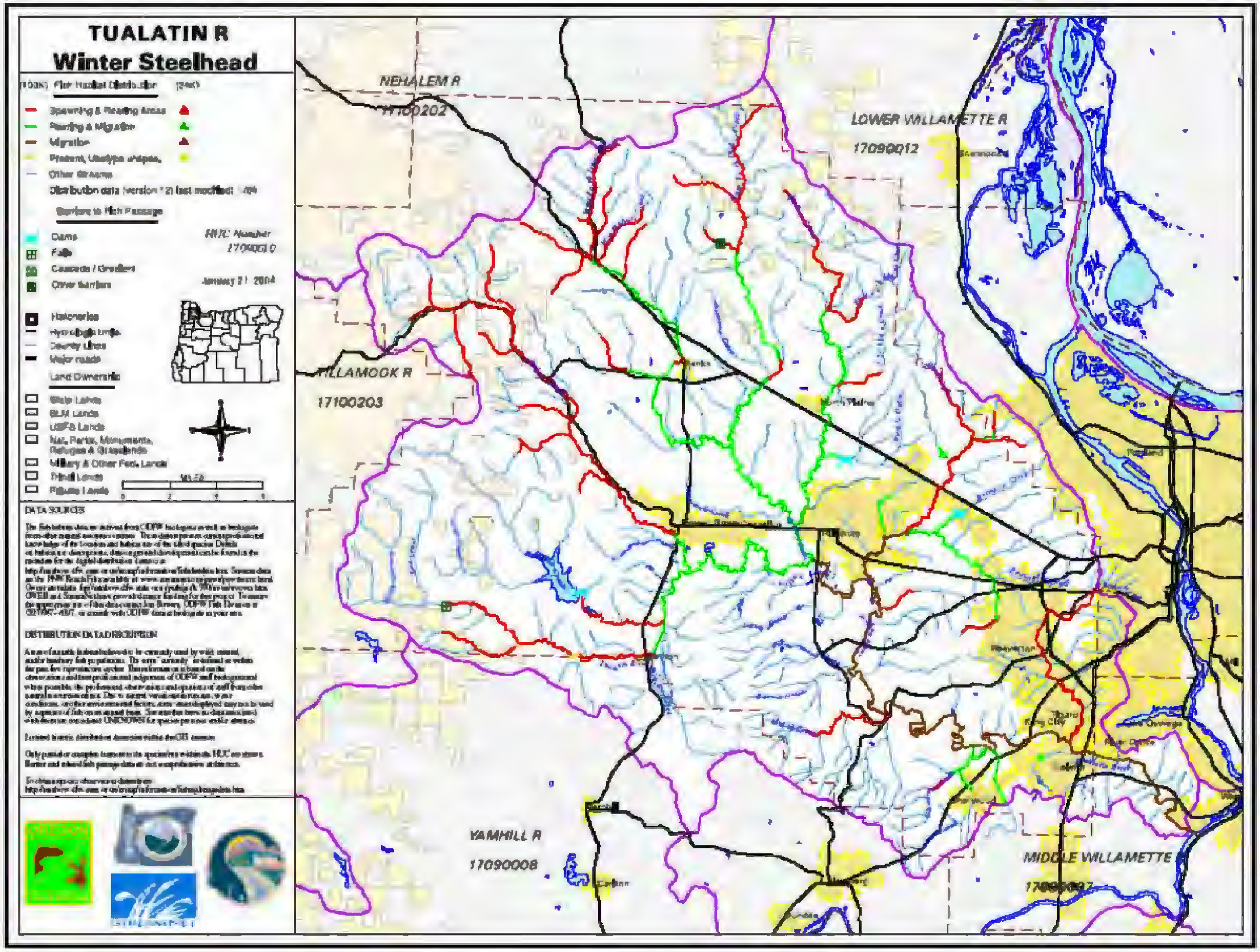
Coho, Chinook, steelhead, and cutthroat were observed in different parts of Tryon Creek during different seasons of the year. Of all the salmonid species observed, cutthroat trout were most abundant, with population estimates of 53 individuals in the spring, 36 in the summer, and 24 in the fall (ODFW 2002). Salmonid densities averaged 0.059 fish per square meter basinwide, and ranged from 0.047 fish per square meter in the lower canyon reach (Tryon 2) to 0.068 fish per square meter in the Willamette confluence reach (Tryon

1). Although the upper stream reach running through Tryon Creek State Natural Area (Tryon 3) and above (Tryon 4) resulted in lower biotic integrity (IBI) scores, species density per water surface area was relatively equal throughout all of the Tryon Creek Basin.

APPENDIX L:

2002 ODFW Tualatin Basin Fish Distribution Maps

See Maps on following Pages


TUALATIN R
Winter Steelhead
(100K) Fish Habitat Distribution (24K)
Spawning & Rearing Areas
Rearing & Migration
Migration
Present, Unknown Use
Other Streams
Distribution data (version 1.2) last modified: 1/04
Barriers to Fish Passage
Dams
Falls
Cascade / Gradient
Other barriers
Hatcheries
Hydrologic Units
County Lines
Major roads
Land Ownership
State Lands
BLM Lands
USFS Lands
Nat. Parks, Monuments, Refuges & Grasslands
Military & Other Fed. Lands
Tribal Lands
Private Lands
HUC Number
17090010
January 21, 2004
MILES
0
2
4
6
DATA SOURCES
DISTRIBUTION DATA DESCRIPTION
NEHALEM R
17100202
LOWER WILLAMETTE R
17090012
TILLAMOOK R
17100203
YAMHILL R
17090008
MIDDLE WILLAMETTE R
North Plains
Portland
Beaverton
Tigard
King City
Lake Oswego
Sherwood
Carlton

TUALATIN R
Coho Salmon

(100K) Fish Habitat Distribution (24K)

- 🟥 Spawning & Rearing Areas ▲
- 🟩 Rearing & Migration ▲
- 🟫 Migration ▲
- 🟨 Present, Usetype unspec. ●
- — Other Streams

