FINAL SUBMITTAL

Comparative Valuation of Ecosystem Services: Lents Project Case Study

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Prepared for

City of Portland
Watershed Management Program

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June 2004

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1 SUMMARY OF FINDINGS

Using a natural, or ecosystems, approach for the Lent's Flood Abatement Project could provide more than $30,000,000 in economic value to the public over a 100-year timeframe. Five "ecosystem services" would increase productivity at quantifiable levels as a result of floodplain function improvements and riparian restoration. Economic models and published literature and studies were used to assign economic values to these increased services.

2 INTRODUCTION

2.1 GOALS AND OBJECTIVES

Ecosystems provide society with a range of natural services and functions collectively known as ecosystem services (Daly 1997, Brown 2001, Roodman 1998). Ecosystem services represent the conditions or processes that sustain life. Some of the services provided by watershed ecosystems in the Pacific Northwest include water supply, fish habitat, air purification, erosion control, and nutrient cycling.

These conditions or processes produce benefits that have economic utility or satisfy an economic want. Sometimes the translation of benefits into goods is explicit and the connection is accounted for by society through market trading. Often, however, the connections are not abundantly clear because of the way we currently measure costs and benefits today. This analysis seeks to clarify these connections, accounting for goods that are not traded directly in markets such as biodiversity and avoided nuisances.

Interference with or degradation of ecosystem services can result in a decline in water quality, air quality, soil stability, and biodiversity that leads to a decrease in the quality of life for our communities. In response to degradation or loss of ecosystem services, projects are being proposed to restore and protect watershed ecosystems, and development projects that may impact natural resources face increasing scrutiny from regulatory agencies and the public. The objective of ecosystem economics is to quantify and value the ecological and economic benefits of services protected or restored and to use the information to improve the efficiency and effectiveness of environmental management.

The goal of this project is to develop a tool, Comparative Valuation of Ecosystem Services (CVES) analysis, to quantify changes to ecosystem services resulting from implementing selected projects or programs and to assign economic values to those changes. This tool will aid decision-makers in setting priorities and evaluating project alternatives. By understanding the economic value of ecosystem services, project managers and decision makers will be better prepared to accurately weigh the benefits of programs and projects designed to meet regulatory mandates and agency and stakeholder objectives.

2.2 MAJOR STEPS OF THE CVES ANALYSIS

Note: Material in this section is a summary of the CVES methodology discussed in greater detail in Appendix A.

The Comparative Valuation of Ecosystem Services (CVES) analysis applies ecosystem economics to projects or policies to enhance decision-making. To more fully understand the economic importance of ecosystem services, those services affected by a particular project or policy decision, these services must be identified, measured, and assigned defendable economic values.

The values are largely derived from environmental economics techniques that fall into three categories:

1. Revealed preference method – hedonic studies of property values and travel cost analysis of expenditures
2. Stated preference method – contingent valuation surveys of individuals' willingness to pay
3. Avoided cost or replacement value method - cost of developing single-objective alternatives to ecosystem services.

It is important to note that all of these methods are likely to underestimate the full range of economic values specific to given resources. For example, a hedonic analysis of property values will likely underestimate the full value of ecosystem services because it measures only the values of services captured by property values. This is typically limited to amenity values and may exclude values associated with other services, such as water quality and habitat for wildlife.

The CVES analysis has several components as shown in Figure 1A CVES analysis reaches beyond the bounds of conventional impact assessment. The analysis integrates biophysical and economic quantification and incorporates systems dynamics modeling (Ford 1999) that demonstrates the depth and breadth of services affected by a particular project or suite of projects, or by a policy decision.

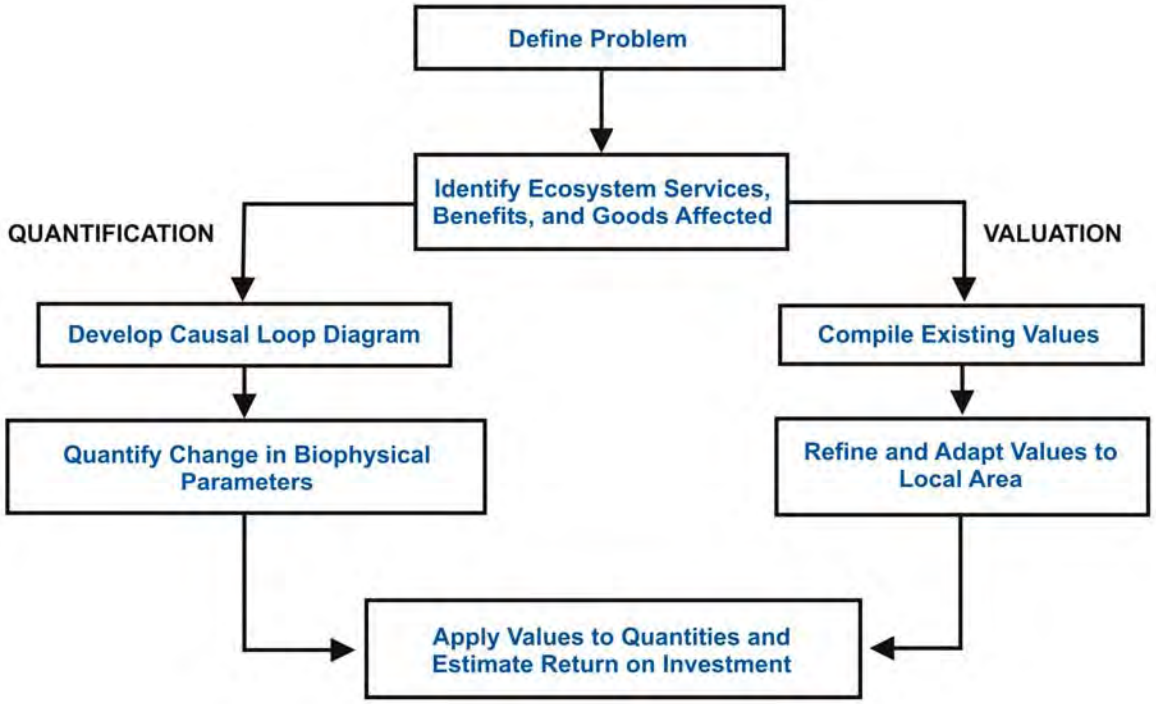

Figure 1. CVES Analysis Process Flow Diagram

2.3 USES FOR THE CVES ANALYSIS

The City of Portland's Watershed Management Program will use the case study to inform design decisions. The city seeks to understand the tradeoffs of choosing design features that provide ecosystem function in comparison to those that provide much less ecological benefit. The City of Portland's objectives (City) fall into three distinct categories. All three categories are related to return on investment. The categories are:

1. What is the return on investment in an ecosystem service-oriented (ESO) project versus a single-objective project?[1]
2. What is the relative return on investment in different types of ESO projects or similar ESO projects in different locations?
3. What is the return on investment for an ecosystem protection policy such as riparian buffers?

The CVES analysis is designed to be flexible so that both local and regional scale assessments can be conducted.

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[1] Single-objective projects focus on one result, such as a reduction of flood damages for a 10-year event.

3 LENTS FLOOD ABATEMENT PROJECT

3.1 LENTS PROJECT DESCRIPTION

The Lents area faces a high risk each winter that Johnson Creek will overflow its banks and flood nearby roads and properties. The past history of flooding in this area demonstrates the severity of the problem:

- 37 out-of-bank flood events since 1941. Of these,
- 28 out-of-bank flood events resulted in property damage, and
- 21 out-of-bank flood events were "nuisance events" (a 10-year flood or less).

Storing the nuisance flood is the target (level) of flood protection endorsed by the City of Portland, as described in the Johnson Creek Restoration Plan (Bureau of Environmental Services 2002). This level of flood protection is intended to relieve the most frequently flooded areas, and is considered to be practical to manage. The focus of the Johnson Creek Restoration Plan is to gain the maximum benefit for flood storage, water quality, and fish and wildlife habitat, while maximizing public safety and cost benefit, with projects that promote natural floodplain function. The preferred management approach would promote natural floodplain function.

The City of Portland Bureau of Environmental Services (BES) has been working with the Lents community and other city bureaus since November 2000 to develop flood management alternatives as part of the Portland Development Commission Lents Urban Renewal Project. The objective is to store waters generated by up to 10-year flood events (nuisance floods) in ways that will improve the environment while also expanding options for community redevelopment (BES 2002).

The preferred project approach would manage nuisance floodwaters south of SE Foster Road between SE 112th Avenue and Interstate 205 (see Figure 2.) The total project area is approximately 140 acres. The project area includes a patchwork of residential, commercial, industrial, and vacant parcels The City of Portland owns 40 percent of the property needed for the project (Bowker 2002). The project area is divided into two sub-areas, East and West Lents. The combined area of these sub-areas is required to meet the nuisance flood control objective (defined as a flood-storage capacity of 200 acre-feet (Bowker 2001). Construction would include creating a wider, two-stage channel within Johnson Creek. The design would also include off-channel storage areas within the adjacent floodplain, and flood relief channels to route waters to storage locations or create alternative downstream flow paths. The City of Portland has estimated that the construction cost of this project would be $35 million (Bowker 2002)[2].

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[2] This estimate does not include financing charges, inflation, discounting, taxes lost from properties removed, ecosystem services lost temporarily as a result of grading during project construction, or any operations and maintenance costs over time.

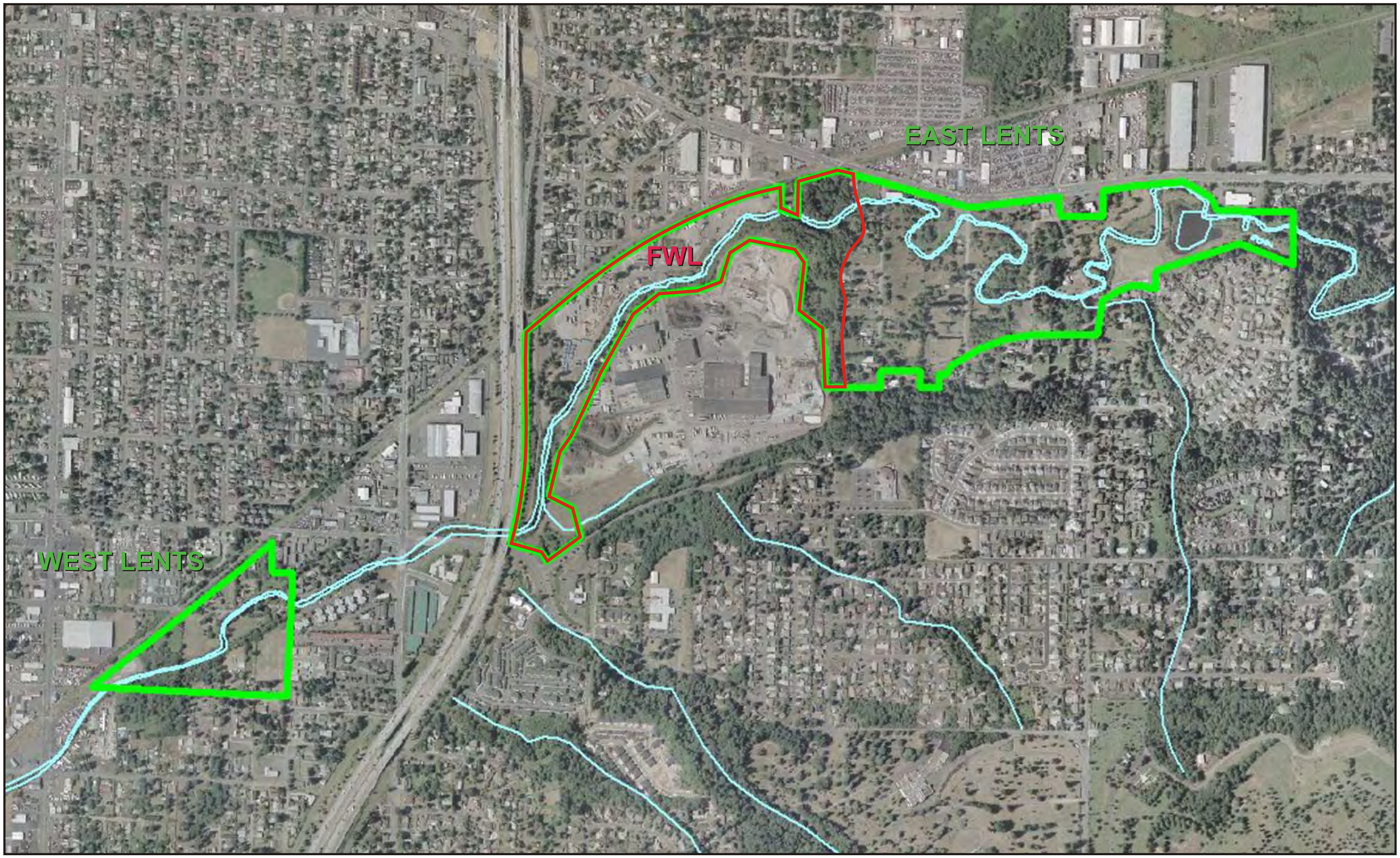

Figure 2
Lents Project Area

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When evaluating this project for selection as a CVES analysis test case, the construction cost for the project had been estimated, but the benefits were described qualitatively only. The CVES analysis describes benefits quantitatively as well, and compares restoration of natural floodplain function (ecosystem service oriented approach) with a single objective approach. The CVES analysis also provides the means to assess the value of certain aspects of the project independently. For example, the East Lents sub-area includes a portion the Freeway Land Company (FWL) property that the City is trying to obtain (approximately 45 acres)[3]. The benefits attributable to this portion of the overall flood abatement project area is assessed separately in order to identify the significance of this property to overall project benefits.

3.2 BROADER PURPOSE OF LENTS PROJECT CASE STUDY

The purpose of the Lents Project Case Study is to identify the return on investment in an ecosystem services-oriented flood abatement project, as compared with a single-objective, flood storage approach. The Lents flood abatement project involves enhanced wetlands and floodplains in a redevelopment setting. By understanding the return on investment for the project, environmental managers can better understand the benefits of restoring and protecting ecosystem services to meet public goals. Also, by seeing the CVES analysis applied to a specific City project, staff can evaluate the value of this analysis for decision-making and public outreach and education.

4 METHODS USED FOR LENTS PROJECT CASE STUDY

4.1 IDENTIFICATION OF MAJOR ECOSYSTEM SERVICES

A causal loop diagram (Ford 1999) was created to better define the problem and the potential solutions. The diagram provided a visual map of the way the system functions and how this function may be affected by decisions. It also provided a transparent way to include ecological, social, and economic factors and their respective relationships. Figure 3 shows the causal loop diagram for the Lents Project Case Study.

Although not all of the factors represented in the causal loop diagram could be quantified and valued for this analysis, the following five Lents project services were quantified:

- Flood abatement
- Biodiversity maintenance, as represented by avian habitat improvement and salmonid habitat improvement
- Air quality improvement, by removal of ozone, sulfur dioxide, carbon monoxide, carbon, and particulate matter
- Water quality improvement, by reduction of water temperature

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[3] The FWL area identified for this project is required to meet the nuisance flood abatement objective set for this project (Cargill, pers. com., 2003).

- Cultural services, including the creation of recreational opportunities and the increase of property values

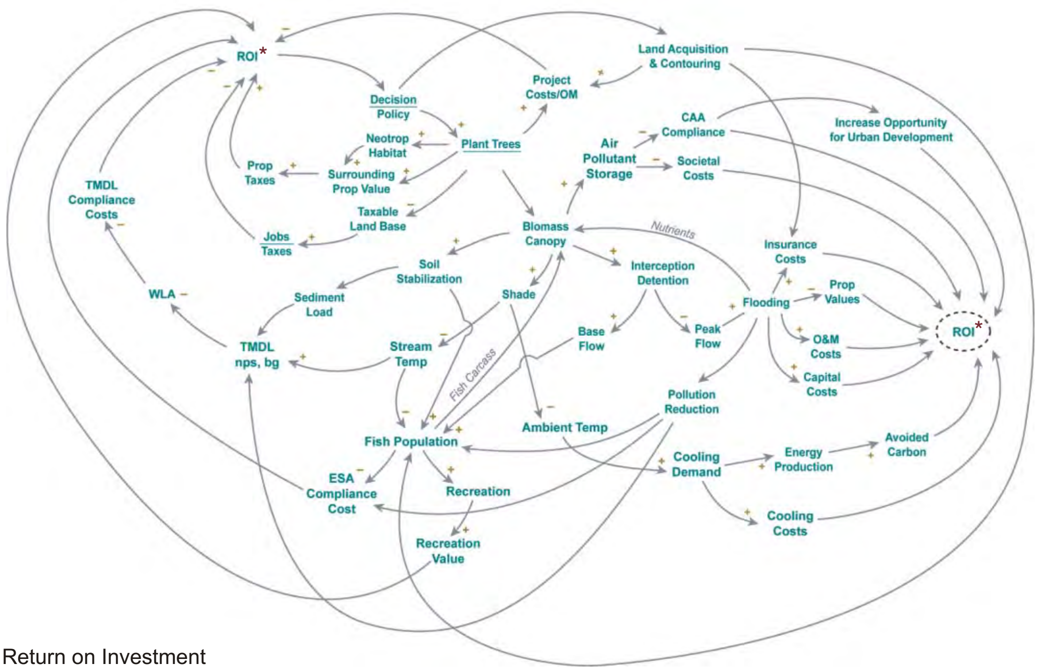
Some of the ecosystem services provided by riparian areas are illustrated in Figure 4. The services circled are those which fall into the above list of project services quantified in the analysis.