Distribution data (version 12) last modified: 1/04

Barriers to Fish Passage

- Dams
- ⊞ Falls
- ☒ Cascade / Gradient
- ⊞ Other Barriers

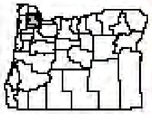
HUC Number:
17090010

January 26, 2004

- ■ Hatcheries
- — Hydrologic Units
- — County Lines
- — Major roads

Land Ownership

- ☐ State Lands
- ☐ BLM Lands
- ☐ USFS Lands
- ☐ Nat. Parks, Monuments, Refuges & Grasslands
- ☐ Military & Other Fed. Lands
- ☐ Tribal Lands
- ☐ Private Lands



MILES
0 2 4 6

DATA SOURCES

The fish habitat data are derived from ODFW biologists as well as biologists from other natural resource entities. These data represent current professional knowledge of the location and habitat use of the listed species. Details on habitat use descriptions, data origin and development can be found in the metadata for the digital distribution datasets at http://rainbow.dfw.state.or.us/nrimp/information/fishdistdata.htm. Streams data are the PNW Reach Files available at www.streamnet.org/pnwr/pnwrhome.html. Other metadata: ftp://rainbow.dfw.state.or.us/pub/gis/k100/metadata/[illegible]. OWEB and StreamNet have provided major funding for this project. To ensure the appropriate use of this data contact Jon Bowers, ODFW Fish Division at (503)947-6097, or consult with ODFW district biologists in your area.

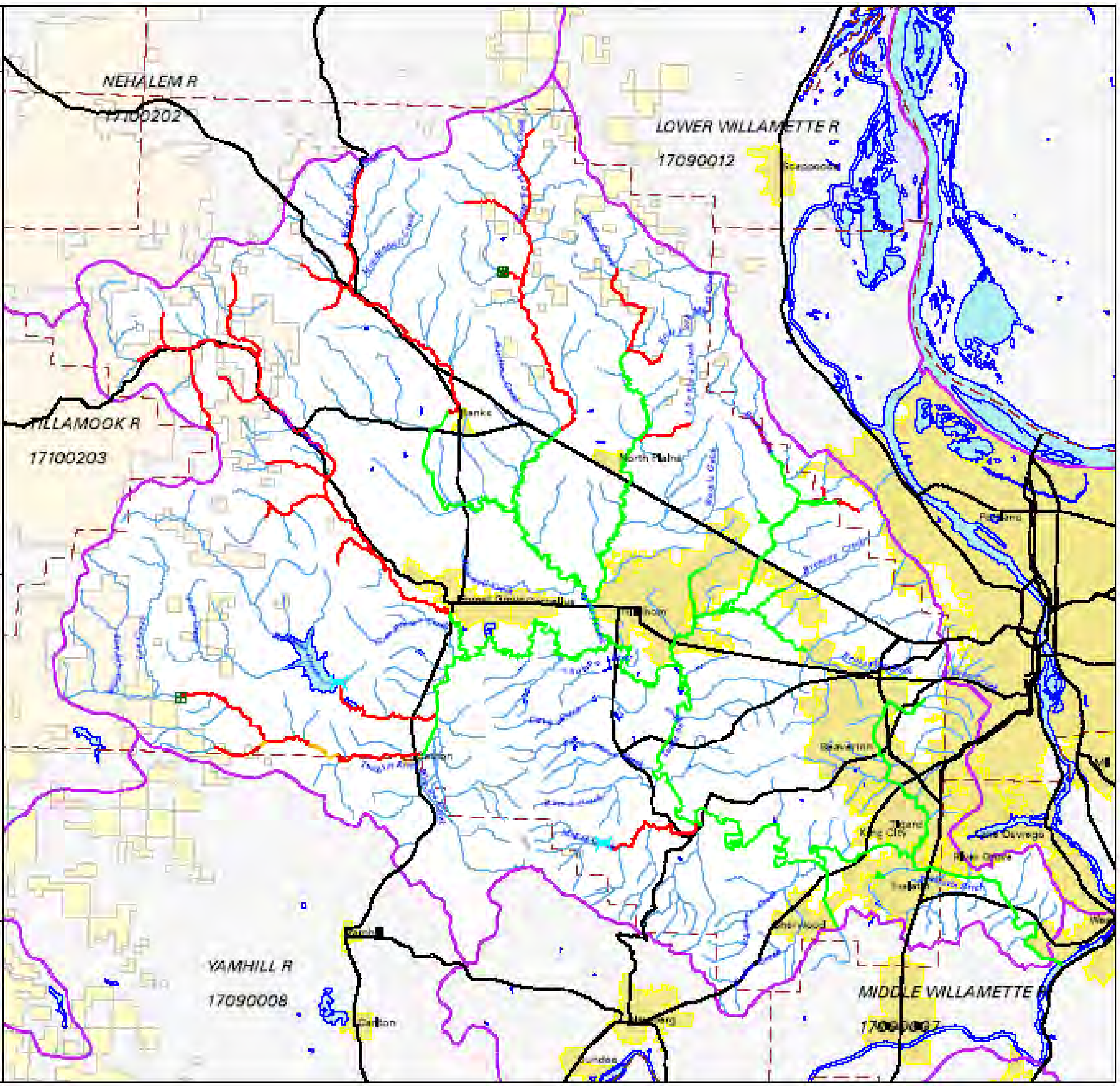
DISTRIBUTION DATA DESCRIPTION

Areas of suitable habitat believed to be currently used by wild, natural, and/or hatchery fish populations. The term "currently" is defined as within the past five reproductive cycles. This information is based on the observations and best professional judgement of ODFW staff biologists and, where possible, the professional observations and opinions of staff from other natural resource entities. Due to natural variations in run size, water conditions, or other environmental factors, some areas displayed may not be used by a species of fish on an annual basis. Streams that have no data associated with them are considered UNKNOWN for species presence and/or absence.

Limited historic distribution data exist within the GIS datasets.

Only partial or complete barriers to the species/run within the HUC are shown. Barrier and related fish passage data are not comprehensive at this time.

To obtain species observation data sets see:
http://rainbow.dfw.state.or.us/nrimp/information/fishsightingsdata.htm



Analysis of Habitat Potential in Tyron Creek for Coho Salmon and Steelhead Trout

Mobrand Biometrics, Inc.

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Previous sections have reported on the considerable work being done by City departments and others to characterize the physical condition of Tryon Creek. The measurement of these conditions can be judged relative to indices and benchmarks recommended by management agencies. However, it is useful to bring together the detailed knowledge of physical conditions in Tryon Creek into an overall measure of watershed condition or "health". Watershed health is a relative term: one way to measure health is in terms of the potential of the watershed to support species of interest. To characterize the environment, we use species that would be expected to thrive in Tryon Creek absent habitat change brought about by urbanization of the watershed. The biological performance of the species becomes a gauge of ecological health. This provides a biological measure of urbanization that integrates across all of the previously discussed physical measures.

To provide an integrative measure of overall watershed health in Tryon Creek, the city is using the technique known as Ecosystem Diagnosis and Treatment (EDT) to characterize the potential of the stream to support two native salmon species: coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*). EDT is more fully described in Appendix 1. EDT is a widely used salmon habitat model that provides a "diagnosis" of a stream in terms of its suitability for particular salmon species. Coho and steelhead were chosen as indicator species because they are typical of streams in the lower Willamette River such as Tryon Creek and provide an indicator of a type of biological community and physical environment that would typify similar streams. Coho and steelhead uses the environment in different ways and so together provide a broad diagnosis of habitat conditions in Tryon Creek. The two species are used as indicators of desirable environmental conditions in the lower Willamette River, i.e. a healthy stream is defined as one that supports native species such as coho and steelhead. The purpose of the EDT diagnosis is to evaluate the health of Tryon Creek and to provide a framework for restoration and management of Tryon Creek.

EDT uses habitat-survival relationships to estimate the abundance and productivity of fish populations based on the condition of the stream habitat. The abundance calculated by EDT is a measure of the quantity and quality of suitable habitat; productivity is the maximum survival that could be expected from the habitat and is measured as the number of adult fish produced from a group of eggs (return/spawner). EDT also measures the life history diversity of fish. This is an important measure of fish population health that is based on the number of weeks within a year and the amount of area within the stream where suitable conditions exist. Greater life history diversity means that fish have wider opportunities to find suitable conditions and to weather changes in the environment that occur from year to year.

Approach

The analysis of salmon habitat potential in Tryon Creek was approached in the following steps:

1. Stream definition. For the analysis, Tryon Creek was defined as the stream from its mouth to the confluence with Falling Creek (stream mile 4) and including Arnold Creek (1.2 miles) and Falling Creek (1.8 miles). Two natural passage barriers were included: Marshall Cascade (stream mile 3.5) and Arnold Falls (3.1 miles from the mouth of Tryon Creek).
2. Stream layout. Tryon Creek was divided into stream reaches--portions of the stream delineated by tributaries, valley form or other features. Stream reaches were defined by the Oregon Department of Fish and Wildlife (ODFW). The ODFW reaches were augmented by obstruction reaches where culverts or natural obstructions existed. This resulted in a total of 51 reaches including two natural obstructions (Marshall Cascade and Arnold Falls) and 12 culverts (Table 1).
3. Data collection. Most data on physical habitat in Tryon Creek was collected by the Oregon Department of Fish and Wildlife as part of their Aquatic Inventory Project. This included stream measurements, habitat types, large wood, substrate condition and riparian cover. Flow, temperature and water quality were provided from various city and municipal sources described in previous sections of this report.
4. Model parameterization. Information from these sources was assembled for entry into the Ecosystem Diagnosis and Treatment (EDT) model. Empirical measurements of habitat parameters were converted to categorical ratings used in EDT for each of the 51 reaches in the analysis.
5. Model characterization of the habitat. The EDT model itself was used to compute the equilibrium abundance, productivity and life history diversity of coho and steelhead as a function of the physical habitat variables. Total potential of the stream was assessed as the performance of a coho or steelhead population in the creek. Reach level conditions were assessed for each coho or steelhead life stage.

Table 1. EDT reaches for Tryon Creek.