4.2 QUANTIFICATION AND VALUATION OF ECOSYSTEM SERVICES

This analysis quantifies and places a value on the changes in ecosystem services attributable to the project during a 100-year period. It is assumed that some of the benefits, such as recreation and fish habitat, will not start accruing until approximately year 10 because it will take time for the restored and replanted riparian areas to establish and provide services. Figure 5 provides a project-specific summary of the services, related benefits and goods, methods of quantification and valuation, and values identified for each service.

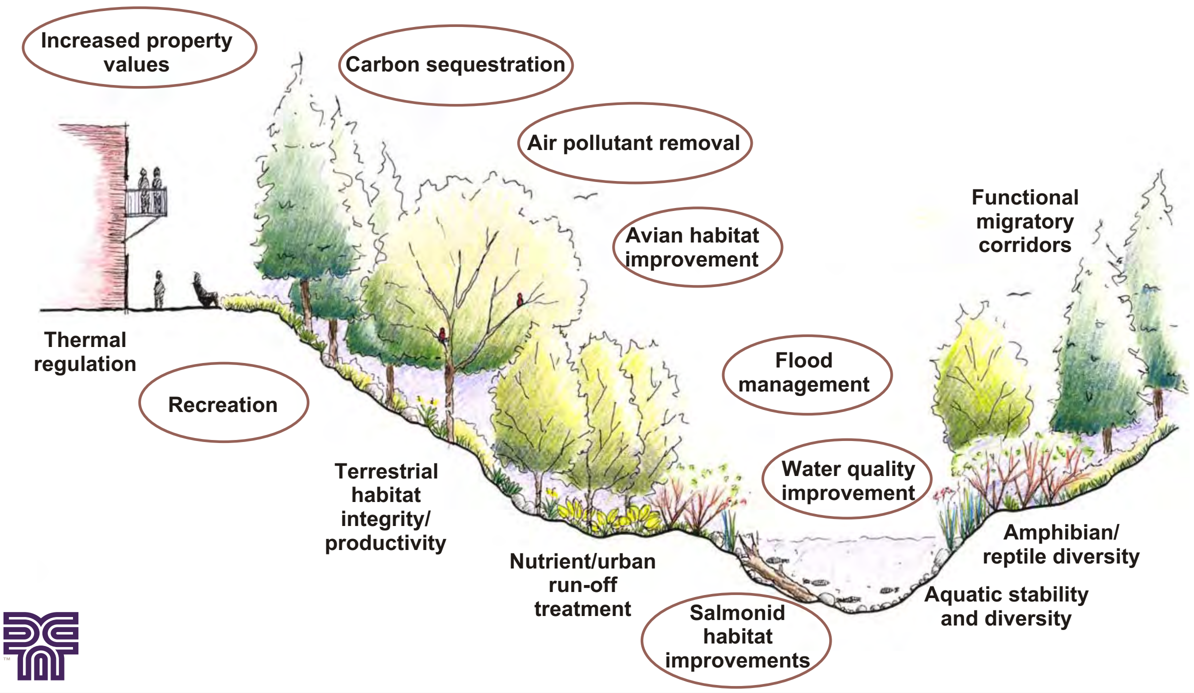
The Lents CVES analysis assessed the amount of change in biophysical conditions that would result from the project. The following assumptions were made as part of the assessment, based on discussions with BES, Johnson Creek Watershed Planning:

- Project benefits are based on nuisance floods (5-, 7-, and 10-year events).
- Post-project, Lents/Foster Road flooding is likely to occur during storms that are larger than the 10-year event.
- Recreation areas are assumed to be open space, providing only passive recreational opportunities.
- 80 percent of the project area will be graded during construction.
- A 120-foot forested corridor will be planted along both sides of Johnson Creek.
- There will be a minimum of 32 acres of riparian forest at East and West Lents combined (minus Freeway Land Parcel).
- There will be a minimum of 24 acres of riparian forest at the FWL portion of the East Lents sub-area.
- Fish habitat components are included (e.g., overflow channels will act as winter off-channel habitat).



* ROI - Return on Investment

Figure 3
Lents Casual Loop Diagram



○ Service quantified in the Lents Analysis

Figure 4
Riparian Services

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FIGURE 5
Lents Ecosystem Valuation Summary

ECOSYSTEM SERVICE *(condition or process)*	BENEFIT *(a thing that promotes well-being)*	GOODS *(has economic utility or satisfies an economic want)*	GOODS QUANTIFICATION	VALUATION QUANTIFICATION - METHOD	VALUE *(the monetary worth in 2002 dollars)*
VEGETATION AND SOIL SERVICES					
Thermal Regulation	Reduced water temperature	Increased fish populations	HeatSource model[1] Ecosystem Diagnosis and Treatment (EDT) model[2] GIS	Contingent Valuation, net willingness-to-pay for improved fish habitat.	$4.22 per month per household Total: $4 million over 100 years
		Avoided ESA compliance costs	Not available	PDX ESA compliance costs (avoided costs) not estimated	Not available
		Avoided CWA compliance costs (avoided TMDL)	Not available	PDX TMDL compliance costs (avoided costs) not estimated	Not available
			Not available	Industry compliance costs (avoided costs) not estimated	Not available
			Not available	Cost of lost future development opportunities (avoided costs) not estimated	Not available
Air Purification					
Ozone, sulfur dioxide, nitrogen dioxide, particulate matter, carbon monoxide abatement	Clean air	Reduced respiratory illness resulting in avoided health care costs	CITYgreen[3] (based on Seattle air shed)	Avoided health care costs based on amount of pollutant removed	**CO** $0.44 per lb removed per year Total: $36,220 over 100 years **$PM_{10}$** $2.05 per lb removed per year Total: $980,573 over 100 years **SO_2** $0.57 per lb removed per year Total: $121,530 over 100 years **O_3** $3.07 per lb removed per year Total: $1,393,773 over 100 years
		Avoided CAA compliance costs	Not available	PDX and industry compliance costs (avoided costs) Future industry opportunity (*x* additional emissions available) Air pollution credits (direct)	
Carbon sequestration	Reduced global warming	Carbon banking (storage)	CITYgreen	Value of carbon credits (direct)	**C** $9.50 per ton removed per year Total: $12,539 over 100 years

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[1] Temperature modeling was completed using the HeatSource Model for Johnson Creek, developed and maintained by the Oregon Department of Environmental Quality (ODEQ). http://www.deq.state.or.us/wq/TMDLs/WQAnalTools.htm

[2] Salmon population capacity and productivity was estimated using the City of Portland Ecosystem Diagnosis and Treatment (EDT) model, developed and maintained by Mobrand Biometrics. http://www.mobrand.com/MBI/edt.html

[3] Air pollutant removal services provided by existing and proposed vegetation communities/land cover types were modeled by CITYgreen v5.0 (American Forests 2003) software, running as an extension to Arcview GIS software. http://www.americanforests.org/productsandpubs/citygreen/

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FIGURE 5
Lents Ecosystem Valuation Summary

ECOSYSTEM SERVICE *(condition or process)*	BENEFIT *(a thing that promotes well-being)*	GOODS *(has economic utility or satisfies an economic want)*	GOODS QUANTIFICATION	VALUATION QUANTIFICATION - METHOD	VALUE *(the monetary worth in 2002 dollars)*
Water Purification					
Bacteria filtering – fecal coliform, E.coli, Pesticides filtering - Dieldren, DDT	Clean water, Improved fish habitat	Potable water Water contact recreation Avoided water purification Fishing Avoided CWA (TMDL) compliance costs	Johnson Creek listed for: Temp, bacteria, pesticides and toxins. However, there is only temperature data for Lents. Acreage was used instead.	Meta Analysis, combined results from CV and avoided-costs studies, of value of wetland for providing water-quality services (Woodward and Wui 2001).	$549 per year per acre of wetland Total: $2,388,982
Precipitation Interception and Storage	Flood mitigation	Reduced flood damage	HEC-RAS	Avoided flood damage estimates based on survey of 1996 flood damages (Woodward Clyde [no date]) scaled to 10-year flood event	**Residential** - $66,700 per 10-yr flood event for all residences Total: $5,437,451 over 100 years **Business** - $457,065 per 10-yr flood event for all businesses Total: $ 4,163,416 **Utilities** - $10,500 per 10-yr flood event Total: $208,171 over 100 years **Emergency services** - $5,000 per 10-yr flood event Total: $45,255 over 100 years
		Reduced road closures	Traffic Counts for Foster Road (PDOT)	FEMA Benefit-Cost Manual (2003)	$32.23 per vehicle hour of delay Total: $5,260,972 over 100 years
BIODIVERSITY MAINTENANCE					
Avian Habitat Improvement	Habitat for wintering/ migratory species	Increased recreational opportunities	Habitat Suitability Index[4]	Meta-analysis of wildlife habitat based on recreational observation (e.g., bird watching) and on contingent valuation of habitat (Woodward and Wui 2001)	$403 per acre per year Total: $1,600,461 over 100 years
	Refugia for at risk species (e.g., migratory song-birds)	Increased recreational opportunities	(see above)		
Salmonid Habitat Improvement	Fish/aquatic species population stability	Avoided ESA compliance costs	Not available	Not available	Not available
		Increased fish population	Already counted	(see Thermal Regualtion)	
CULTURAL SERVICES					
	Natural area, open space	Recreation opportunity	Parks has no estimate of the number of visitors. Default value of 20,000 was used.	Unit day value based on the quality of the recreational experience[5]	$4.00 per day per user Total: $3 million
		Increase value for adjacent properties	GIS	Hedonic analysis specific to amenity value of parks in Portland (property w/in 1,500' of park) (Lutzenhiser and Netusil 2001)	One time $1,671 increase per property Total: $2,832,346

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[4] The amount of avian habitat created by the project is based on the plant community types and Habitat Suitability Index (HSI) models created by the U.S. Fish and Wildlife Service (USFWS 1982, USFWS 1983, and Brooks 1994). http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiindex.htm

[5] Unit Day Value method for evaluating recreation benefit used for the recreational analysis of Westmoreland Park (Tetra Tech, Inc. 2003).

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The valuation of ecosystem services affected by the Lents Project Case Study was based on numerous information sources. Whenever possible Portland area data were used. For example, valuation of reduced flooding stems from surveys of residences and business affected by previous floods in the Lents area. In cases where local data were not available, values for ecosystem services were based on data reported in economics literature. For example, the value of water quality services was based on a national study of the value of ecosystem services provided by wetlands and riparian areas.

Values estimated using local data and non-local data are complementary. Non-market valuations often rely on multiple sources. The professional judgement employed by the researchers is verified through peer reviews. More discussion regarding the sources of information for the values of ecosystem services and the valuation methods is provided in Appendix B.

Unless specified otherwise, it is assumed that the real (inflation-adjusted) values per household (or per capita) of ecosystem services remain constant over time. Also, it is assumed that the natural assets at issue, once they are restored at Lents, and the relevant population of households enjoying them, will persist in perpetuity (Portney and Weyant 1999; Solow 1974; Weitzman 2001). These assumptions have a couple of important implications for the Lents CVES analysis. First, the nominal value, i.e., the value unadjusted for inflation, of these natural assets will increase at the same rate as the values for other goods and services in the economy. Second, the rate at which one should discount the future real (inflation-adjusted) values of these natural assets declines the further in the future that the values originate.

For this analysis, future values are discounted using declining discount rates. Values that will accrue in the near future, 6[4] to 25 years, are discounted at 3 percent. Values accruing in the medium future, 26 to 75 years, are discounted at 2 percent, and values accruing in the distant future, 76 to 100 years, are discounted at 1 percent.

These discount rates were selected based on Weitzman’s (2001) analysis of the appropriate discount rate for the analysis of natural resource projects with long time horizons. Weitzman’s declining discount rates reflect two important points on this topic as described in the economics literature. First, projects with long lives should discount future costs and benefits to some extent (Portney and Weyant 1999). A positive discount rate means that policy decisions made today will give less weight to future costs and benefits than to current costs and benefits. Second, a positive but declining discount rate reflects a balance between economic efficiency and intergenerational equity (Solow 1974; Portney and Weyant 1999). Economic efficiency argues that discount rates should reflect the current cost of capital for typical investments in today’s economy, e.g., building a strip mall. Intergenerational equity argues that natural resources play a vital

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[4] Note that many of the ecosystem values do not start accruing until year 10, allowing time for the restored and replanted riparian areas to establish.

role in sustaining society and should be treated differently than strip malls. For this reason, some economists argue that analyses of natural resource projects with long lives should use a zero discount rate (Solow 1974; Portney and Weyant 1999). However, to be conservative, the declining discount rates are used to estimate benefits for this analysis.

4.2.1 Flood Abatement

The nuisance floods assumed to cause damages include the 5-year, 7-year and 10-year floods (Figure 6). During the 100-year period selected for the analysis it is assumed that there would be ten 10-year floods, fifteen 7-year floods, and twenty 5-year floods based on probability. The avoided flood damage costs were estimated for area residences, businesses, and utilities, along with Foster Road closure costs associated with motorist delays and City of Portland costs for emergency services.

The value of mitigating the nuisance flood is based on damages caused by past flooding, as reported by Lents-area residents and businesses. In a study for the City of Portland, Woodward Clyde surveyed the residents of the area for information on damages associated with the February, 1996, Johnson Creek flood (Woodward Clyde 1996). Based on a survey of area residents, businesses, utility companies and City staff, Woodward Clyde estimated damages to homes, commercial and business entities, roads and bridges, utilities, and the cost of emergency services provided by the City. Woodward Clyde described flood damage by reach along Johnson Creek. Reach 5, from the I-205 bridge to 118th street, roughly corresponds to the area in the Lents project. However, because floodwaters for the 1996 flood inundated a larger area, and for a longer period of time, than do the floodwaters typical of a nuisance flood, the damage estimate for the 1996 flood was adjusted down based on the differences between the nuisance and 1996 floods in terms of peak flows and the volume of floodwater.

The basis used for the downward adjustment was the area flooded by the 1977 flood, which, according to City staff, approximates the flood area of the nuisance flood (Cargill 2003). The Lents Technical Memorandum 1 (Bowker et al. 2001) describes peak flows and the 24-, 48-, and 72-hour flood volumes for flood events in the Lents area from 1941 to the present. A comparison of flow and volume statistics for the 1996 and 1977 floods indicated that statistics for the 1977 flood are 95% to 73% of the flow and volume statistics for the 1996 flood. (For example, the 24-hour peak flows for the 1996 and 1977 floods are 2,380 and 2,250 cfs, respectively.) Therefore, the damages described by Woodward Clyde in Reach 5 of Johnson Creek from the 1996 flood were multiplied by 95% and 73% to calculate the high and low estimates of the value of damages from the nuisance flood.

This damage assessment was conducted for all of the avoided flood costs described below. Value ranges were identified and the midpoint of the ranges was selected as the default values for the analysis.