Reach	Description	Length (mi)	Cum. length	Slope
Tryon1	Tryon from the mouth to HWY 43 culvert	0.20	0.20	1.6%
Tryon43CulvertObstr	Obstruction rating for HWY 43 culvert	0.00	0.2	
Tryon43CulvertLength	Length of culvert under HWY 43	0.05	0.2	4.0%
Tryon2	HWY 43 to Nettle Creek	0.83	1.1	1.1%
Tryon3A	Nettle Creek to Park Creek	0.74	1.8	0.8%
Tryon3B	Park Creek to Lewis and Clark Cr.	0.65	2.5	0.8%
Tryon3C	Lewis and Clasrk Creek to Boone's Ferry Rd.	0.21	2.7	1.5%
TryonBFCulvertObstr	Obstruction rating for Boone's Ferry Rd. culvert.	0.00	2.7	
TryonBFCulvertLength	Length of culvert under Boone's Ferry Road	0.03	2.7	3.0%
Tryon4A	Canyon section above Boone's Ferry Road	0.58	3.3	3.2%
TryonMapleCulvertObstr	Obstruction rating for Maple Crest Dr culvert	0.00	3.3	
TryonMapleCulvertLength	Length of culvert under Maple Crest Dr.	0.02	3.3	3.0%
Tryon4B	Maple Crest to Marshall Cascade	0.18	3.5	3.7%
TryonMarshallCascadeObstr	Obstruction rating for Marshall Cascade	0.00	3.5	
Tryon4CMarshallLength	Length of Marshall Cascade and Marshall Park	0.07	3.6	11.1%
Tryon18CulvertObstr	Obstruction rating for culvert on Tryon Creek at 18th Place	0.00	3.6	
Tryon18CulvertLength	Length of culvert at 18th Place	0.01	3.6	4.0%
Tryon4D	SW 18th culvert to Lancaster	0.46	4.0	3.2%
TryonLancasterCulvertObstr	Obstruction rating for culvert on Tryon Creek at Lancaster	0.00	4.0	
TryonLancasterLength	Length of culvert under Lancaster Road	0.02	4.0	3.0%
Tryon4E	Lancaster Rd. to Falling Creek	0.05	4.1	0.4%
Arnold1A	Mouth to Arnold Road	0.14	0.1	3.1%
ArnoldCulvert1Obstr	Obstruction rating for culvert at Arnold Road	0.00	0.1	
ArnoldCulvert1Length	Length of culvert at Arnold Road.	0.02	0.2	3.0%
Arnold1B	Arnold Rd to driveway	0.22	0.4	3.8%
ArnoldCulvert2Obstr	Obstruction rating for culvert at first driveway	0.00	0.4	
ArnoldCulvert2Length	Length of culvert at first driveway	0.01	0.4	3.5%
Arnold1C	Short reach from culvert to Arnold Cascade	0.04	0.4	4.5%
ArnoldCascadeObstr	Obstruction rating for Arnold Cascade	0.00	0.4	
ArnoldCascadeLength	Reach length for Arnold Cascade	0.03	0.5	25.1%
ArnoldCulvert3Obstr	Obstruction rating for culvert at SW 16th	0.00	0.5	
ArnoldCulvert3Length	Length of culvert at SW 16th.	0.02	0.5	4.0%
Arnold1D	SW 16th to second driveway	0.10	0.6	1.1%
ArnoldCulvert4Obstr	Obstruction rating for culvert at second driveway on Arnold Creek	0.00	0.6	
ArnoldCulvert4Length	Length of culvert at second driveway on Arnold Creek	0.01	0.6	1.5%
Arnold1E	Second driveway to Lancaster Road	0.24	0.8	1.9%
ArnoldCulvert5Obstr	Obstruction rating for culvert at Lancaster Road	0.00	0.8	
ArnoldCulvert5Length	Length of culvert at Lancaster Road	0.02	0.8	3.0%
Arnold1F	Lancaster to Oak Creek	0.40	1.2	3.7%
Falling1A	Mouth of Falling Creek to 35th Ave.	0.20	1.4	2.5%
Falling26CulvertObstr	Obstruction rating for culvert on Falling Creek at SW 26th Avenue.	0.00	1.4	
Falling26CulvertLength	Length of culvert.	0.01	1.5	2.0%
Falling1B	SW 26th Avenue to SW 35th	0.70	2.2	2.0%
Falling35CulvertObstr	Obstruction rating for culvert on Falling Creek SW 35th	0.00	2.2	
Falling35CulvertLength	Length for culvert on Falling Creek SW 35th	0.05	2.2	5.0%
Falling1C	SW 35th to Huber	0.30	2.5	2.0%

Potential use of Tryon Creek by Coho and Steelhead

Tryon Creek is a small stream draining a watershed of steep canyons that, under natural conditions, would be heavily forested. Although heavily urbanized in its upper reaches, the watershed retains considerable forest, especially in the lower portion within Tryon Creek State Park. The lower portion is generally low gradient (1% or less) with a larger flood plain compared to upper reaches. Starting about Boones Ferry Road the stream becomes restricted by steep canyon walls while gradient increases (3-4%). Marshall Cascade on Tryon Creek is a natural waterfall/cascade. It would have formed a complete blockage to coho salmon and would have severely impeded steelhead migration. Arnold Falls on Arnold Creek would have been a complete impediment to both coho and steelhead. Total length of stream potentially accessible to anadromous fish in Tryon Creek is 3.9 miles; culverts reduce accessibility under current condition to 2.7 miles.

Coho salmon and steelhead were used to characterize the habitat in Tryon Creek because they would be expected to thrive in a stream like Tryon Creek under natural conditions. The two species have different life histories and so experience the habitat in Tryon Creek in different ways. Coho spawn in the fall (October to December). Juveniles emerge the next spring and live for one year in freshwater and would leave Tryon Creek in the spring following their emergence. They spend one to two years in the ocean and return to Tryon Creek in September. Steelhead spawn in early spring (March-April). Important to this habitat analysis is that juvenile steelhead would spend two years in Tryon Creek before heading to the ocean in contrast to coho that would spend only a single year in Tryon Creek. Steelhead spend one to three years in the ocean and would return to Tryon Creek in December.

The EDT estimate of restored habitat potential in Tyron Creek is about 600 coho and 125 winter steelhead. This is an estimate of the ultimate potential of the stream with current limitations removed—current conditions do not appear to be capable of supporting viable populations of either species. The estimate of coho potential is greater than steelhead because the greatest area of habitat (i.e. length and width) is in the low gradient reaches typical of the park area that would favor coho over steelhead. Many of the steeper reaches favored by steelhead consist of narrow, tightly confined reaches that provide little capacity for steelhead.

Major Findings regarding current conditions of Tryon Creek[1]

- The condition of habitat in Tryon Creek that is currently accessible to anadromous fish (i.e. downstream of Boones Ferry Road) appears unable to support a viable population of either coho or steelhead. The complete EDT population report is provided as Appendix 2 (coho) and Appendix 3 (steelhead).
- Current habitat useable by anadromous salmon is limited to the lower portion, primarily in Tryon Creek State Park. The low gradient habitat within the park is

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[1] Findings should be considered preliminary and are subject to revision and change.

more suitable for coho than for steelhead. Hence, although neither coho nor steelhead appear to be viable in the present habitat, the currently accessible habitat has greater potential for coho than for steelhead (Appendices 2 and 3).

- Steelhead are limited in Tryon Creek by the small size of the creek above Boone's Ferry Road and because they spend two years in Tryon Creek and are exposed to current habitat limitations to a much greater degree than are coho. Also, in contrast to coho that spawn in September to December, steelhead spawn in March to April and migrate up Tryon Creek in winter. This is the period of highest flow in the creek when flow and habitat limitations limit incubation survival and spawning success.
- Culverts block much of the habitat in Tryon Creek and are a major factor limiting the current potential of the creek. Presently over 30% of the salmon habitat in Tryon Creek is blocked by the impassable culvert at Boones Ferry Road. However, the impact of the partial barrier at Highway 43 is of greater concern because of its impact on accessibility of the habitat within Tryon Creek State Park, which under any circumstances would be the most productive portion of the stream. <u>In fact, within the model, removal of the culverts, and especially the culvert at Highway 43 allowed for a small, but potentially viable population of coho (but not steelhead) to persist in Tryon Creek.</u> These culverts also limit the potential benefit from other habitat restoration efforts since they would impede access to improved habitat.
- <u>Ranking of habitat conditions.</u> In EDT, we are able to examine the condition of each reach and assign a rank based on its importance for protection of the current condition and for restoration of conditions. The ranking of protection value is a measure of the importance of the reach to supporting the current, albeit limited, potential of the stream for coho and steelhead. Restoration ranking is a reflection of the potential of restoration actions to increase the potential of the stream for coho and steelhead. Currently, culverts severely limit the distribution of fish within the creek and the ability to evaluate habitat conditions. For this reason, habitat priorities were evaluated in EDT <u>with the culverts removed</u>; natural barriers at Marshall Cascade and Arnold Falls were retained in the analysis.