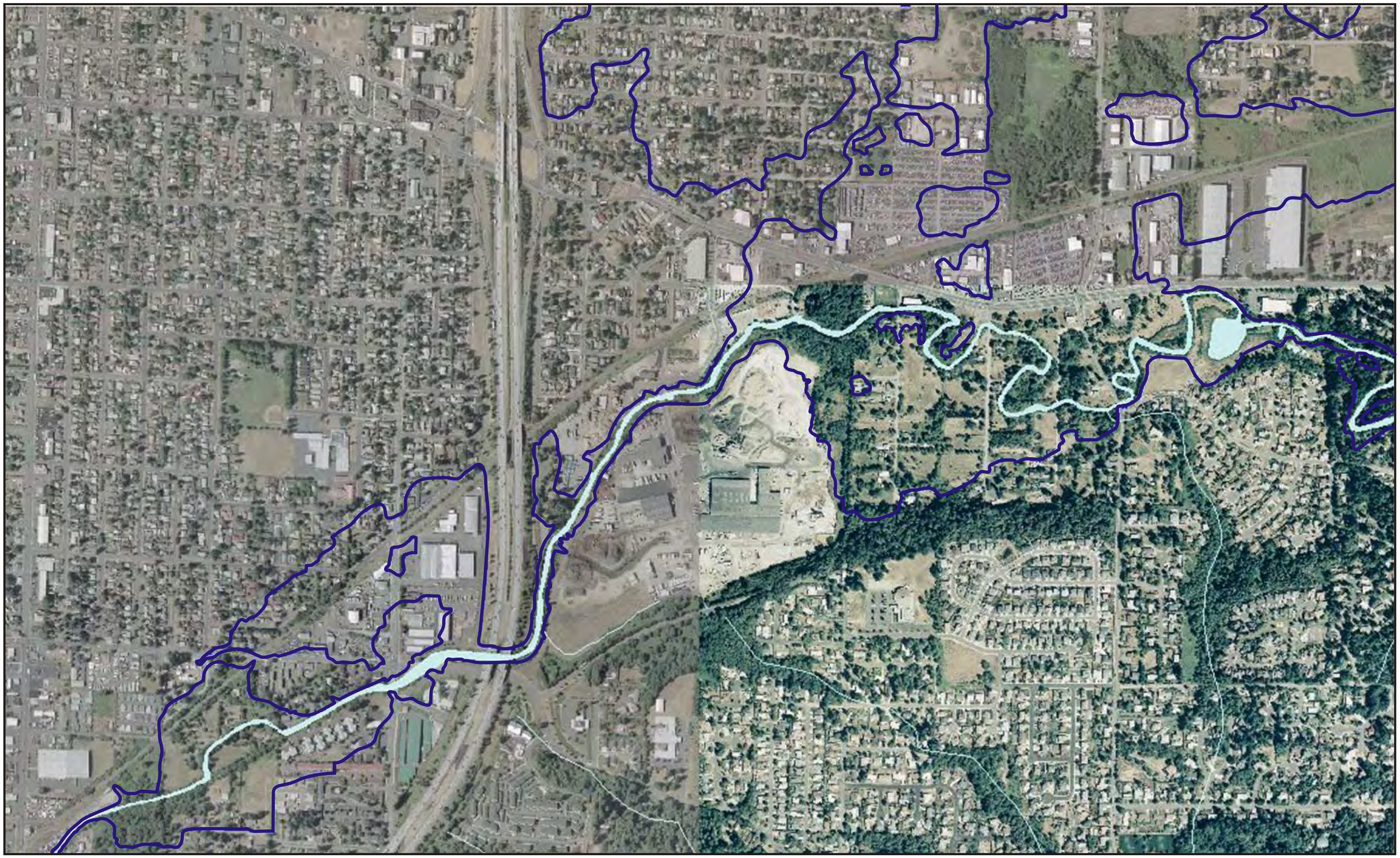

Figure 6
Lents Flood Footprint

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4.2.1.1 Businesses and Residences

The number of residences and businesses affected by nuisance flooding was estimated by counting the number of each type of parcel within the 10-year nuisance flood footprint provided (in GIS format) by the City of Portland. The damages that would occur in a 7-year flood event were assumed to be 50% of the amount of damage caused by a 10-year event. The damages from a 5-year event were assumed to be 10% of the amount of 10-year event damage. This adjustment was made arbitrarily for the purpose of carrying out the analysis, as there are no comparative cost statistics available for the smaller flood events.

Business costs estimated for the 10-year nuisance flood are between $397,211 and $516,919 per event, measured in 2002 dollars (Woodward Clyde 1996). The default value used in the model is $457,065 per event for all businesses affected by a 10-year nuisance flood. Estimated residential costs for a 10-year nuisance flood are between $57,961 and $75,431 per event, measured in 2002 dollars (Woodward Clyde 1996). The default value used in the model is $66,700 per event for all residences affected by the 10-year nuisance flood.

Only the avoided costs to area residences are anticipated to increase in value faster than the rate of inflation. The real (adjusted for inflation) average annual increase in property values in the Portland area is four percent per year based on data from the previous 20 years. This increase in value was applied to avoided residential flood costs.

4.2.1.2 Utilities

Damage to utilities included damage to the PGE substation located within the nuisance flood footprint and interruption of phone service in the area. As above, 7-year flood damages were assumed to be 50% of those a 10-year event, and 5-year flood damages were estimated at 10% of the 10-year event damages. This adjustment was arbitrarily applied for the purpose of carrying out the analysis of this test case, as there are no comparative cost statistics available for the smaller flood events.

Phone line costs (interruption of service) for the 10-year nuisance flood are estimated to range from approximately $9,125 to $11,875 per event, measured in 2002 dollars (Woodward Clyde [no date]). The default value used in the model is $10,500 per event for the 10-year event. Costs to shut down the substation and reroute power in case of flooding at the PGE substation in Lents are estimated at $12,500 per event, measured in 2002 dollars.

4.2.1.3 Road Closures

Foster Road runs close to Johnson Creek east of I-205, and road closures occur there with nuisance flooding. Road closures require detours that increase travel times and costs. Road closure costs were based on the traffic counts for the area as provided by the

Portland Department of Transportation (PDOT), the projected rate of increase in traffic over time, and the average length of road closure as a result of nuisance flooding. PDOT reported average daily traffic volumes in 2000 for Foster Road at SE 122nd Avenue, which is on the eastern boarder of the nuisance flood footprint for the Lents project area. Based on this, the initial traffic volume used to model closure costs is 25,000 vehicles per day. Average length of nuisance flood road closure is estimated to be between two and 24 hours, according to two Foster road businesses (Nonneman, Koistinen 2003). The default value for the duration of Foster Road closure during a 10-year nuisance flood used to estimate closure costs was 10 hours. The duration of road closure was scaled such that a 7-year event would last 50 percent as long as a 10-year event and a 5-year event would last 25 percent as long as a 10-year event. This adjustment was arbitrary and for the purpose of carrying out the analysis of this test case.

The length of time motorists are expected to be delayed due to out-of-direction travel to circumnavigate Foster Road at Lents is unknown. For the purpose of the analysis, one hour was arbitrarily selected as the default value for out-of-direction travel time.

The Federal Emergency Management Agency (FEMA) *Benefit-Cost Manual* estimates the value of motorist delay due to flooding to be $32.23 per motorist per hour of delay (FEMA 2003). The road closure avoided costs for the Lents project were calculated by multiplying the duration of road closure (10 hours for a 10-year event), by the number of motorists per hour (daily traffic divided by 24 hours), by the length of delay to motorists (one hour), by the value of motorist delay.

4.2.1.4 City of Portland

City of Portland flood costs were estimated based on the cost of emergency services per flood event. Estimated costs of City emergency services for the 10-year nuisance flood are between $4,643 and $6,042 per event, measured in 2002 dollars (Woodward Clyde 1996). The default value used in the model is $5,000 per event for the 10-year event. The services needed per flood event were scaled for different size flood events. The emergency services needed for a 7-year event were assumed to be 50 percent as much as for a 10-year event. The emergency services needed for a 5-year event were assumed to be 10 percent as much as for a 10-year event. This adjustment was arbitrarily applied for the purpose of carrying out the analysis of this test case, as there are no comparative cost statistics available for the smaller flood events.

4.2.2 Maintenance and Restoration of Biodiversity

4.2.2.1 Salmonid Habitat Improvement

The value for improved salmonid habitat was calculated based on a series of contingent-valuation (CV) studies that estimated the value of improved salmon habitat. Applying these studies to a specific project has its drawbacks, which are described below. For this reason, the estimated value has been used as an *indicator* of the true value of improved habitat. As used here, the value of the Lents project is calculated by apportioning area residents' willingness to pay for restored salmonid runs based on this project's potential contribution to a fully restored run.

The City's Ecosystem Diagnosis and Treatment (EDT) model for Johnson Creek (Mobrand Biometerics, 2004) indicates that habitat improvements incorporated into the Lent's Flood Abatement project have the potential to increase coho salmon abundance by 248 returning spawners. The model predicts that a fully restored (pre-development) Johnson Creek could support a total abundance of 4,094 additional returning spawners. Therefore, this project represents 6 percent of a fully restored run (248 additional spawners /4094 total spawners =.06). The EDT model predicts the habitat improvement in terms of salmonid capacity, productivity and abundance. (Coho salmon are the only fish species evaluated).

These improvements in fish habitat are a reflection of incorporating features such as riparian function, off-channel habitat, decreased summer (high) water temperatures, large wood, and other features into the final design. Based on the level of improvement in salmonid capacity and productivity in the Lents area, the EDT model provides an estimated number of returning coho spawners in Johnson Creek attributable to this project.

Helvoigt and Montgomery (2003) calculated the willingness to pay per Oregon household, per month, to improve water quality that would lead to improved salmon runs. Oregon residents indicated a willingness to pay $4.22 per month per household (in 2002 dollars) to improve salmonid runs (Helvoigt and Montgomery 2003).

The drawback to the Helvoigt and Montgomery study is that it is not specific to the Lents area or to a specific habitat improvement project. To estimate the number of households that would be willing to pay for this project, the potential population was arbitrarily limited to the Johnson Creek Watershed, assuming that watershed residents would place value in restored salmonid runs in Johnson Creek. All other households in the Portland area, and visitors to the rehabilitated areas around Johnson Creek, were assumed to place zero value on the improvements. It was assumed that watershed residents' willingness to pay $4.22 per month per household (in 2002 dollars) to improve salmonid runs represents the total value area residents place on restored runs. To apportion the percentage of the total value watershed residents are willing to pay on an annual basis, the total annual willingness to pay was multiplied by the percentage of a totally restored coho population this project contributes (6 percent, per the EDT model).

GIS was used to estimate the number of households within the Johnson Creek watershed. The total number of households based on a count of 45,608 single family and 1,385 multifamily residences was estimated to be 48,378 household (as a conservative assumption, multifamily residences were counted as two households each). Therefore, the program calculates a benefit of 48,378 x $4.22 x .06 = $12,249.31 per month based on improved salmonid habitat and population levels.

4.2.2.2 Wildlife Habitat Improvement

Improvement in avian habitat was quantified as the indicator for wildlife habitat created by the project. The amount of avian habitat created is based on the plant community types and Habitat Suitability Index (HSI) models created by the U.S. Fish and Wildlife Service (USFWS 1982, USFWS 1983, and Brooks 1994). HSI models were developed for green-back heron and yellow warbler (neotropical migrants), and black-capped chickadee (songbirds).

The HSI of a habitat for a particular species is measured on a scale that ranges from 1.0 (optimum habitat) to zero (unsuitable habitat). For the purposes of this study, the HSI was multiplied by available habitat providing the number of habitat units (HUs). As the replanted vegetation matures, the number of HUs within the Lents project increase. The model multiplies HUs by the value of improved habitat to derive the overall habitat improvement valuation.

The value of improved avian habitat in the Lents area is based on results of studies conducted nationwide on the values provided by wetlands and riparian areas. Woodward and Wui (2001) estimated the relationship between improved water quality and the associated value of avian habitat based on a mix of CV and travel-cost studies. Woodward and Wui estimate this value on a per-acre of wetland basis. The benefit of improved avian habitat is assumed to accrue to birdwatchers in the Lents area.

A drawback of this study is that it reports an average value for studies conducted across the U.S. This average value may be greater or less than the true value of the improved habitat as measured in the Lents area.

4.2.3 Air Quality Improvement

The CITYgreen v5.0 (American Forests 2003) software, running as an extension to Arcview GIS software, models air pollutant removal services provided by existing and proposed vegetation communities/land cover types. CITYgreen provides results in terms of pounds of ozone (O_3), sulfur dioxide (SO_2), particulate matter (PM_{10}), and carbon monoxide (CO) removed, as well as tons of atmospheric carbon (C) sequestered per year, using the Seattle air shed as the reference condition. The amount of air pollutants removed is based on tree growth simulation and pollutant removal efficacy of the plant community types. The model's default vegetation values are 56 acres of riparian forest, 33 acres of mixed hardwood, 33 acres of scrub shrub, and 17 acres of meadow. It is assumed that there will be a meadow type community under the tree canopy for ease of maintenance and for public safety.

The value of air quality improvement attributable to the Lents project is based on the pounds of air pollutants removed by the reforested areas of the project and the health care costs of treating ailments associated with the air pollutants. CITYgreen (American Forests 2003) provides the following avoided health care costs per pound of air pollutant removed per year:

CO	\$0.44 per pound removed per year
PM_{10}	\$2.05 per pound removed per year
SO_2	\$0.57 per pound removed per year
O_3	\$3.07 per pound removed per year

The value of avoided health care costs increase over time at an inflation-adjusted rate of 2.5 percent per year, which represents the average annual change (net of general inflation) in health care costs in the Portland area over the past 20 years.

The value of carbon sequestration was also estimated in the analysis of air quality improvement. Using information from The Climate Trust in Portland, Oregon, the amount individuals and businesses are paying for carbon offset credits is estimated to be between \$4 and \$25 per ton of carbon, depending on the type of transaction and level of monitoring and verification (Clark 2003). The Climate Trust charges between \$9 and \$10 per ton of carbon sequestered. For the purpose of estimating value of carbon sequestered by the Lents flood abatement project, \$9.50 per ton of carbon was used as the default value.

The Climate Trust noted that, while it is important to value climate control activities such as carbon sequestration, caution should be used when selecting a set value for an urban tree-planting project. The economic value of carbon sequestration is driven by who is willing to buy certain sequestration projects. Companies like The Climate Trust spend time evaluating carbon projects in terms of “additionality” (the additional carbon credits the project is generating beyond normal, expected conditions). Currently, urban tree planting is generally not a project that sells very well in the carbon market because it is difficult to prove additionality. That said, revegetation of riparian areas in urban watersheds can have real value in the marketplace. For example, The Climate Trust recently funded reforestation of the Deschutes riparian area for the purpose of carbon sequestration[5] (Clark 2003).

4.2.4 Water Quality Improvement

Johnson Creek is on the section 303(d) list of the Clean Water Act for pesticides and toxins, bacteria, and temperature. Temperature changes attributable to planting a 120-foot

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[5] The Climate Trust paid \$780,000 in carbon offset funds to the Deschutes Resources Conservancy to help landowners restore riparian areas. By 2006, 1,500 to 1,800 acres of riparian area will be restored and actively sequestering carbon. (http://www.climatetrust.org/CTDeschutesNews.pdf)

wide riparian corridor at Lents were quantified and used for the fish habitat analysis. Pesticides and toxins are considered to be associated with the sediment load coming from upstream of the Lents project area. The Lents flood abatement project is not anticipated to significantly affect sediment load. Because no data were available for bacteria for the project site, the assessment of generalized water quality benefits for this analysis was based on project acreage. It is assumed that 80 percent of the project site will be wetland. Identified wetland values are available on a per-acre basis.

The value of water quality services provided by the restored riparian habitat in the Lents area is based on the results of Woodward and Wui's nation-wide study of the value of ecosystem services. They report a value for water quality services per acre of wetland. This value represents the combined results from CV and avoided-costs studies. Given that the values were not measured locally, the true value of improved water quality services in the Lents area may be less than or greater than the values reported by Woodward and Wui (2001).

4.2.5 Cultural (Societal) Services

4.2.5.1 Amenities

Studies throughout the U.S. have found increased property values adjacent to open spaces and parks. The amenity value of the proposed Lents park and restored riparian area is based on the results of a hedonic analysis of the impact of Portland parks on local property values. Lutzenhiser and Netusil (2001) estimated the value of parks and open space in the Portland area for homes within 1,500 feet of an open space amenity. GIS was used to estimate the number of single family residences within 1,500-foot of the Lents project area. There are approximately 1,695 single family residences within 1,500 feet of the project area (1,309 residences within 1,500 feet of East and West Lents minus FWL, and 386 residences within 1,500 feet of the FWL portion of the East Lents site). The analysis assumes that visitors to the park who live farther than 1,500 feet from the project place no amenity value on the open space resource. The amenity value of the Lents project was calculated as a one-time increase in local property values based on the lower bound of estimated value from the Lutzenhiser and Netusil study ($1,671 per property).

4.2.5.2 Recreation

Part of the Lents flood abatement project includes plans for developing an urban park. Recreational value of this park is based on the estimated number of users and the Unit Day Value (UDV) of the visit. The City of Portland Bureau of Parks and Recreation has no current estimate of potential users of the new park that will be created by the Lents flood abatement project. The default value used to assess recreation benefits created by the project is 20,000 users annually. This was based on City estimates that up to 1,000,000 people use some portions of the Springwater Corridor each year (Cargill 2003). The Springwater Corridor will pass by the new park, actually touching it at the FWL property.The UDV method for evaluating recreation benefit was used for the recreational analysis of Westmoreland Park (Tetra Tech, Inc. 2003). The UDV is based on criteria that include recreational experience, available opportunities, carrying capacity, accessibility, and environmental quality. Based on the assumption that the Lents project would create open space with trails running through it that would be limited in winter flooding periods, judgement factors were employed (See Figure 7). For this study the recreational use “score” was calculated to be 25 points. Possible “scores” range from zero to 100.

The Lents project score was converted to a UDV using the UDV conversion table provided in the Westmoreland Park Recreation Analysis. The UDV for this analysis is estimated to be $4.00 per day per user.

To isolate the value attributable to the FWL portion of the East Lents sub-area of the project, a portion of the total recreational value was calculated. Because the FWL directly connects to the Springwater Corridor, which receives high annual usage, the model assigns 40 percent of the total recreational value to the FWL portion.

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Guidelines for Assigning Points for General Recreation

Criteria	**Judgment Factors**				
Recreation experience[1]	Two general activities[2]	Several general activities	Several general activities: one high quality value activity[3]	Several general activities: more than one high quality value activity[3]	Numerous high quality value activities; some general activities
Point Value:	0-**4**	5-10	11-16	17-23	24-30
Availability of opportunity[2]	Several within 1 hr. travel time; a few within 30 min. travel time	Several within 1 hr. travel time; none within 30 min. travel time	One or two within 1 hr. travel time; none within 45 min. travel time	None within 1 hr. travel time	None within 2 hr. travel time
Point Value:	0-**3**	4-6	7-10	11-14	15-18
Carrying capacity[3]	Minimum facility for development for public health and safety	Basic facility to conduct activity(ies)	Adequate facilities to conduct without deterioration of the resource or activity experience	Optimum facilities to conduct activity at site potential	Ultimate facilities to achieve intent of selected alternative
Point Value:	0-2	3-**5**	6-8	9-11	12-14
Accessibility	Limited access by any means to site or within site	Fair access, poor quality roads to site; limited access within site	Fair access, fair road to site; fair access, good roads within site	Good access, good roads to site; fair access, good roads within site	Good access, high standard road to site; good access within site
Point Value:	0-**3**	4-6	7-10	11-14	15-18
Environmental	Low aesthetic factors[4] that significantly lower quality[5]	Average aesthetic quality; factors exist that lower quality to minor degree	Above average aesthetic quality; any limiting factors can be reasonably rectified	High aesthetic quality; no factors exist that lower quality	Outstanding aesthetic quality; no factors exist that lower quality
Point Value:	0-2	3-6	7-**10**	11-15	16-20

[1] Value for water-oriented activities should be adjusted if significant seasonal water level changes occur.
[2] Likelihood of success at fishing and hunting.
[3] Value should be adjusted for overuse.
[4] Major aesthetic qualities to be considered include geology and typography, water, and vegetation.
[5] Factors to be considered to lowering quality include air and water pollution, pests, poor climate, and unsightly adjacent areas.

SOURCE: USACE, Economic Guidance Memorandum 03-04, Unity Day Values for Recreation, Fiscal Year 2003

Note: Bold numbers represent the selected point value.

Figure 7
Guidelines for Assigning Points for General Recreation

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4.3 DEVELOPMENT OF A SYSTEM DYNAMICS MODEL

The CVES analysis estimates the return on investment in the protection and/or restoration of ecosystem services using system dynamics modeling software called STELLA (High Performance Systems, Inc. 2002). The STELLA software, makes it possible to map key physical, biological and social processes, and to check these representations for logic and function through model simulations. The model consists primarily of system tools called "stocks" representing the things or states of being that exist at a point in time and "flows" representing the actions or activities that occur over time. The relationships between stocks and flows are represented in terms of mathematical equations (e.g. exponential increase, random probability of occurrence, etc.).

Stocks and flows were used in the CVES analysis for Lents for each major parameter of the analysis to integrate the quantitative information obtained from data compiled for the biophysical parameters of the system, as well as the economic values estimated for the ecosystem services. The stock and flow diagrams by clicking on the appropriate "toggle button" on the model border. An example of a stock and flow diagram is provided in Figure 8.

In order to compare relative values of different actions or levels of action, stocks and flows can be constructed to represent different elements to isolate certain effects. In addition, a slider tool (Figure 9) in the STELLA model allows users to adjust constant values within a range. For example, the CVES analysis uses a default value of $4.22 per month per household to estimate willingness to pay for improved salmonid habitat. The slider tool allows users to select another value between $2.00 and $7.00 per household per month. In this way scenarios can be developed based on high and low estimates for the amount of change in biophysical characteristics or the upper and lower bounds of the range in estimated values of ecosystem services. Scenarios can be modeled and the respective results compared.

5 ANALYSIS RESULTS

5.1 STELLA MODEL OUTPUT AND DISCUSSION OF RESULTS

Riparian vegetation will provide increasing ecosystem services as vegetation communities establish and evolve through natural stages of productivity, diversity, and resilience. This is captured by the STELLA model. For example, larger, older trees are shown to remove more air pollutants and create more avian habitat as the model projects quantities of these services into the future.

Table 1 illustrates the model run results for valuing seven ecosystem services changing from the Lents project. The cumulative value of ecosystem services and other benefits, including cultural services such as providing recreation opportunity and amenity values (increase in property values), are presented over a 100-year time span.

Table 1. Lents Project: Long-Term Value of ChangedEcosystem Services

Ecosystem Services	Value accrued over 100 years (reported in 2002 $)	Percent of Long-Term Value
Avian Habitat	$ 1,600,461	5%
Salmonid Habitat	$ 4,105,603	13%
Avoided Flooding	$14,694,387	47%
Air Pollution Removal	$ 2,544,635	8%
Water Quality Improvement	$ 2,388,982	8%
Amenity Value	$ 2,832,346	9%
Recreation	$ 3,108,225	10%
Gross Benefits	**$31,274,639**	**100%**

The Lents Project Case Study provides two types of comparison. The values of services provided by the different sub-areas of the project were compared, and the total benefits of the project were compared with a single-objective flood storage approach.

The value of total services provided by the East and West Lents sub-areas were compared to the total for the FWL portion of the East Lents sub-area. The FWL represents 28 percent of the value of the total services created by the Lents flood abatement project. See Figure 10.

The value of services provided by the ecosystem services-oriented approach designed for the Lents flood abatement project is twice as much as would be generated by a single objective flood storage approach (see Figure 11). This comparison assumed that a single objective approach would fully avoid future costs associated with nuisance flooding, but would not create the restored natural system that provides other services such as habitat improvement, cultural services, and air purification.

Despite its relatively small scale, the Lents ecosystem service oriented project results in several million dollars of ecosystem services, resulting from providing air pollution removal, improved water quality and salmonid habitat, increased avian habitat, amenities and recreational opportunities.

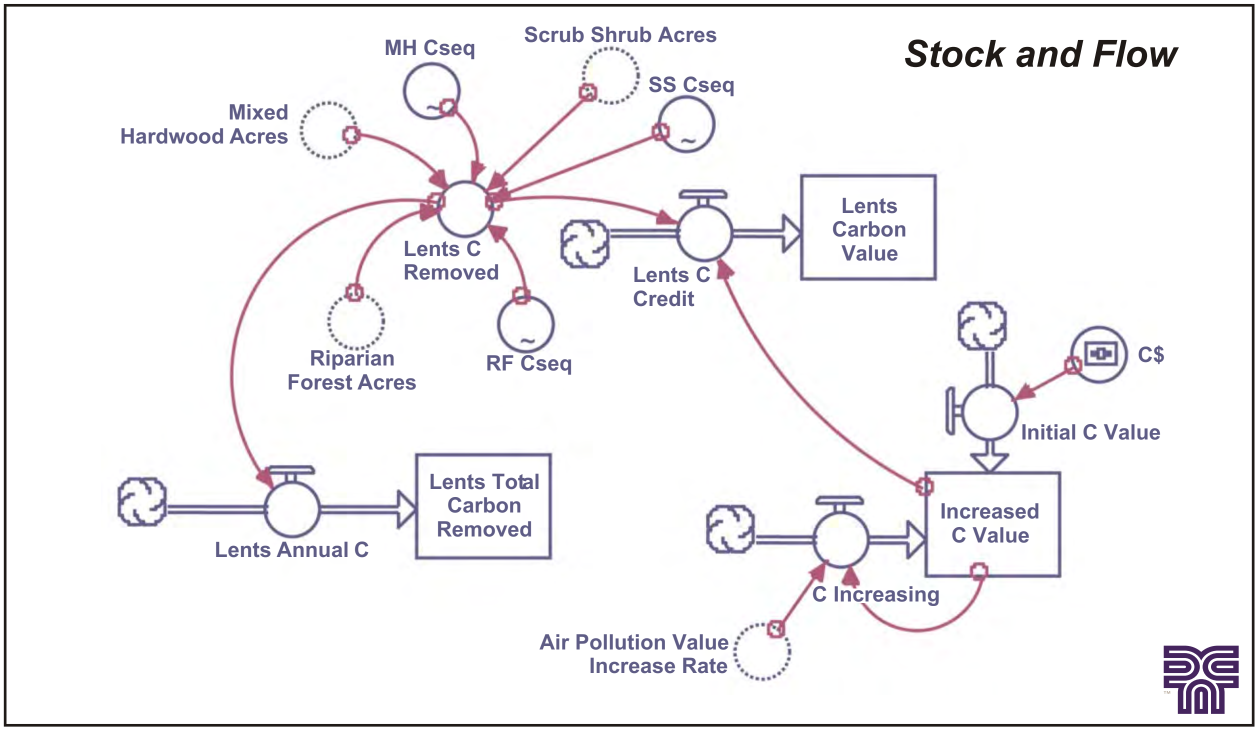
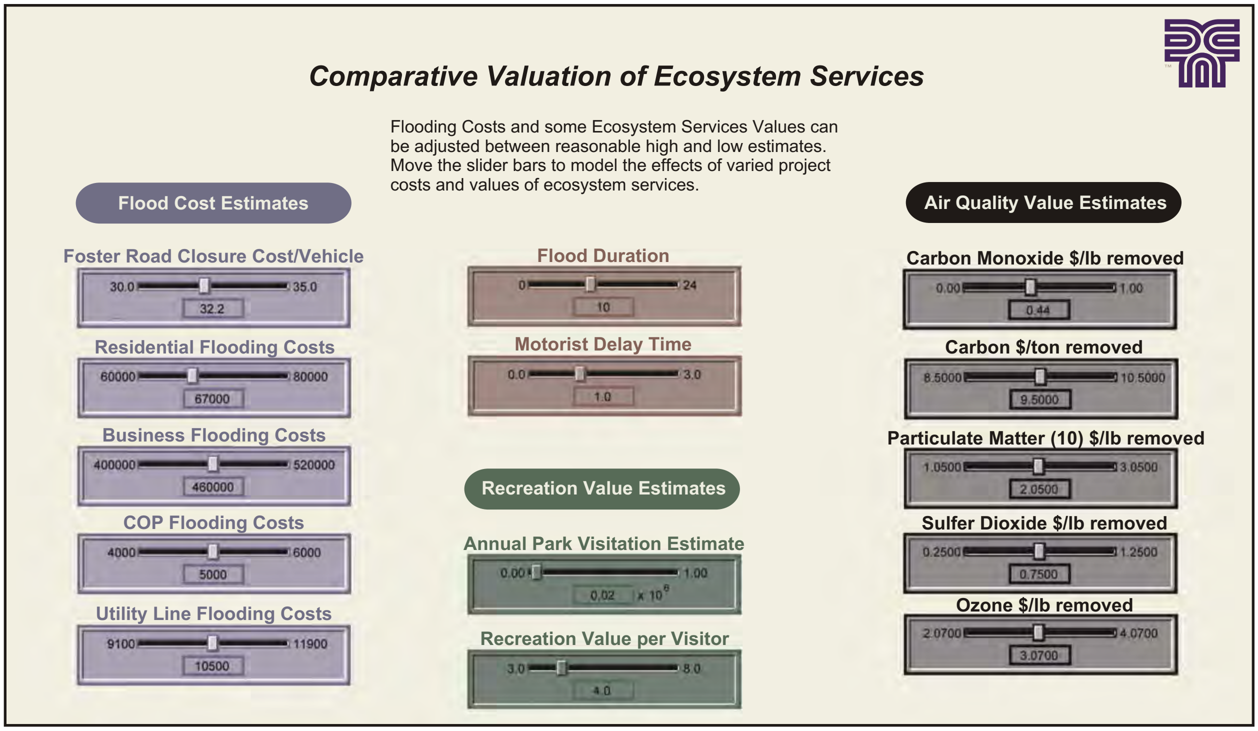


Figure 8
Stella Stock and Flow Diagram of Carbon Sequestration by Restored Riparian Area



Comparative Valuation of Ecosystem Services

Flooding Costs and some Ecosystem Services Values can be adjusted between reasonable high and low estimates. Move the slider bars to model the effects of varied project costs and values of ecosystem services.

Flood Cost Estimates

Foster Road Closure Cost/Vehicle	30.0	35.0	32.2
Residential Flooding Costs	60000	80000	67000
Business Flooding Costs	400000	520000	460000
COP Flooding Costs	4000	6000	5000
Utility Line Flooding Costs	9100	11900	10500

Flood Duration	0	24	10
Motorist Delay Time	0.0	3.0	1.0

Recreation Value Estimates

Annual Park Visitation Estimate	0.00	1.00	0.02 x 10^6
Recreation Value per Visitor	3.0	8.0	4.0

Air Quality Value Estimates

Carbon Monoxide $/lb removed	0.00	1.00	0.44
Carbon $/ton removed	8.5000	10.5000	9.5000
Particulate Matter (10) $/lb removed	1.0500	3.0500	2.0500
Sulfer Dioxide $/lb removed	0.2500	1.2500	0.7500
Ozone $/lb removed	2.0700	4.0700	3.0700

Figure 9
Example of Slider Bar

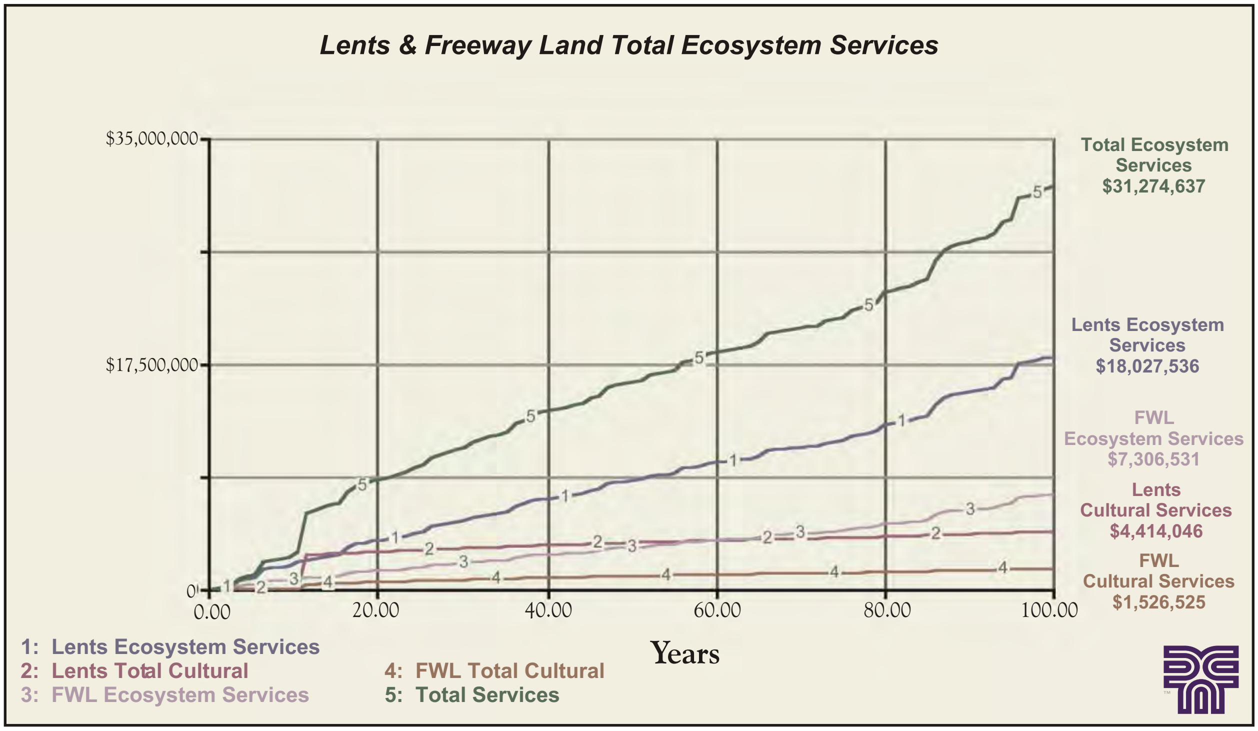


Figure 10

Lents & Freeway Land Total Ecosystem Services

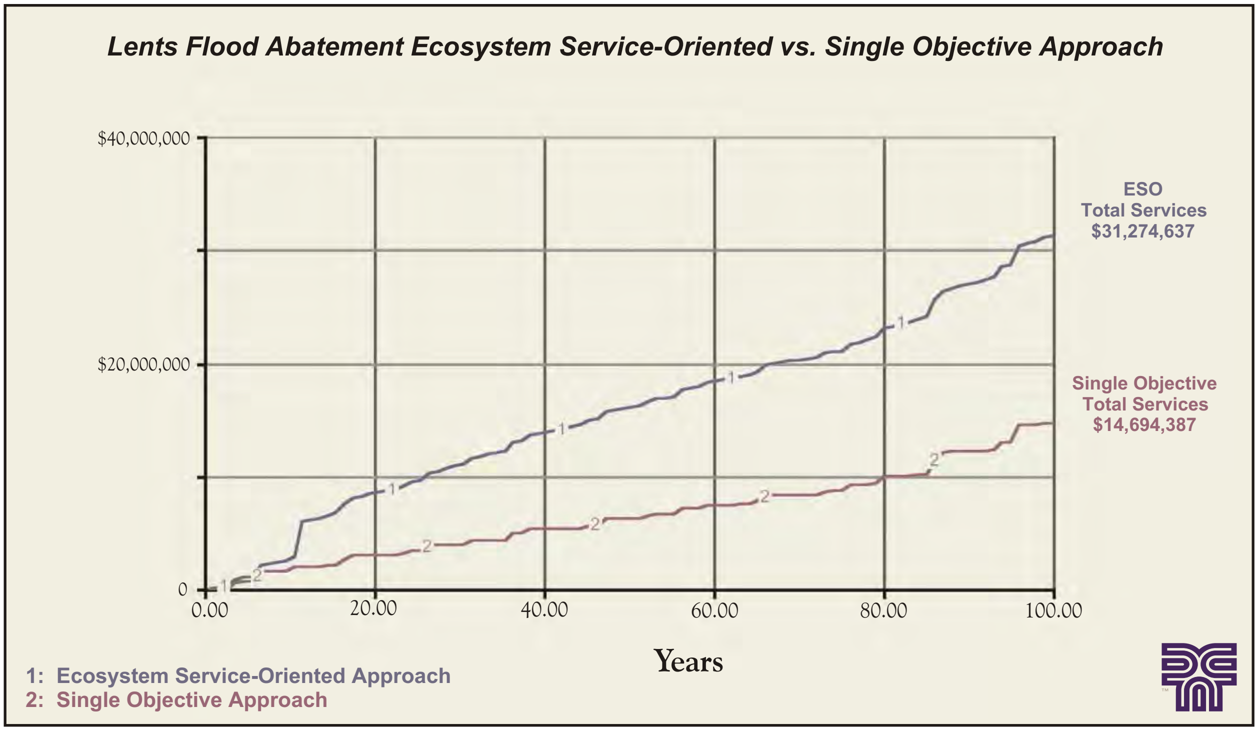


Figure 11

Lents Flood Abatement Ecosystem Service-Oriented vs. Single Objective Approach

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5.2 EXTENT AND LIMITATIONS OF THE ANALYSIS