  An important caveat is that the analysis ranks conditions directly experienced by the fish rather than the causes of the condition. Aquatic conditions experienced by fish and other organisms in a reach are often not the result of local watershed actions but instead are the cumulative result of upstream conditions. For example, flow, temperature, sediment and pollutant conditions, all of which limit habitat potential within Tryon Creek State Park, develop largely as a result of conditions throughout the watershed and cannot be remedied by actions within the park. Restoration of stream conditions requires watershed restoration and management.

  The complete ranking of all accessible reaches in regard to protection and restoration potential indicated by the EDT analysis is provided in Appendix 4 (coho) and Appendix 5 (steelhead). The following tables summarize the top five protection and restoration reach priorities for each species (Table 1 describes each reach):

Coho Salmon Reach Priorities in Tryon Creek		
Rank	Protection Rank	Restoration Rank
1	Tryon 3A	Tryon 2
2	Tryon 2	Tryon 3A
3	Tryon 3B	Tryon 3B
4	Tryon 3C	Tryon 3C
5	Tryon 4A	Tryon 4A

Steelhead Reach Priorities in Tryon Creek		
Rank	Protection	Restoration
1	Tryon 2	Tryon 4A
2	Tryon 4A	Tryon 1
3	Tryon 3A	Tryon 3B
4	Tryon 3C	Tryon 3A
5	Tryon 4B	Tryon 2

Conditions within Tryon Creek State Park (reaches 2 and 3) are high protection and restoration priorities for both coho and steelhead. Reach 4, just above the present blockage at Boone’s Ferry Road, also ranked high for restoration and protection potential for both coho and steelhead. Steelhead priories are shifted upstream relative to coho, however, potential anadromous fish production is limited in the upper reaches above Reach 4. This is because very small, confined reaches characterize the upper portions of the watershed, while the barriers at Marshall Cascade and Arnold Falls impede natural access.

A final point is that these ranking focus strictly on fish populations originating within Tryon Creek itself. The lower reaches of the creek, especially Tryon 1 below Highway 43 may also provide benefit for other Willamette River populations by providing off channel refuge. Juvenile salmonids have been reported from Tryon 1 that are difficult to account for as originating from Tryon Creek and are likely mainstem migrants using lower Tryon Creek as resting or feeding habitat.

- Limiting Conditions. The low gradient, slow water conditions that characterize the lower portion of Tryon Creek (especially within Tryon Creek State Park) are particularly suited for coho salmon. Steelhead are also more limited in Tryon Creek than are coho because they spend an additional year in the creek. However, current conditions do not appear to be capable of supporting a viable population for either species. As noted previously, the presence of culverts in Tryon Creek, especially the culvert at Highway 43, severely limits the present capabilities of the habitat to support coho; in the model, a small but potentially viable population of coho developed within the park with removal of the Highway 43 culvert. In addition to the culverts, the stream has several conditions that limit habitat and are related to land use within the watershed. These are summarized in figures 1 and 2 and the points below. Figures 1 and 2 list the top restoration reaches (table above) and the top three life stages affected by conditions in the priority reaches. The figures also provide a ranking of the habitat attributes in terms of their impacts on these life stages. Overall, limiting factors for coho and steelhead in Tryon Creek can be summarized as follows:
    1. Lack of habitat complexity. In its natural condition, a stream like Tryon Creek would be expected to have an array of pools, riffles, side channels and backwaters caused by large amounts of downed wood and trees, and by a meandering stream channel. Logs would form deep pools to shelter adults and juveniles while backwaters and off-channel areas would provide areas for juvenile fish to escape winter flow peaks. In contrast, Tryon Creek currently has little large wood in the stream, even within the park, and, for the most part, the stream is confined within a single, simplified channel. In EDT, this considerably reduced the survival of juvenile coho and steelhead and reduced spawning success.
    2. Too much fine sediment. Tryon Creek drains a watershed that is characterized by a natural abundance of fine silt. Land use practices likely have exacerbated the natural condition of the stream to transport high levels of fine sediment. Fine sediment from steeper upper reaches tends to settle out in the low gradient area within the park. Turbidity increases sharply during storm events. Fine sediment and silt can bury and suffocate eggs and emerging salmon juveniles. In the analysis, fine sediment, embedded substrate and turbidity reduced survival of spawning and egg incubation life stages for coho and steelhead.
    3. Lack of aquatic insects. A curious feature of Tryon Creek is the lack of aquatic insects even in areas within the park that appear relatively natural. Aquatic larvae of stoneflies, mayflies and other insects form the primary food for juvenile salmon during the summer. The lack of aquatic insects in Tryon Creek has not been explained although water quality and sediment have been suggested as causes. The lack of food, related to the scarcity of aquatic insects, limited survival of juvenile coho and steelhead in the model in the active growth and rearing periods during summer and fall.