5.2.1 Full Range of Impacts

City projects that affect riparian and wetland areas generate a range of biophysical and economic impacts. Deliberations on these projects typically focus on project costs without considering the biophysical and related economic benefits of the project. The CVES method helps improve this process by providing estimates of biophysical and economic information ecosystem services not previously included in the City's review of riparian related projects. In addition, CVES provides transparent documentation of hypothesis and assumptions used for decision-making.

While the CVES method is adaptable to an array of projects and ecosystem services, current constraints on data prevent an analysis of the full range of impacts of ecosystem services oriented projects. For example, improving riparian habitat and water quality in the Lents area may positively impact the City's Clean Water Act (CWA) and Endangered Species Act (ESA) responsibilities for Johnson Creek. These impacts may include reduced staff time and expenses for CWA and ESA permitting, future development limits, and possible future environmental compliance requirements (e.g., Clean Air Act [CAA], CWA, ESA, Goal 5). Given the information available at this time, however, the study was not able to explore the relationship between the Lents project and the City's current and future regulatory responsibilities and expenditures.

A related point is that protecting or improving riparian habitat and the associated ecosystem services in the Lents portion of Johnson Creek may help to maintain the biophysical integrity of Johnson Creek, both upstream and downstream from the Lents area. This analysis focuses primarily on the Lents portion of Johnson Creek without considering the interactions between Lents and the rest of Johnson Creek.

5.2.2 Local Estimates of Value

Whenever possible, local sources were used to estimate the value of ecosystem services. For those services for which no local sources were available, values were approximated using results from studies conducted elsewhere. Based on the review of the economic literature, studies were selected that most closely approximate the conditions and ecosystem services found in the Lents area. (See Appendix B for more information on the extent of review of the economic literature.) In some cases, however, the studies available from the literature were not a close match to the Lents area. The drawbacks of using these studies are described in Section 4.1 Quantification and Valuation of Ecosystem Services.

Conducting local studies of the values of ecosystem services can address some of the data deficiencies described above. For example, studies such as that by Lutzenhiser and Netusil (2001) target values specific to a given ecosystem service in the Portland area. Similar studies for values of ecosystem services associated with water quality and fish and wildlife habitat would benefit from an analysis of the projects in the Portland area that address riparian and wetland ecosystem services.

5.2.3 Discussion of Inherent Uncertainties in Modeling, Data, and Results

The system dynamics model incorporates data and modeling results from other sources that include inherent uncertainties. While the assumptions and uncertainties are documented here, the level of confidence in various quantification and valuation data varies.

One of the major sources of uncertainty stems from assumptions made about discounting and value increases over time. The total value of ecosystem services over 100 years is most affected by the average annual increase in value above inflation and the variable discount rate applied to services. For example, it was assumed that the value of avoided health care costs associated with air pollutant removal would increase at a rate of 2.5 percent above inflation. This resulted in a total value of $2,544,635 in air quality improvement value over the 100-year period. If the rate of increase were four percent above inflation, then the total value of air quality improvement over 100 years would be $7,275,869. Also, the value of ecosystem services rose rapidly when the discount rate fell at year 75 from 2 percent to 1 percent. Therefore, it is important to recognize that the values humans place on ecosystem services in the future is very important to the total estimated value of these services over the long term.

6 CONCLUSIONS

6.1 POLICY / PLANNING IMPLICATIONS OF THE LENTS PROJECT CASE STUDY RESULTS

The Lents Project Case Study demonstrated that managing flooding by restoring the historic floodplain provides ecosystem services that have quantifiable value that can be estimated in dollars. The values calculated by the Lents Project Case Study represent the return on investment in an ecosystem services-oriented approach at Lents. Comparing the ESO approach to a single objective approach for flood abatement at Lents shows that the CVES analysis can respond to the first question: What is the return on investment in an ESO project versus a single-objective project? Isolating the value of a portion of the project area (FWL) shows that the CVES analysis tool can also be site specific and respond to part of the second question: What is the relative return on investment in similar ESO projects in different locations?

Through this case study, the project team gained a better understanding of the value of restoring ecosystem services to meet city and stakeholder goals, and the value of this analysis as a planning tool. It was also recognized that the public will benefit by having information that quantifies ecosystem services and enables them to make informed choices about issues facing their community.

As a tool, the CVES analysis provides a transparent documentation of the biophysical and economic aspects of riparian restoration. Most notably, the CVES analysis provides a working hypothesis that allows policy makers to link information about a project's impacts on biophysical variables with related changes in economic values. Using the CVES analysis to evaluate riparian-related projects, City staff, decision-makers, and stakeholders can review more than just cost considerations or a single regulatory requirement, e.g., impacts on water temperature. Participants and reviewers can consider a more complete description of a project's impacts on ecosystem services and related economic values relative to a wide range of possible objectives.

A broadened and more comprehensive description of ecosystem services and related economic values is beneficial for a number of reasons, including:

- Additional information on ecosystem services and economic values will help decision-makers and others select restoration projects based on a more complete description of the likely outcomes of the projects, thereby improving project efficiency and effectiveness.
- The continuing decline in the quality of ecosystem services provided by riparian and other vegetated areas in the Portland metro region as a result of urbanization represents lost services and value to area residents and businesses. As ecosystem services continue declining, society loses the associated economic values provided by those services. Additionally, society must make increasingly larger investments to replicate or replace these natural services (CSO, health costs, carbon sequestration, etc.)
- A more complete understanding of the range of ecosystem services affected by a restoration project will help to identify stakeholders with an interest in the outcome of the project. For example, the CVES analysis identified area households that would likely benefit from the amenity values associated with the Lents flood abatement project. Larger-scale revegetation efforts could demonstrate important public benefits in summer temperature regulation and healthier air conditions. An evaluation of the project based exclusively on project costs will not acknowledge these broader social and environmental benefits.

- This decline in quality contributes to the City's costs associated with the Clean Water Act, Endangered Species Act, Clean Air Act, Goal 5, and the City's CSO program. As ecosystems continue to decline, systems resilience is more impaired, leaving species, air, and water more vulnerable to declines (Gunderson and Holling 2002).

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APPENDICES

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APPENDIX A: OVERVIEW OF COMPARATIVE VALUATION OF ECOSYSTEM SERVICES ANALYSIS

Table of Contents

List of Figures

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1 OVERVIEW OF COMPARATIVE VALUATION OF ECOSYSTEM SERVICES ANALYSIS

1.1 ECOSYSTEM SERVICES

Gretchen C. Daily of the Center for Conservation Biology at Stanford states, “Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage, timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors. In addition to the production of goods, ecosystem services are the actual life-support functions, such as cleansing, recycling, and renewal and they confer many intangible aesthetic and cultural benefits as well.” (Daily 1997).

Identifying ecosystem services that are most important to, or most influential on, City policy and stakeholder issues is one of the outcomes of this phase of work. The water quality, air quality, and endangered species issues currently faced by the City of Portland pertain directly to the interference with or degradation of the region’s natural ecosystem services.

The following is a list of ecosystem services considered to be present and significant to the Pacific Northwest region. Figure 1 is an example of a suite of ecosystem benefits occurring in a riparian corridor.

1.1.1 Climactic Controls

The Pacific Northwest region is subject to seasonal flooding and drought conditions. The severity of the impact of these cyclical climactic conditions is a function of the ecosystem’s ability to play its mitigating role relative to the location of substantial human development. Much of the western portion of Oregon receives high annual rainfall and has many rivers and streams that carry runoff to the ocean. Human development in close proximity to rivers and streams that naturally flood during wet weather conditions (i.e., flood plains) has resulted in great expenditures to mitigate recurring flood impacts. Ecosystems naturally attenuate rainfall and help to dissipate high flow rates through riparian vegetation, soil porosity and naturally meandering streambeds. Vegetation can significantly moderate extreme weather conditions, and mitigate drought conditions (Daily 1997).

1.1.2 Water Cycling

The water cycle is driven by the sun that causes evaporation and transpiration, accumulating water vapor in clouds that precipitate on the land, the water then collecting in lakes, rivers, and oceans, or infiltrating into the ground ready to start the cycle again. In the Pacific Northwest region, we have come to depend on an abundant supply of freshwater. The annual rainfall in the Willamette Valley is between 40 and 45 inches and in Portland the annual average is approximately 36 inches (Oregon Economic and Community Development Department and Oregon Climate Service). Not all precipitation immediately runs off and is transported as surface water through rivers and streams. Some is stored as snow pack in the higher elevations, or infiltrated and stored as groundwater. Snow pack provides a freshwater reservoir to be released in the spring and summer months. Infiltration of rainfall recharges aquifers and raises the water table that helps to sustain stream flow through the summer months. Snow pack is affected by global climate change, which changes the distribution of precipitation, while infiltration is hampered by impervious surfaces created by roads, buildings, parking lots, and other elements of the built environment. The human impacts on the water cycle affect the availability of surface and groundwater supplies (Daily 1997).

1.1.3 Vegetation

The high levels of precipitation in the region result in excellent growing conditions for a variety of plants. Vegetation provides a myriad of functions that support the delicate balance of life. Tree canopy is particularly important for its thermoregulation function in riparian areas and adjacent to development. “Healthy trees require healthy soils, adequate water, and clean air. In turn, when trees are healthy, they provide many valuable services such as improving air quality, reducing atmospheric carbon, slowing stormwater runoff and reducing peak flow (American Forests 2001). Vegetation provides food and shelter for other organisms, reduces air and water temperatures, intercepts precipitation, provides soil stabilization, and also provides aesthetic benefits. The built environment reduces vegetation and percent canopy cover, thereby resulting in a loss of essential functions that can, in some cases, be replaced by technology, but only at high cost.

1.1.4 Soil Services

As noted, vegetation depends on healthy soils. Soils provide water absorption, which allows for supply of water to plant roots, groundwater and surface water. Soils provide physical support and nourishment to plants. “Soils consume wastes and the remains of dead plants and animals, rendering their potential toxins and human pathogens harmless, while recycling their constituent materials into forms usable by plants. In the process, soil organisms regulate the fluxes of the important greenhouse gases, CO_2, CH_4, and N_2O. Soils play a critical role in fueling the entire terrestrial food chain and is an important feature of many aquatic systems as well.” (p.113, Daily 1997). The nutrient cycle, hydrologic cycle and biodiversity are all tied to soil fertility and functionality.

1.1.5 Air Purification

Smog, ozone layer depletion, global warming, and acid rain are just some of the signs of a decline in air purification function provided by our ecosystem. Forests and other highly vegetated areas help to remove pollutants such as ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, and particulate matter, as well as providing carbon sequestration. Some examples of forest air purification capacity include:

- A single tree stores on average 13 pounds of carbon annually and a community forest can store 2.6 tons of carbon per acre per year (Coder 1996 as cited in Adolfson Associates 2003)
- Deciduous trees remove approximately 9% of airborne particulates and evergreens remove approximately 13% (Westcott 2002 as cited in Adolfson Associates 2003)
- One acre of trees generates enough oxygen each day for 18 people (Adolfson Associates 2003)
- In one urban park (212 hectares), tree cover was found to remove 48 pounds of particulates, nine pounds of nitrogen dioxide, six pounds of sulfur dioxide, and half a pound of carbon monoxide on a daily basis (Coder 1996 as cited in Adolfson Associates 2003).

The ecosystem's air purification function is critical to long term human health, as well as the health of other organisms. Therefore, thresholds for sustainability must be understood and carefully managed.

1.1.6 Water Purification

Ecosystems, primarily vegetation, soils and microorganisms, provide runoff filtration, pollution uptake and digestion, precipitation interception and storage. These functions are critical to managing water quality, and water quantity as it relates to water quality. In the 2000 National Water Quality Inventory prepared by the US Environmental Protection Agency, "States reported that 61% of assessed rivers and stream miles, 54% of assessed lake acres, 49% of assessed estuarine square miles, and 22% of assessed Great Lakes shoreline miles fully support the water quality standards evaluated." (EPA 2003). Federal, state and local government incur high costs for monitoring, assessment, and clean up of water quality in compliance with the Clean Water Act. Citizen action suits against agencies that are not able to achieve water quality goals also add cost. Non-point pollution poses a serious challenge for jurisdictions attempting to improve water quality and requires examination of aquatic systems degradation on the watershed scale.

1.1.7 Erosion Control

Erosion by wind or water can have negative impacts on water quality, soil fertility, air quality, and habitat. Material transport is a naturally occurring process in watersheds. However, the quantity of sediment in stream or particulate matter in the air increases as vegetation is stripped from the land, leading to negative impacts such as fine sediment deposition in streams where benthic organisms can be smothered. Controlling erosion by protecting vegetation can minimize these detrimental impacts, while allowing nutrient transfer to continue.

1.1.8 Nutrient Cycling

Nutrients are the building blocks of life. There are six elements (hydrogen, carbon, oxygen, nitrogen, phosphorus, and sulfur) that primarily compose living tissue. “These elements, or macronutrients, combine in various ways to make up more than 95 percent of all living things.” (p. 74, Daily 1997). These elements can be found in solid, liquid, and gaseous forms and are therefore distributed across the earth by way of the climactic, hydrologic and sedimentary cycles. The physical cycles are in part responsible for the amounts and flows of the important elements available to ecosystems to sustain life. There are also chemical reactions and biological metabolism that affect the flow of nutrients essential for life. “Although great stocks of all of these nutrients exist in the earth’s crust in different (but not always accessible) forms, at any one time the natural supply of these vital elements are limited. Therefore, they must be recycled for life to regenerate continuously.” (p. 74, Daily 1997).

1.1.9 Biodiversity Maintenance

“Biodiversity, or biological diversity, is the variety of life at all levels of organization, from the level of genetic variation within and among species to the level of variation within and among ecosystems and biomes… The ability of ecosystems to provide a sustainable flow of goods and services to humans is likely to be highly dependent on biodiversity.” (p. 93-94, Daily 1997).

It is thought that more diverse ecosystems are more likely to resist and recover from disturbances. Biodiversity provides ecosystems with a buffer from naturally occurring pest infestations, floods, fires, and other catastrophic events, thereby protecting the flow of ecosystem services (Wilson 2002).

1.1.10 Pollination

Honeybee pollination services to U.S. crops are estimated to be on the order of $1.6 – 5.7 billion annually. (p. 141, Daily 1997). Quantification of the value of agricultural pollination has been conducted for certain crops in various locations, but there are more extensive benefits attributable to pollinators. Pollinators play a key role in the structure and diversity of plant life that is vital to the health and function of the overall ecosystem. Pollinators account for the propagation of 80 percent of the species of our food plants worldwide (Buchmann 1997).