4. Increased peaks in flow. Urban streams often respond rapidly to storm events and have more frequent peak flows than would occur in a more natural setting. This is related to the increase in roads, parking lots and other impervious surfaces in the watershed. These cause winter rainfall to move rapidly across the surface and through storm drains to the stream rather than entering more gradually through groundwater. These peak flows often coincide with spawning especially for steelhead that spawn in early spring (March-April). Coupled with the lack of off-channel refuge areas, peak flows can flush out juvenile fish. In the EDT analysis, changes in the flow patterns limited spawning success and on over-winter survival of juveniles.
5. Constricted channel form. Survival of most juvenile life stages was reduced by the simplified stream channel. The channel form of Tryon Creek generally consists of a single channel; moderate downcutting in the park and more severe downcutting below Highway 43 further constrain and simplify the channel. Riparian areas, while present through the park and elsewhere consist largely of alders and shrubs that provide fewer benefits for aquatic habitat formation. The result is that fish have less cover, adults and juveniles are exposed to peak flow events and redds (nests) can be disturbed by movement of sediment in high flow periods. In EDT, channel form and conditions decreased survival of incubating eggs and most juvenile life stages for both coho and steelhead.
6. Possible presence of pollutants. The water quality assessment of Tryon Creek discussed in previous sections identified several potential water quality problems in Tryon Creek. However, water quality monitoring is still limited and it was not possible to fully characterize pollutants within the EDT model. However, a reasonable hypothesis was developed that posed a diminution of water borne pollutants but an accumulation of sediment pollutants in a downstream direction. Based on this hypothesis, EDT identified pollutants as having a potentially important limiting effect on the spawning and incubation life stages.

A reach-by-reach depiction of limiting conditions for each life stage is included as Appendix 4 (Coho) and Appendix 5 (Steelhead).

Figure 1. Reach and attribute priorities for coho restoration in Tryon Creek. Attribute rankings include ties. Some reaches do not have a single top ranked attribute but may have several second and third ranked attributes.

Priority Restoration Reaches	Life Stage	Channel Stability	Chemicals	Competition w/ hatcher	Competition other spp	Flow	Food	Habitat Diversity	Harassment	Obstructions	Oxygen	Pathogens	Predation	Sediment	Temperature	Key Habitat
Tryon 2	Egg incubation	1	2											1		3
	Winter rearing	2	3			2	2	1						3		
	Summer rearing	3	2		2	2	1	1					3	3	2	3
Tryon 3A	Egg incubation	1	2			2								1		3
	Summer rearing	3	2		2	2	1	1				3	3		2	3
	Fry colonization	2	2		3	2	2	2				3	3		2	3
Tryon 3B	Egg incubation	1	2			2								1		3
	Summer rearing	2	2		2	1	1	1				3	2		2	3
	Fry colonization	2	2		3	2	2	2				3	3		2	3
Tryon 3C	Winter rearing	2	3			2	2	1						3		
	Summer rearing	3	2			2	2	1				3	3		2	
	Fry colonization	1	1		3	1	2	1								3
Tryon 4A	Egg incubation	1	2											1		3
	Winter rearing	2	2			1	1	1						3		2
	Summer rearing	2	2			1	1	1				3	2		2	3

Figure 2. Reach and attribute priorities for steelhead restoration in Tryon Creek. Attribute rankings include ties. Some reaches do not have a single top ranked attribute but may have several second and third ranked attributes.

Priority Restoration Reaches	Life Stage	Channel Stability	Chemicals	Competition w/ hatche	Competition other spp	Flow	Food	Habitat Diversity	Harassment	Obstructions	Oxygen	Pathogens	Predation	Sediment	Temperature	Key Habitat
Tryon 4A	Age-0 Winter rearing	2	2			1	2	1						3		2
	Age-1 Summer rearing	2	2		2	1	2	1					3	3	2	3
	Egg incubation	2	2			3								1	3	3
Tryon 1	Age-0 Winter rearing	3				2	3	2						2		3
	Age-1 Summer rearing	3				2	3	2					3		3	
	Age-2 Summer rearing	3				2		2								3
Tryon 3B	Egg incubation	3	2			3								1	3	3
	Age-0 Summer rearing		2		3	1							3		2	
	Age-0 Winter rearing	2	2			2	2	2						2		3
Tryon 3A	Egg incubation		2											1	3	3
	Age-0 Summer rearing		3		3	1	2	2				3	3		2	
	Age-0 Winter rearing	3	3			2	2	2						2		3
Tryon 2	Egg incubation	3	3											1	3	
	Age-0 Summer rearing	2	3			2	2	2						3		3
	Age-1 Summer rearing	3	3		3	2	2	2						3		3

Conclusion

This analysis used a salmonid-habitat model, Ecosystem Diagnosis and Treatment (EDT) to estimate the current and fully restored potential of Tryon Creek to support coho salmon and steelhead trout, native species that would be expected in Tryon Creek. Although Tryon Creek is not systematically surveyed for spawning salmon, there have been few recent sightings of adult salmon in the creek. The results of this analysis were consistent with this and found that current habitat conditions are inadequate to support a viable population of either species. The stream is small with many relatively steep, naturally confined reaches except for the lower portion within Tryon Creek State Park. Even under non-developed conditions, the stream would be expected to produce relatively small numbers of salmon—the estimated potential is 600 coho and 125 steelhead under fully restored conditions. While these numbers may appear insignificant relative to the production and restoration of salmon in the Willamette River basin, they can be highly significant to the cultural values of the Portland Metropolitan Area and especially to those living within the watershed. The stream and the state park are important icons for the city that belie the relatively small capacity of the stream.

Small stream such as Tryon Creek are biologically important because of the important contribution they can make to the habitat and life history diversity of salmon in the lower Willamette River. Historically, small streams like Tryon Creek, Johnson Creek, Kellogg Creek, Abernethy Creek and others were probably biologically linked to the larger populations in the Clackamas River. These small streams would have been part of the larger complex of aquatic habitats and salmonid population structure that existed in the lower Willamette River. While perhaps not contributing greatly to the overall abundance of fish in the Willamette River, the smaller streams would have provided a diversity of biological options for salmon and contributed to the strength and resilience of the overall population complex. In the current situation, with habitat quality and fish abundance reduced throughout the lower Willamette River, the importance of the habitat and life history diversity afforded by the smaller streams is likely to be an important factor in the restoration of lower Willamette River salmon and steelhead.

The analysis has allowed us to trace the current lack of use of Tryon Creek by anadromous fish to specific reach level and watershed scale problems. Culverts, especially the culvert at Highway 43, limit the potential of the current habitat and the value of any other restoration actions. The analysis has identified a set of limiting conditions and indicated priorities for restoration and protection of habitat conditions within the stream in addition to culverts. These priority protection and restoration areas largely fall within, and just above, Tryon Creek State Park. This is not only because the park provides the best current habitat conditions within the watershed but also because habitat in this lower portion is likely to be intrinsically the best in the stream. It has a low gradient and a relatively large flood plain that contrasts with much of the other areas of the stream that are steeper and often tightly confined by valley walls.