1.1.11 Cultural and Aesthetic Values

“Natural resource values that are independent of people’s present use of resources have been variously termed ‘existence values,’ ‘intrinsic values,’ ‘nonuser values,’ and ‘nonuse values.’ These values are said to arise from a variety of motives, including a desire to bequeath certain environmental resources to one’s heirs or future generations, a sense of stewardship and responsibility for preserving certain features of natural resources, and a desire to preserve options for future use. The irreversibility of some environmental changes, such as extinction of a species or destruction of a unique scenic resource or ecological system, has been a key component in most discussions of nonuse value." (Kopp 1993).

Cultural and aesthetic values along with existence values of ecosystem services are hard to quantify, but they are real nonetheless. "Natural rivers and waterscapes are sources of inspiration and deep cultural and spiritual values; their beauty enhances the quality of human life." (Postel 2003). Nomadic cultures place high value on ecosystems services that provide them with food, shelter and the naturally occurring cycles, which guide their way of life. By contrast our society has become disconnected from the cultural ties to the ecosystem. However, there is still an aesthetic value placed on the existence of intact ecosystems as demonstrated by people's willingness to donate money to protect rainforests and arctic wildlife they may never see. Ecosystems provide benefits to us just by being in existence.

1.1.12 Recreational Services

Swimming, fishing, boating, hunting, wildlife viewing, hiking, and picnicking are just some examples of the many recreational opportunities provided by natural ecosystems and watersheds in particular. Recreation is a benefit that many communities are bound by their ordinances to provide. The cost of building parks versus protecting open space in proximity to urban centers is worth evaluating. People are willing to travel great distances to reach open space and this cost to each individual, as travel costs rise, could be reduced if ecosystems are enabled to provide this service for "free" close to urban centers.

1.2 ECOSYSTEM SERVICES VERSUS BENEFITS AND GOODS

As described at the beginning of this section, ecosystem services represent the conditions or processes that sustain life. These conditions or processes are related to quality of life in terms of the benefits they produce that promote well-being. These benefits are translated into goods that have economic utility or satisfy an economic want. Sometimes the translation of benefits into goods is explicit and the connection is accounted for by society through market trading. Often, however, the connections are not abundantly clear by the nature of how we measure costs and benefits today. This analysis seeks to clarify these connections, accounting for goods that are not traded directly in markets such as biodiversity and avoided nuisances.

Ecosystem services such as those described above can produce multiple benefits and even more goods. For example, vegetation can provide thermal regulation (condition/process) which reduces air and water temperature (benefit). A reduction in stream or river temperature can provide goods such as increased fish populations, avoided ESA compliance costs, increased recreational fishing opportunities, avoided CWA compliance costs, and potentially reduced energy costs that would be spent on chilling stream temperatures to meet regulatory standards. The translation of ecosystem services into economic goods is a process that requires an understanding of the value of ecosystem services that humans sometimes think they receive for free. The value can be described in terms of what humans pay to artificially replace these services or to repair damages when services are disrupted through ecosystem degradation. The valuation process is described in the section below.

2 METHOD FOR CVES ANALYSIS

The Comparative Valuation of Ecosystem Services (CVES) analysis carries out ecosystem economics through the quantification and valuation of the ecological and economic benefits of environmental goods and services. For society to more fully understand the economic importance of ecosystem services, society must identify and measure the services affected by a particular project or policy decision and assign defendable economic values to those services.

The CVES analysis has several components (Figure 2). The goal of the CVES analysis is to assign economic value to the changes in ecosystem services resulting from implementing a project or policy to inform decision makers for setting priorities and evaluating project alternatives. This analysis reaches beyond the bounds of conventional impact assessment in that it incorporates systems dynamics modeling demonstrating the depth and breadth of services affected by a particular project, or suite of projects, or a policy decision.

2.1 DEFINE SCOPE OF PROJECT OR PROGRAM ACTIONS

Because systems thinking leads to an ever expanding web of linkages among natural and built environments, it is important to clearly define the boundaries of the analysis based on the actions and intent of the project or program to be analyzed. Matching team expectations with availability of data and information helps to set boundaries and define what would be feasible and meaningful. Setting boundaries is aided by a well-defined project or program scope.

The scope of the project should include the geographic location, purpose of the project (program or policy), proposed action(s), and alternatives. This determines the geographic scope for the analysis and sets the stage for the level of detail and rigor that is needed for the analysis. In addition, defining the scope will help identify stakeholders, select objectives and provide the context for data and information collection. The ability to identify the biophysical changes and the ability to quantify those changes, substantively improves the valuation efforts.

If the problem has been identified, but the solution has not been well defined, it is possible to still conduct this analysis to aid in refinement of the proposed action and aid decision making. However, this will add a step to the analysis in which the action is defined based on stakeholder objectives and ecosystem services substantively affected.

2.2 IDENTIFY PARAMETERS

The parameters are determined by the project scope and problem definition. The problem should be fairly clear based on the scope, though stakeholders may have different ideas of how the problem is defined. For example, if the problem is flooding, one stakeholder may want to reduce or eliminate risk of property damage, while another stakeholder may desire improved fish passage and fish habitat damaged by high flows in a constrained flood plain. Defining the problem that affects both of these stakeholders will aid in developing a solution that has a broader spectrum of benefits.

When the problem has been defined, it is then possible to begin identifying ecosystem services substantively affected. We have developed a matrix for the CVES analysis that lists regionally significant ecosystem services and translates them into benefits and goods. The matrix identifies general methods of quantification and valuation of these goods. The matrix shown in Figure 3 shows the general categories to help in brainstorming which ecosystem services are affected by a particular problem and the related benefits and goods. For a particular project, program or policy decision, the matrix should be tailored to reflect the services substantively affected and the specific benefits and goods that are pertinent to the problem and action being considered.

The matrix can be a useful tool in understanding the problem and developing a solution that maximizes benefits. Ideally the solution would protect ecosystem services that are currently functioning, and/or restore ecosystem services that are failing under current conditions.

2.3 DEVELOP CAUSAL LOOP DIAGRAM TO REPRESENT SYSTEM

This section discusses the purpose of a causal loop diagram, the key components, and how the analysis uses causal loop diagramming.

The purpose of the causal loop diagram is to better define the problem and the potential solutions. The diagram provides a visual map for the way the system functions and how this function may be affected by decisions. “In systems dynamics, the term ‘mental model’ includes our beliefs about the networks of causes and effects that describe how a system operates, along with the boundary of the model (which variables are included and which are excluded) and the time horizon we consider relevant – our framing or articulation of the problem.” (p.16, Sterman 2000). Understanding the dynamic complexity of the system can be enhanced and deepened by developing a system model.

The causal loop diagram maps the potential full effect (over space and time) of a particular project, program or policy. Figure 4 is an abbreviated causal loop diagram for the action of planting trees for riparian restoration. It demonstrates the ecosystem services supported by vegetation and the benefits expected with functional services.

2.4 IDENTIFY DATA AND INFORMATION SOURCES

2.4.1 Quantification of Key Services

The CVES analysis takes advantage of data and information that have been generated by biophysical models used to investigate the project location to the extent that they are available. If there are no models or existing data and information for a particular ecosystem service identified as a key parameter in the analysis then assumptions about the type of relationships that result in change must be made and documented. These assumptions are based on professional judgement, experience and understanding of similar systems.

If existing biophysical modeling is available and relevant to the ecosystem services being evaluated, they need to be obtained and reviewed. City of Portland and other jurisdictions have spent significant resources on monitoring and modeling flooding, fish populations and water quality constituents, along with vegetation coverage and erosion. Incorporating the results of these efforts into the CVES analysis provides further utility of these resources and an opportunity to evaluate the integrity and usefulness of these data sets for project and policy decision making. The analysis process may identify other or revised monitoring and modeling efforts that can provide better data for ecosystem analysis.

The process of quantification entails measuring the difference between current conditions and the conditions after the project or policy is put in place. The amount of change in ecosystem condition or process will indicate the magnitude of impact (positive or negative) the project or policy will have on ecosystem services. Using existing models to help ascertain the magnitude of change is the first step. The next step is determining which goods are affected by the change in ecosystem services and by how much. For example, vegetation restoration adjacent to buildings can (through the American Forest's CITYgreen model) correlate the increase in canopy cover with the amount of ambient air temperature reduction, and the corresponding reduction in air conditioning costs. This entails modeling the relationship between the ecosystem benefit and the good in a systems dynamics model.

2.4.2 Valuation of Key Services

Many ecosystem services suffer from what economists describe as market failure, or the inability to be sold or exchanged in established markets (Pearce 1986). Established markets for ecosystem services fail, in part, because people who have not paid for a service, such as the services available from a clean stream or river, can't be prevented from enjoying the benefits of the service. A related cause of market failure is that in some cases one person's use or enjoyment of the resources does not prevent or preclude others from enjoying the service. Flood mitigation provided by riparian areas is one example. If you can't charge people to use the service and if you can't limit the number of people who enjoy a service, it's difficult to establish a market for the service.

However, there are some established markets where ecosystem services are exchanged for money. These markets involve purchasing credits from a wetland-mitigation bank or buying air-pollution credits. Property markets may also capture some values associated with ecosystem services such as view and open-space amenities. For those ecosystem services that do not have established markets, there are a number of techniques that provide insights into the economic values of these services.

The values are largely derived from environmental economics techniques that fall into three categories:

1. Revealed preference method – hedonic studies of property values and travel cost analysis of expenditures
2. Stated preference method – contingent valuation surveys of individuals' willingness to pay
3. Avoided cost or replacement value method - cost of developing engineered alternatives to ecosystem services.

It is important to note that all of these methods are likely to underestimate the full range of economic values specific to given resources. For example, a hedonic analysis of property values will likely underestimate the full value of ecosystem services because it measures only the values of services captured by property values. This is typically limited to amenity values and may exclude values associated with other services, such as water quality and habitat for wildlife.

To the extent possible, the CVES analysis relies on existing values determined for ecosystem services by other studies using the methods described above. An extensive literature review is conducted to generate a database of economic values. The sources reviewed for information on the economic value of ecosystem services include:

- A general search of relevant web sites
- Relevant bibliographies available on web sites of academic researchers
- Periodical indices of academic journals
- Industry trade journals
- Environmental Valuation Reference Inventory (EVRI) database

The values for the CVES analysis are selected based on whether they are verified and tested, adaptable, reasonable according to professional judgement, and in the range of industry standards. The selected values are calibrated to the particular location being analyzed using the benefit-transfer method. The benefit-transfer method, for example, may estimate the values of water-quality services of riparian areas in Portland based on studies conducted on riparian areas in Denver, Colorado. The advantage of this method is that it is less time consuming and expensive than site-specific original research. The disadvantage is that study conditions may differ between the study site (e.g., Denver in the example above) and the policy site (Portland).

To help minimize the disadvantage for the purposes of the CVES analysis, the benefit-transfer method is conducted with input from interviews with leading academic researchers regarding their studies of the economic values of ecosystem services. The interviews will provide insights into “best methods” of applying economic values measured elsewhere to Portland-area projects, and any limitations associated with this process. In addition, case studies of municipalities that have applied ecosystem values as part of protection and restoration efforts are examined to collect relevant information on their experiences. These interviews with academic researchers and the review of municipalities’ experiences help to identify the quality and accuracy of values for various scales of projects and determine the level of uncertainty accompanying these values.

The values determined for a particular project or suite of projects are added to the ecosystem services matrix and used in the systems dynamics model designed to merge the biophysical quantities with the ecosystem service values.

2.5 SYSTEMS DYNAMICS MODEL

The CVES analysis estimates the return on investment in the protection and/or restoration of ecosystem services using a systems dynamics modeling software called STELLA. The STELLA software and associated systems thinking framework enables the mapping of key physical, biological and social processes, and to check these representations for logic and function through model simulations. The model primarily consists of stocks and flows representing the things or states of being that exist at a point in time and the actions or activities that occur overtime. The relationships between stocks and flows are represented in terms of mathematical equations (e.g. exponential increase, random probability of occurrence, etc.).

The stocks and flows used in the CVES analysis are based on the causal loop diagram created in an earlier step that helped to define the types of relationships occurring in the system. A systems dynamics model is generated that integrates the quantitative information obtained from data compiled for the biophysical parameters of the system and the economic values estimated for the ecosystem services. Assumptions and levels of uncertainty are described for each stock and flow.

Figure 5 illustrates a part of a STELLA model. Three stock and flow diagrams that are used to quantify change in the system and apply values to these quantities are shown.

In order to compare relative costs and benefits of different actions or level of action, stocks and flows can be constructed to represent different elements to isolate certain effects. In addition the slider tool in the STELLA model allows users to adjust constant values within a range. Scenarios can be developed based on high and low estimates for the amount of change in biophysical characteristics or the upper and lower bounds of the range in estimated values of ecosystem services. Scenarios can then be modeled and results compared. Results are in terms of net benefit over time.

3 PROJECT SELECTION PROCESS AND ROI ARCHETYPES

To refine the CVES analysis and assess its utility for City projects and policies, a test case project was selected for analysis. The City of Portland project management team developed a set of criteria for screening potential projects or policies that could benefit from application of the CVES analysis. These criteria include:

- Touches on a number of ecosystem services
- Relatively simple (technically)
- Not too narrow a scope (of action or policy)
- Substantial related information is accessible
- Time frame includes several decades
- Substantive, unresolved issues remain to be analyzed
- Would/could benefit River Renaissance Program
- Includes potentially large public investment
- Does not carry heavy political baggage

A number of projects were evaluated for the CVES analysis using these criteria. These projects fall into three distinct categories that represent the City's objective in pursuing the value of ecosystem services. All three categories are related to the return on investment (ROI) in ecosystem services oriented (ESO) projects or policies. Hence, these categories have been termed ROI archetypes. They are:

1. What is the return on investment in an ESO project versus a single objective project?
2. What is the relative return on investment in different types of ESO projects or similar ESO projects in different locations?
3. What is the return on investment for an ecosystem protection policy such as riparian buffers?

The projects evaluated include:

- Portland's Urban Forestry Management Plan
- Alsop-Brownwood Flood Mitigation and Restoration Project
- East and West Lents Flood Relief Project
- Westmoreland Park Section 206 Project – Ecosystem Restoration
- Taggart Pipeshed Flood Hazard Mitigation Project

Many of these would benefit from a CVES analysis, but did not meet certain criteria. For example, with the Taggart Pipeshed Flood Hazard Mitigation Project there was concern that potential alternatives did not touch on a wide enough range of ecosystem services, and there weren't many substantive, unresolved issues. The East and West Lents Flood Relief Project, however, met all of the criteria for a test project for the CVES analysis.

Lents flood mitigation work is technically feasible, touches on multiple ecosystem services, has existing data sets and has an appropriate planning time frame of more than two years.

The following services were selected as a sample set of services implicated in the Lents project that translate into things that promote well-being and can be quantified and valued.

- Precipitation interception and storage
- Water purification
- Thermal regulation (water)
- Air purification
- Biodiversity maintenance

The Lents project features being considered as part of the Lents flood mitigation project involves enhanced wetlands and floodplains in a redevelopment setting. These features are expected to provide for improvements in the selected ecosystem services over time and improve watershed health. These improvements will be valued in economic terms and presented as a range of economic values or return on investment.

By understanding the return on investment in Lents, environmental managers will gain a better understanding of the benefits of these ecosystem services in meeting city and stakeholder goals and the value of this analysis as a planning tool. The public will also benefit by having information that quantifies ecosystem services and enables them to make informed choices facing their community.