It is emphasized, however, that restoration of conditions within the park will rely on restoration and management of conditions in the upland areas further up in the Tryon Creek watershed. Table 2 provides a general listing of habitat limitations identified in this analysis and a brief list of their sources. This table is not intended to be exhaustive in either the identification of problems or the sources. Instead, it emphasizes the linkage between instream problems, perceived by fish and other organisms, and the upland and local sources. If the majority of productive potential lies within Tryon Creek State Park, there is little that can be done within the park to correct major problems such as flow, temperature, sediment and pollutants. Solutions to these problems lie in the upper reaches and in terrestrial areas where problems begin and accumulate downstream. This is not to say that restoration within the park and elsewhere is not needed. In particular, correction of passage problems associated with culverts, especially the culvert under Highway 43, should rank as high priorities. Addition of large wood throughout the lower area (including the park) and channel improvements in the first reach (below Highway 43) are also reach level restoration priorities. However, these localized actions will provide little benefit if more pervasive watershed problems persist. In short, restoration of a measure of the productive potential of Tryon Creek cannot be approached piece-mile but will require a strategic effort throughout the Tryon Creek watershed.

Table 2. Priority habitat problems in Tryon Creek and likely sources.

Problem	Source
High sediment levels	1. Construction runoff 2. Street runoff 3. Eroding banks where riparian vegetation is reduced or missing
High summer water temperatures	1. Decreased groundwater input from impervious surfaces 2. Solar warming in the summer due to reduced riparian forest (especially in smaller upper reaches and tributaries).
Reduced wood and habitat complexity in the stream	1. Sparse riparian forest dominated by small alder and shrubs 2. Removal of instream wood by residents and city workers
Increase in size and frequency of high flow events	1. Fast surface runoff from streets, parking lots and highways 2. Constriction of channel and lack of floodplain water storage
Lack of connectivity and migration restrictions	1. Numerous and poorly designed or maintained culverts 2. Simplified channel with few refugia
Pollutants and water quality problems	1. Runoff from streets, highways and parking lots 2. Runoff from yards 3. Point sources

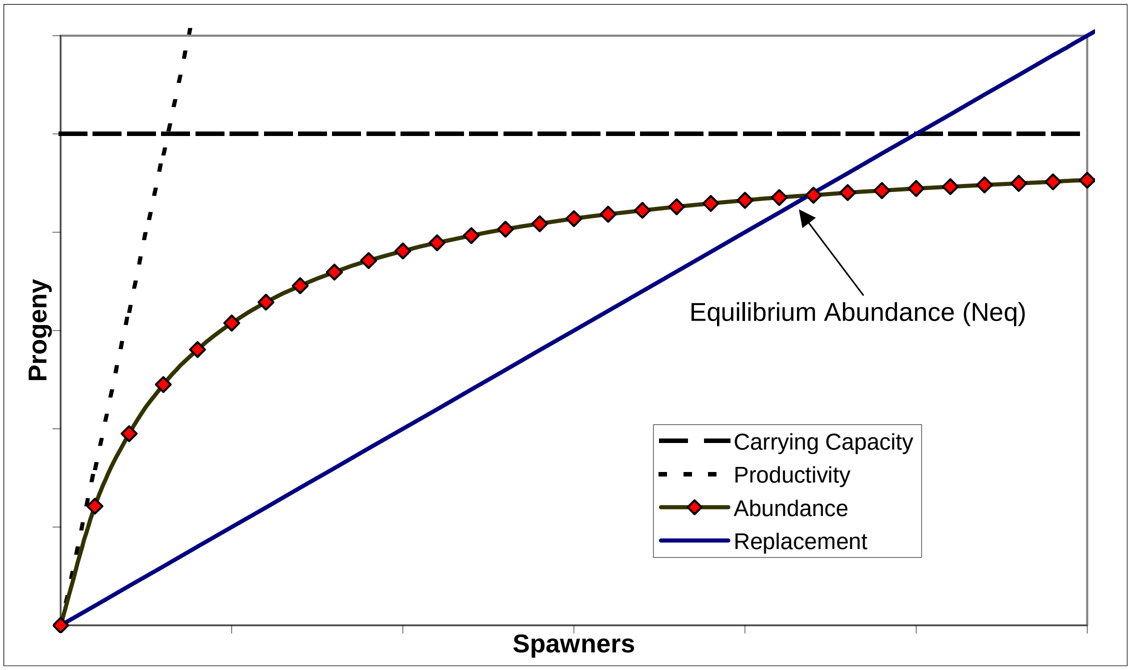
Appendix 1. Description of Ecosystem Diagnosis and Treatment

Ecosystem Diagnosis and Treatment (EDT) is a tool for assessment and analysis of a stream with respect to a salmonid fish species. EDT is a deterministic, steady state habitat rating procedure that estimates the potential of a stream to support a fish species. Habitat constraints can be identified as a basis for targeting and prioritizing restoration efforts. Habitat is assessed within a defined study area, which is usually all or part of a stream. Conditions outside the study area, such as in the ocean, are characterized by fixed rates that place the study area in the context of conditions experience by the focal species across its life history.

Habitat is evaluated along multiple life history trajectories. A *life history trajectory* is the string of life stages, starting and ending with spawning, that form a complete life history of the focal species. Each life stage that takes place within the study area is associated with habitat in a stream reach. A set of relationships linking life stage survival and capacity to habitat attributes are used to estimate life stage survival and capacity in the reach. A viable life history trajectory reflects a string of habitat of suitable quality and quantity (Independent Scientific Group 2000) over a sequence of life stages. The productivity and capacity of each life stage are linked to estimate the productivity and capacity of the entire life history trajectory. Multiple life history trajectories are evaluated by starting trajectories at intervals along a stream and at different weeks within a year. The array of life history trajectories is a relative measure of the potential life history diversity afforded by the spatial and temporal heterogeneity of habitat conditions within the study area. This is a measure of the breadth of habitat defined by the area and time within a stream providing suitable conditions for the focal species. Trajectories can be combined to estimate the total capacity (quantity of suitable habitat), productivity (quality of habitat) and life history diversity (breadth of habitat) of a population of the focal species in the habitat within the study area.