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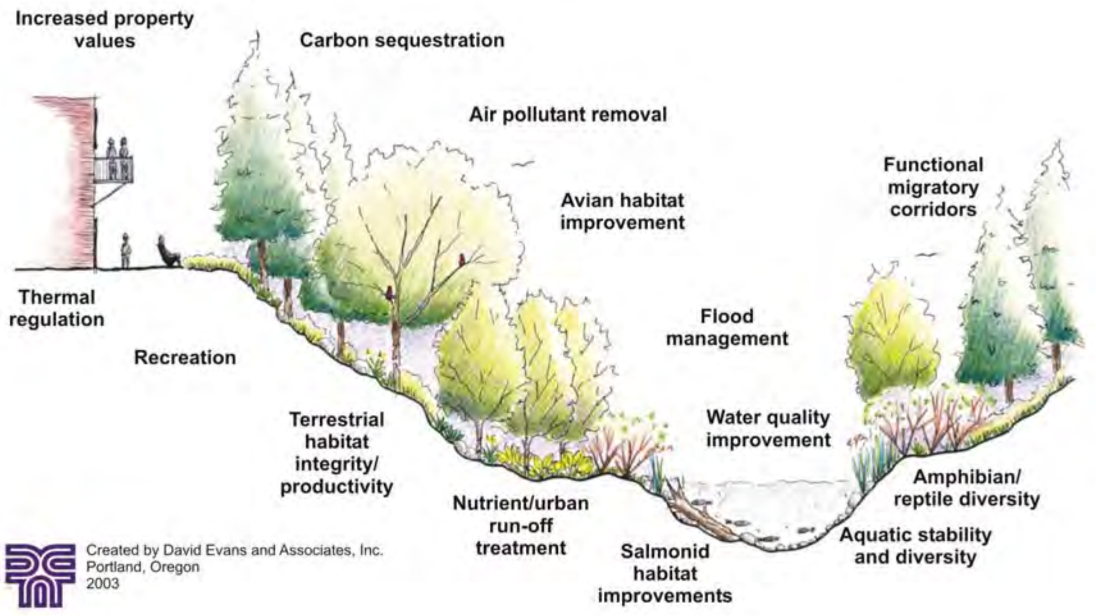
FIGURES AND TABLES



Created by David Evans and Associates, Inc.
Portland, Oregon
2003

Figure 1. Riparian Functions and Processes

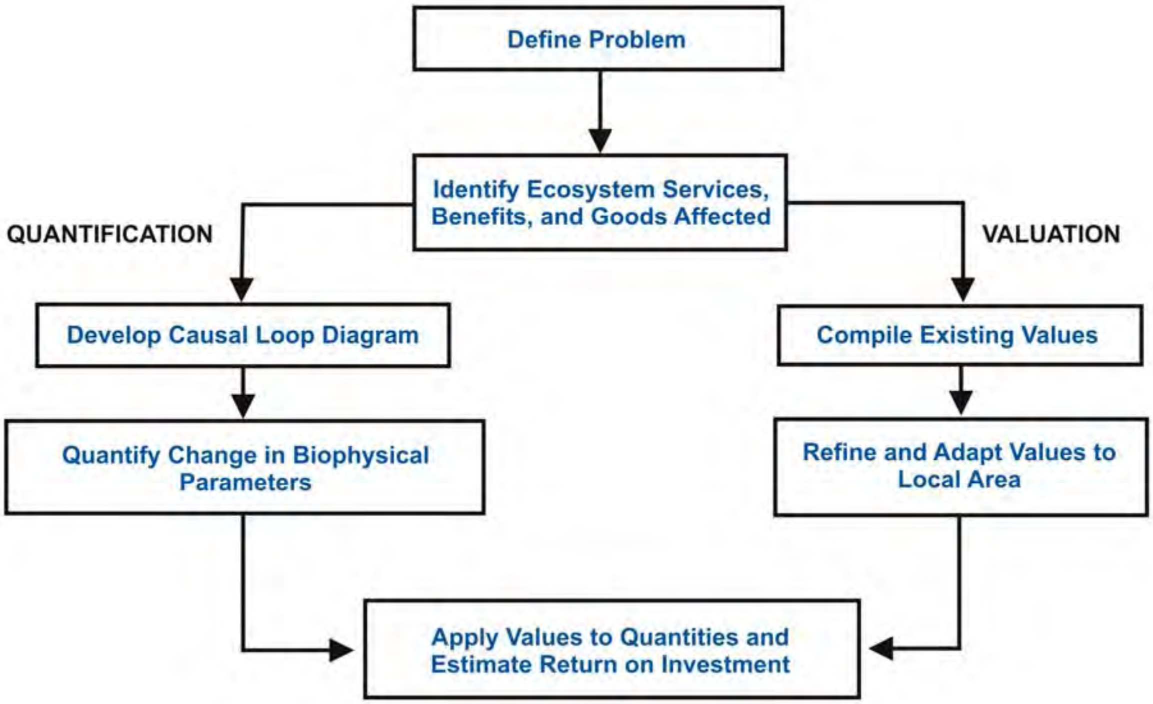


Figure 2. CVES Analysis Process

Figure 3. Ecosystem Matrix

ECOSYSTEM SERVICE ***(condition or process)***	**BENEFIT** ***(a thing that promotes well-being)***	**GOODS** ***(has economic utility or satisfies an economic want)***	**PERTINENT?**	**GOODS QUANTIFICATION***	**VALUATION QUANTIFICATION METHOD**	**VALUE** ***(the monetary worth)***
WATER CYCLING						
Groundwater (aquifer) recharge	Stable water supply	Avoided drinking water facility				
VEGETATION AND SOIL SERVICES						
Thermal Regulation	Reduced ambient temperatures	Kilowatt-hours saved (less air-conditioning)				
		Avoided carbon generation (less energy generated)				
	Reduced water temperature	Increased fish populations				
		Avoided ESA compliance costs				
		Increased recreational opportunities				
		Avoided CWA compliance costs (avoided TMDL)				
Air Purification						
Ozone, sulfur dioxide, nitrogen dioxide, PM, carbon monoxide abatement	Clean air	Reduced respiratory illness				
		Avoided CAA compliance costs				
Carbon sequestration	Reduced global warming	Carbon banking (storage)				
Water Purification						
Runoff filtering; Pollution uptake (bacteria, toxics, nutrients, metals, etc.)	Clean water	Potable water Avoided water purifiation				
		Water contact recreation (swimmable)				
		Avoided CWA compliance costs (avoided TMDL)				
	Improved aquatic habitat	Fishing				
		Avoided ESA Compliance costs				
	Improved aesthetic quality	Increased recreational opportunities				
		Water contact recreation				

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ECOSYSTEM SERVICE *(condition or process)*	BENEFIT *(a thing that promotes well-being)*	GOODS *(has economic utility or satisfies an economic want)*	PERTINENT?	GOODS QUANTIFICATION*	VALUATION QUANTIFICATION METHOD	VALUE *(the monetary worth)*
VEGETATION AND SOIL SERVICES	**(continued)**					
Precipitation Interception and Storage	Flood mitigation	Reduced flood damage (safe and healthy communities)				
		Avoided stormwater detention facilities				
		Reduced insurance payment				
		Increased property value				
	Base flow maintenance	Increased fish populations				
		Increased recreational opportunities				
	Stable water supply	Avoided drinking water facility				
Erosion Control	Streambank stabilization	Increased fish populations				
		Increased recreational opportunities				
		Reduced dredging				
	Clean water/reduced turbidity (TSS)	Recreation (river boating/swimming)				
		Avoided CWA compliance costs (avoided TMDL)				
		Increased fish populations				
	Improved soil fertility	Increased crop production				
Nutrient Cycling						
Nitrogen fixation	Improved soil fertility	Reduced fertilizer requirements				
Uptake N, P, K, etc.		CWA compliance (avoided TMDL)				
OM AND WASTE DECOMPOSITION	Detoxification of wastes, pathogens	Avoided water purification				
		Increased recreational opportunities				

ECOSYSTEM SERVICE *(condition or process)*	BENEFIT *(a thing that promotes well-being)*	GOODS *(has economic utility or satisfies an economic want)*	PERTINENT?	GOODS QUANTIFICATION*	VALUATION QUANTIFICATION METHOD	VALUE *(the monetary worth)*
BIODIVERSITY MAINTENANCE						
Biological control/stability	Terrestrial species population stability	Increased recreational opportunities				
	Habitat for wintering/ migratory species	Increased recreational opportunities				
	Fish/aquatic species population stability	Increased recreational opportunities				
	Refugia for at risk species (e.g., migratory song-birds)	Avoided ESA compliance costs				
Genetic resources maintenance	Genes for resistance to pathogens	Reduced use of pesticides				
	Integrity of native species/sustainability of populations	Avoided restoration costs New medicines				
		Avoided ESA compliance costs				
POLLINATION	Reproduction of agricultural/other domestic crops	Increased crop production				
	Reproduction of native plant populations	Improved aesthetic				
CULTURAL SERVICES						
Existence of properly functioning ecosystem condition	Integrity of native species/sustainability of populations	Cultural value spiritual value aesthetic amenity art rcreation science education				

** at project level*

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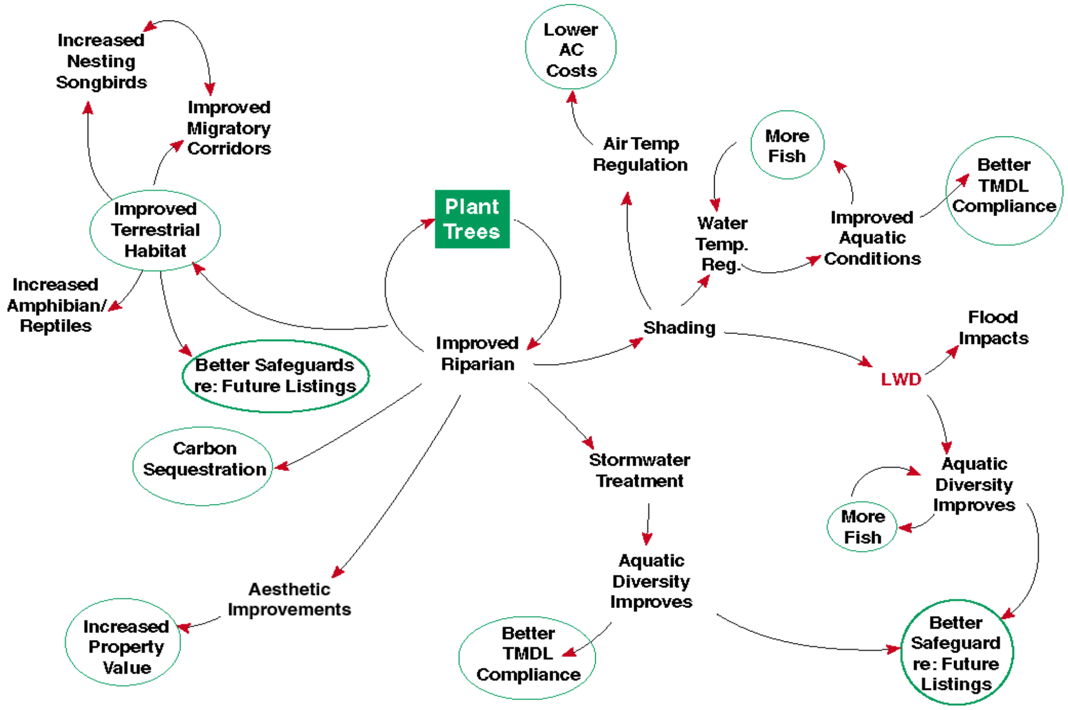

○ **Places where opportunities for quantification of ecosystem services lie.**

Figure 4 Causal Loop Diagram

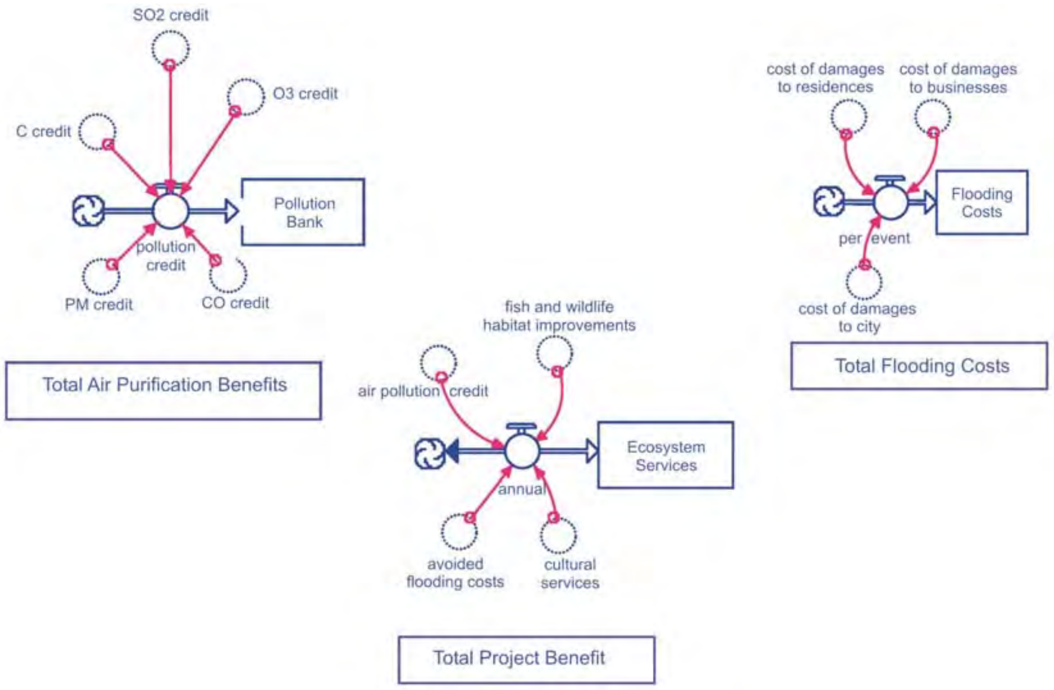

Figure 5. Stock and Flow Diagram

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APPENDIX B: TECHNICAL MEMORANDUM ON THE ECONOMIC ANALYSIS OF THE ECOSYSTEM SERVICES IN THE LENTS AREA

Prepared by ECONorthwest

Technical Memo on the Economic Analysis of Ecosystem Services in the Lents Area

February 18, 2004
Revised March 22, 2004

Prepared for

David Evans and Associates and the City of Portland

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I. Introduction

The section of Johnson Creek that passes through Portland's Lents neighborhood frequently overflows its banks and floods the surrounding area. The flood-management plan developed by the City of Portland's Bureau of Environmental Services, in consultation with local stakeholders, emphasizes restoring floodplain functions and riparian areas. The restored areas will hold a sufficient volume of water so that frequent, or nuisance, floods do not inundate the Lents neighborhood.

David Evans and Associates and ECONorthwest, working with City staff, calculated the effects of the City's Lents flood-management plan on ecosystem services and related economic values. This technical memo describes background information to ECONorthwest's economic analysis. The terms "we" and "our" refer to ECONorthwest.

There remain four sections in this memo:

Section II, The Economic Values of Ecosystem Services, summarizes the work by economists and others who study the relationship between ecosystem services provided by natural areas and the related benefits and values of these services to society.

Section III, Methods of Estimating the Economic Values of Ecosystem Services, describes the techniques economists use to calculate the economic values of ecosystem services.

Section IV, Sources of Information, describes the sources on which we relied for information on the values of ecosystem services.

Section V, Ecosystem Services Affected by the Lents Flood-Management Plan, describes the ecosystem services that the plan likely will affect and the economic values of these services used in our analysis.

II. The Economic Values of Ecosystem Services

In one of the most widely-cited references in the field of environmental science, the author, Gretchen C. Daily, describes ecosystem services and the related benefits to society.

> "Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage, timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors. The harvest and trade of these goods represent an important and familiar part of the human economy. In addition to the production of goods, ecosystem services are the actual life-supporting functions, such as cleansing, recycling, and renewal,

> and they confer many intangible aesthetic and cultural benefits as well." (Daily 1997)

Economic literature addresses the importance of ecosystem services provided by riparian areas, upland forests and other natural areas. Many economists describe the ecosystem services provided by natural areas and the economic values of these services. They include Balmford (2002), Costanza (1997), Costanza (1998), Farber (2002), Howarth (2002), King (2003), Hueting (1998), Templet (1998), de Groot (2002), and Heal (2000). For illustration, we quote from Costanza (1997), and King (2003).

> "Ecosystem functions refer variously to the habitat, biological or system properties or processes of ecosystems. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions." (Costanza, 1997, page 253)

> "Ecosystem functions are the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of an ecosystem; in other words, what the ecosystem does. Some examples of ecosystem functions are provision of wildlife habitat, carbon cycling, or the trapping of nutrients. Thus, ecosystems, such as wetlands, forests, or estuaries, can be characterized by the processes, or functions, that occur within them."

> "Ecosystem services are the beneficial outcomes, for the natural environment or people, that result from ecosystem functions. Some examples of ecosystem services are support of the food chain, harvesting of animals or plants, and the provision of clean water or scenic views. In order for an ecosystem to provide services to humans, some interaction with, or at least some appreciation by, humans is required. Thus, functions of ecosystems are value-neutral, while their services have value to society." (King, 2003, no page number)

Natural resources provide a range of ecosystem services that benefit society in urban areas including:

- Riparian areas along streams, rivers and wetlands mitigate flooding and help reduce flood-related property damage.
- Riparian areas also filter sediment and toxins from surface runoff, which helps maintain water quality in urban streams and rivers.
- Urban forests absorb air pollutants and help maintain air quality. The shading from urban trees may help reduce the "heat island" effect, which can reduce cooling costs in summer.

- Open space and parklands provide recreational amenities.
- Riparian and wildlife habitat support a range of species with cultural and economic significance.

In the past, most studies of ecosystem services focused on resources found in rural or wilderness areas, such as rain forests, agricultural land and upland watersheds. This focus makes sense because these resources provide significant ecosystem services. More recently, however, researchers have come to recognize that natural ecosystems in urban areas also provide valuable services. Irvine (2002) describes the importance of restoring and protecting ecosystem services in urban areas.

> "The urban ecological restoration movement is a relatively new phenomenon that is helping to revitalize cities across the world. Its proponents recognize that the broader ecological crises facing the globe are deeply rooted in the urban environment with its ever expanding population—it is estimated that the global populations will be 10 billion by 2025 and the vast majority will live in urban areas. The links between how we manage our cities thus has significant implications not only at the local level, but at a global scale as well. Ecological restoration recognizes that a sustainable world-view can only be achieved through actions to restore and conserve natural systems—the parklands, waterfronts and rivers that wind their way through our cities." (Irvine 2002)

Researchers identify two general classes of economic benefits of ecosystem services, macro and micro benefits. At the macro level, ecosystem services have global importance and values because they affect critical biological processes that sustain life on earth (Costanza et al. 1997; de Groot et al. 2002; Howarth and Farber 2002). Costanza (1997) describes the values of these services as,

> "The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet." (page 253)

At the micro or local level, information on the relative scarcities and qualitative conditions of natural resources signal changes in the economic benefits and values of these services (Howarth and Farber 2002). For example, degrading riparian areas that protect water quality represents a lost service and value. Area residents and businesses must either live with more polluted water, or restore water quality by paying for water treatment or restoring riparian areas.