Biological capacity and productivity used in EDT are the parameters of the Beverton-Holt production function (Beverton and Holt 1957). This function has been in standard use in fisheries population assessment for many years (Hilborn and Walters 1992) and allows the habitat assessment in EDT to be related to fish population attributes (e.g., McElhany and others 2000). Productivity is the density independent component of fish survival. As abundance increases, density dependent factors decrease survival due to competition for limited resources (food and space) until the population approaches the carrying capacity of the environment (Figure 1). Moussalli and Hilborn (1986) showed that the Beverton-Holt function for a population is the integration of similar functions for each life stage. Because each life stage take place in a discreet type of habitat at specific locations within a stream, each reach of a stream can be treated as a separate Beverton-Holt function. Each reach has a capacity, based on the quantity of habitat, and a productivity, based on the quality of that habitat. An EDT assessment of habitat is a process of computing the capacity and productivity of different life stages of a focal

Figure 1. Beverton-Holt Production Function. In EDT, Capacity is a function of habitat quantity, Productivity a measure of habitat quality. Equilibrium abundance (Neq) is derived from capacity and productivity.



species in each reach of a stream, integrating them into life history trajectories and then into populations.

Information in EDT is organized for each reach along the longitudinal stream course. A reach is a geomorphically defined segment of a stream, delineated, for example, by tributary confluences, change in valley form or other features. Habitat in each reach is assessed for different life stages of the focal species. Life stage assessments in each reach are then assembled to form life history trajectories. All viable life histories in a defined portion of a stream are integrated to compute the quantity and quality of habitat for the population. Habitat is described in regard to 16 composite attributes describing physical and biological elements of the environment (Table 1). These are defined in the model on the basis of measurable attributes of each reach (Table 2).

Table 1. EDT Habitat Attributes

	Factor	Definition
1	Channel stability	The effect of stream channel stability (within reach) on the relative survival or performance of the focus species; the extent of channel stability is with respect to its streambed, banks, and its channel shape and location.
2	Chemicals	The effect of toxic substances or toxic conditions on the relative survival or performance of the focus species. Substances include chemicals and heavy metals. Toxic conditions include low pH.
3	Competition (with hatchery fish)	The effect of competition with hatchery produced animals on the relative survival or performance of the focus species; competition might be for food or space within the stream reach.
4	Competition (with other species)	The effect of competition with other species on the relative survival or performance of the focus species; competition might be for food or space.
5	Flow	The effect of the amount of stream flow, or the pattern and extent of flow fluctuations, within the stream reach on the relative survival or performance of the focus species.
6	Food	The effect of the amount, diversity, and availability of food on the relative survival or performance of the focal species.
7	Habitat diversity	The effect of habitat complexity within a stream reach on the relative survival or performance of the focus species.
8	Harassment	The effect of harassment, poaching, or non-directed harvest (i.e., as can occur through hook and release) on the relative survival or performance of the focus species.
9	Key habitat	The relative quantity of the primary habitat type(s) utilized by the focus species during a life stage; quantity is expressed as percent of wetted surface area of the stream channel.
10	Obstructions	The effect of physical structures impeding movement of the focus species; structures include dams and waterfalls.
11	Oxygen	The effect of the concentration of dissolved oxygen within the stream reach on the relative survival or performance of the focus species.
12	Pathogens	The effect of pathogens within the stream reach on the relative survival or performance of the focus species.
13	Predation	The effect of the relative abundance of predator species on the relative survival or performance of the focus species.
14	Sediment load	The effect of the amount of fine sediment present in, or passing through, the stream reach on the relative survival or performance of the focus species.
15	Temperature	The effect of water temperature with the stream reach on the relative survival or performance of the focus species.
16	Withdrawals (or entrainment)	The effect of entrainment (or injury by screens) at water withdrawal structures within the stream reach on the relative survival or performance of the focus species.

Table 2. EDT Environmental Quality Attributes and Functional Organization

Attribute Number	Functional Category	Environmental Attribute
1	1. Biological Interactions	1.1 Benthos diversity and production
2		1.2 Fish community richness
3		1.3 Fish pathogens
4		1.4 Fish species introductions
5		1.5 Harassment
6		1.6 Hatchery fish outplants
7		1.7 Predation risk
8		1.8 Salmon Carcasses
9	2. Valley and channel form	2.1 Confinement - natural (valley)
10		2.2 Confinement - Artificial (channelization)
11		2.3 Obstructions to fish migration
12		2.4 Gradient
13	3. Habitat Structure	3.1 Bed scour
14		3.2 Embeddedness
15		3.3 Fine sediment
16		3.4 Wood
17	4. Riparian Condition	4.1 Riparian function
18	5. Flow quantity and change	5.1 Flow - Intra daily (diel) variation
19		5.2 Flow - change in interannual variability in high flows
20		5.3 Flow - intra-annual flow pattern
21		5.4 Flow - changes in interannual variability in low flows
22	6. Water Quality	6.1 Alkalinity
23		6.2 Dissolved oxygen
24		6.3 Metals/Pollutants - in sediments/soils
25		6.4 Metals - in water column
26		6.5 Miscellaneous toxic pollutants - water column
27		6.6 Nutrient enrichment
28		6.7 Turbidity
29		6.8 Hydrologic regime - regulated
30		6.9 Hydrologic regime - natural
31	7. Water Temperature	7.1 Temperature - daily minimum (by month)
32		7.2 Temperature - daily maximum (by month)
33		7.3 Temperature - spatial variation

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Appendix 2. EDT Population Report for Coho Salmon in Tryon Creek.

Appendix 3. EDT Population Report for Winter Steelhead in Tryon Creek

Appendix 4. Reach Attribute Report for Coho Salmon in Tryon Creek including Restoration and Protection Priorities.

Appendix 5. Reach Attribute Report for Steelhead in Tryon Creek including Restoration and Protection Priorities.