Balmford (2002) and Farber (2002) note that measures of the economic values of ecosystem services calculated for marginal changes in the supply of services are not representative of the values for larger or what they refer to as "threshold" changes in supply. As described by these researchers, at the margin, there's a linear relationship between changes in the supply of services and changes in values. Once the supply of ecosystem services reaches a critical or threshold level, however, changes in services and changes in values exhibit a nonlinear relationship. For example, as water becomes scarce in a region, the value of a gallon of water may increase dramatically once the supply falls below a critical or threshold amount.

Double counting of economic values may occur when a given ecosystem function supplies multiple services (de Groot et al. 2002; Turner et al. 1998). For example, a wetland's ability to regulate surface runoff and flooding may be valued separately but these services are also related. De Groot (2002) suggests that one method of avoiding double counting services and values is to develop dynamic models that account for the interrelationships among ecosystem functions, services and values.

Our analysis of the Lents flood-management project focuses on the economic benefits of ecosystem services at the local or micro level. In Sections IV and V we describe the data and other information used in our analysis of the change in value of the services affected by the project. In this analysis, we relied on local data, non-local data or both when the data were available, sound and relevant. As background to the discussion of economic values specific to the Lents analysis we describe, in Section III, methods of estimating the economic values of ecosystem services.

III. Methods of Estimating the Economic Values of Ecosystem Services

Ecosystem services generally do not have economic measures or values established in a market place. Decisionmakers know the relative value or importance of an acre of land in an urban area, or the earning potential of factory workers because markets exist that established these values in standard units. Not so for ecosystem services. For example, a market does not exist that signals or describes the values of *all* the ecosystem services provided by a forest. Markets exist for some services, such as lumber production, but not others, such as carbon sequestration, wildlife habitat for species with commercial and cultural significance, or erosion control that maintains water quality.

In general, many ecosystem services suffer from what economists describe as market failure, or the inability to be sold or exchanged in a market (Pearce 1986). Established markets for ecosystem services fail in part because people who have not paid for a service, such as the services available from a clean stream or river, cannot be prevented from enjoying the benefits of the service. Also, those that degrade a service, e.g., by polluting a river, do not suffer economic consequences. A related cause of market failure is that in some cases one person's use or enjoyment of a resource does not prevent or preclude others from enjoying the service. Flood mitigation provided by riparian areas is one example. If one cannot charge users for a service and if there is no limit on the number of people that can enjoy a service, whether they pay or not, it is difficult to establish a market for the service.

Including information on the impacts of urban development on the values of affected ecosystem services in land-use decisions becomes more difficult without market-driven information. As a result, many decisions ignore the impacts of development on ecosystem services and the related benefits they provide society. Gretchen Daily describes the challenges of including information on the economic importance of ecosystem services in this decision-making process.

> "Just as it would be absurd to calculate the full value of a human being on the basis of his or her wage-earning power, or the economic value of his or her constituent materials, there exists no absolute value of ecosystem services waiting to be discovered and revealed to the world by a member of the intellectual community. Contributors [to this field of economic study] seek primarily to identify and characterize components of ecosystem service value and to make a preliminary assessment of their magnitude, as a prerequisite to their incorporation into frameworks for decision making."
>
> "As a whole, ecosystem services have infinite use value because human life could not be sustained without them. The evaluation of the tradeoffs currently facing society, however, requires estimating the marginal value of ecosystem services (the value yielded by an additional unit of the service, all else held constant) to determine the costs of losing—or the benefits of preserving—a given amount or quality of services. The information needed to estimate marginal values is difficult to obtain and is presently unavailable for many aspects of the services. Nonetheless, even imperfect measures of their value, if understood as such, are better than simply ignoring ecosystem services altogether, as is generally done in decision making today." (Daily 1997)

The fact that most ecosystem services are not traded in markets makes more challenging the task of characterizing the economic importance of these services. Economists, however, have developed a number of techniques that provide insights into the economic importance of ecosystem services. Established markets exist for some ecosystem services in cases where those benefiting from the service can be identified and participation in the market can be limited to those paying for the service. In other cases, economists calculate the value of an ecosystem service based on the cost of providing a comparable service using engineered techniques or projects. Another method relies on individuals' opinions of, and preferences for, ecosystem services. The following subsections describe these techniques.

Established Markets

Established markets exist for some ecosystem services. These markets include purchasing credits from a wetland-mitigation bank or buying air-pollution credits. Property markets may also capture some values associated with ecosystem services such as view and open-space amenities.

Wetland-mitigation banks are public or private lands managed for their natural-resource values. Typically, a developer or government agency purchases mitigation credits to offset damage caused by construction projects (White and Ernst 2003). Oregon, Washington, and California, as well as several states in the east, have established mitigation banks specific to wetlands and their associated ecosystem services (Department of Fish and Game 2001; Toyon Environmental Consultants 1995).

The Chicago Climate Exchange trades carbon emissions. Companies that reduce their carbon emissions may sell emission credits to other companies that face higher emission-control costs. The exchange conducted its first auction for carbon emissions in September, 2003 (Chicago Climate Exchange Website). The Chicago Board of Trade has auctioned allowances for sulfur dioxide since 1993 (U.S. Environmental Protection Agency). The Northeast states and the District of Columbia support the Ozone Transport Commission (OTC). In 1994, the OTC, working with the EPA, put in place a NOx cap and trade system that addresses regional ozone problems (U.S. Environmental Protection Agency 2001). In another example, the Los Angeles area developed an emissions-trading initiative known as the Regional Clean Air Incentives Market (RECLAIM). The RECLAIM program has emissions caps and phased reductions in the allowable emissions of SO_2 and NOx (U.S. Environmental Protection Agency 2001).

Mitigation banks and markets for air-pollution credits do not suffer from market failure because both have mechanisms that identify beneficiaries of the program. Furthermore, the capacity of a mitigation bank or the number of available pollution credits limits the overall size of the market. The transaction prices for these markets provide insight into market values for the ecosystem services associated with wetlands and air quality. These values, however, likely underestimate the true value of these ecosystem services because they represent the *cost* of maintaining a wetland or the *cost* of removing air pollutants, rather than on the values of the range of ecosystem services associated with wetlands or clean air.

Hedonic Analysis

Depending on the location of property relative to natural areas, real-estate values may include values for ecosystem services associated with view and access amenities (Field 1997; Goodstein 1999). Economists measure these amenities by comparing properties near the amenities with similar properties some distance away. This type of study, known as a hedonic analysis, controls for other factors, e.g., number of rooms, size of property, etc., and calculates the portion of a property's value contributed by the amenities (King and Mazzotta 2003). A hedonic analysis of property values will likely underestimate the full value of ecosystem services because it measures only amenity values and may exclude values associated with other services, such as water quality and habitat for wildlife.

In a study specific to the Portland area, Lutzenhiser and Netusil (2001) calculated the impact of urban openspace on property values for parcels adjacent to and near the openspace. Their results indicate that, on average, homes within 1,500 feet of an urban park sold for approximately $1,600 more than comparable homes that were not near an urban park.

In addition to the information available from established markets such as mitigation banks and property markets, quasi-market and non-market sources of information provide additional insights on the economic values of ecosystem services. Quasi-market sources of information include replacement cost, avoided cost, and travel cost. Non-market sources include contingent-valuation studies.

Replacement Cost

Replacement cost represents the cost of replacing ecosystem services provided previously by riparian and wildlife resources (King and Mazzotta 2003). For example, a municipality may have in the past tapped a river for drinking water with little or no chemical treatment because high-quality riparian areas in the city's watershed maintained water quality. Over time, developing the watershed degraded riparian areas, which negatively affected water quality. As a result the municipality upgraded its water-treatment plant to filter and chemically purify the water. The additional filtration and purifying costs represent the replacement cost of the water-quality services provided previously by natural riparian areas.

The City of Wilsonville's new water-treatment facility provides a local example of the replacement cost of water-quality related ecosystem services. The new facility began operating in April of 2002. The plant draws water from the Willamette River and has a treatment capacity of 15 million gallons per day. Given the poor water quality of the Willamette River, however, water must be treated extensively before it can be consumed. Major components of the treatment facility include:

- Intake screens that protect fish and prevent debris from entering.
- Coagulant chemicals that facilitate sedimentation.
- Ozonation that disinfects and breaks down organic chemicals.
- A six-foot thick charcoal filter that removes pathogens and organic chemicals.
- A sand filter that removes particles.
- Chlorine that disinfects (City of Wilsonville).

The plant cost approximately $43 million to design and build (Water Technology). We did not locate information on annual maintenance costs. The City of Wilsonville reports that it funded its portion of the construction costs by implementing a five-step increase in water rates beginning April 2000 and ending April 2002 (City of Wilsonville). To the extent that the water-treatment steps described above replace the water-quality services provided previously by riparian areas, the treatment plant's construction and operating costs represent the cost to residents and businesses of Wilsonville of replacing riparian water-quality services with an upgraded water-treatment plant.

In the example above, the replacement cost underestimates the full value of riparian services because it values only water-quality services. As described above, riparian areas provide a range of services beyond managing water quality such as recreation amenities and flood management.

Avoided Cost

Avoided cost is similar to replacement cost but values are calculated slightly differently (Field 1997; King and Mazzotta 2003). For example, rehabilitating riparian areas for sediment control may yield additional benefits such as improved (reduced) water temperatures in summer, reduced flooding, and improved groundwater recharge. These benefits, in turn, may help a municipality avoid costs associated with complying with the Endangered Species or Clean Water Acts.

As with the other methods described above, the avoided-cost method likely underestimates the full value of services provided by riparian and wildlife areas. In the previous example, the avoided cost does not account for the amenity value of the rehabilitated riparian area.

Travel Cost

Travel-cost studies typically calculate values associated with recreational activities such as fishing, hiking, and birdwatching (Field 1997; Goodstein 1999; King and Mazzotta 2003). For example, researchers calculate the recreational value of a fishing resource based on the amount people spend on travel expenses, such as transportation, food, and lodging, during their fishing trips. Using this method, individuals living near a resource places less value on a resource—due to lower per-trip travel costs—than those who live farther away. However, to the extent that those who live closer visit more often they may place a higher overall value on the resource than those who visit from farther away. Furthermore, some of those who live closer do so precisely because they place a higher value on the resource. Estimating the value they place on the resource by their travel costs likely underestimates the value they place on the resource.

A travel-cost analysis of the value of steelhead fishing in Oregon calculated the value of catching an additional steelhead at approximately $300 (in year 2002 dollars) (Loomis 1989).

One constraint of the travel-cost method is that by focusing on visitor expenditures it ignores other values of the resource. For example, the $300 per fish described above does not include the values of water-quality or flood-management services provided by riparian areas that support the steelhead fishery.

Contingent Valuation

Contingent valuation ("CV") is a commonly-used method of estimating the values of non-market ecosystem services (Field 1997; Goodstein 1999; King and Mazzotta 2003). In a CV study, researchers collect information via questionnaires on the amount respondents are willing to pay to protect a given resource, or the amount they would be willing to accept to allow degradation of a resource. A limitation of CV studies is that because they target specific locations and services, calculated values may not accurately represent values at other locations. Also, the CV method reports people's willingness-to-pay or willingness-to-accept based on respondents' stated preferences to hypothetical alternatives, which may differ from the actual choices at issue.

A contingent-valuation study based on the results of the Oregon Population Survey found that Portland residents indicated an average willingness to pay to improve salmon runs in Oregon of $3 per household, per month (Helvoigt and Montgomery 2003).

Benefit Transfer

The benefit-transfer (BT) method calculates the values of ecosystem services at a site (referred to as the policy site) based on the results from hedonic, contingent-valuation, travel-cost, or other studies conducted elsewhere (referred to as the study site or sites) (King and Mazzotta 2003). For example, a BT analysis may calculate the values of water-quality services of riparian areas in Portland, based on studies conducted on riparian areas in Denver, Colorado. Where applicable, a BT analysis may save both time and money. But the applicability of a BT analysis diminishes the greater the difference between the study site (e.g., Denver in the example above) and the policy site (Portland). To the extent that the differences matter, values measured at the study site or sites may not accurately reflect values at the policy site. Given this constraint, the benefit-transfer method is better suited to providing *insights* into the appropriate range of values for particular services, rather than *specific values*.

A number of economists, including Desvouges et al. (1992), Boyle (1992), Brouwer (2000), and the U.S. Environmental Protection Agency (2000) describe the basic steps in a BT study and the criteria to consider when selecting studies for a BT analysis. The major steps are:

- Identify the environmental good or service at issue.
- Identify affected stakeholders.
- Review existing, relevant studies.
- Assess the transferability of results from study to policy site, taking into account the affected good or service and stakeholders.

The major factors or criteria to consider when assessing the transferability of results between study sites and the policy site include:

- Evaluate the quality of the research conducted at the study sites.
- Seek similar environmental goods or services at the study and policy sites.
- Seek similar population and stakeholder characteristics at the study and policy sites.
- Seek similar baseline measures and magnitude of changes of environmental goods or services at the study and policy sites.
- Account for different values calculated using different valuation methods.

The range of options when considering transferability include (Boyle and Bergstrom 1992; U.S. Environmental Protection Agency 2000):

- Rejecting a study because conditions between the two sites are too dissimilar
- Assessing the magnitude of bias of results from the study site and using these results if the bias, once accounted for, is acceptable.
- Systematically adjusting results from the study site to remove unacceptable bias. One of the main criticisms of the BT method is that analyses conducted at study sites were not designed with the BT method in mind. As a result, it may be difficult to replicate the necessary analytical conditions, techniques, and data at the policy site (Boyle and Bergstrom 1992; Brouwer 2000).

Among the techniques economists use for comparing results across different studies are meta-analysis and Bayesian analysis. A meta-analysis addresses the variability among studies by evaluating the statistical significance between a study's characteristics or variables and the resulting calculated values of ecosystem services (Brouwer 2000; Smith and Pattanayak 2002; U.S. Environmental Protection Agency 2000). While a meta-analysis considers information specific to study sites, a Bayesian (statistical) analysis combines data from study sites with information specific to the policy site (Atkinson 1992; U.S. Environmental Protection Agency 2000). Both the meta-analysis and the Bayesian analysis may be data-intensive and use relatively sophisticated statistical techniques.

As described by Brookshire (1992), the usefulness of BT analyses depend ultimately on the soundness of the analyst's opinion and judgement when deciding if results from study sites are transferable to policy sites.

IV. Sources of Information

We consulted the following sources for information on the calculated values of ecosystem services provided by riparian areas and other natural resources.

- Electronic databases such as ECONLit that list academic articles published in peer-reviewed journals. See Appendix 1 for the list of journals included in this portion of the search.
- Bibliographies of journal articles, reports and unpublished research compiled by academic researchers and posted on their web sites.
- The Environmental Valuation Reference Inventory (EVRI), a subscription-based inventory of academic articles and research results that address the economic values of ecosystem services. EVRI is supported by Environment Canada and the US Environmental Protection Agency.
- The internet, focusing on federal and state government sites.
- Lexis-Nexis, focusing on industry journals, trade publications, newspapers and other periodicals.

We reviewed approximately 550 academic articles and government reports for this analysis. Appendix 2 lists approximately 100 articles that report quantitative information on calculated values of ecosystem services most relevant for the Lents project. We focused on research results reported for study sites in the US, with an emphasis on the Pacific Northwest. We selected a subset of the material listed in Appendix 2 that most closely represented the ecosystem services affected by the Lents project (described below in the next section).

The academic articles listed in Appendix 1 describe values of ecosystem services measured under controlled conditions as required for peer-reviewed academic research. These studies provide valuable information on the calculated values of ecosystem services. Our search also included articles and reports that describe the values of ecosystem services from the perspective of municipal decisionmakers and stakeholders. We reviewed information on approximately 60 municipal projects. Appendix 3 summarizes 18 projects and information on the projects' calculated impacts on ecosystem services or related economic values.

In the next section we summarize the Lents flood-management plan, discuss the plan in the context of riparian-restoration efforts implemented by other municipalities, describe the ecosystem services that the plan will affect, and the economic studies and other information used in our analysis of the economic values of the affected ecosystem services.

V. The Lents Flood-Management Plan

As described in the City's Lents Technical Memorandum 1 (Bowker J. et al. 2001) and Technical Memorandum 2 (Bowker J. et al. 2002), the Lents area faces a risk each winter that Johnson Creek will overflow its banks and flood the surrounding area. This flooding affects homes, businesses, industrial areas, and Foster Road, a major transportation route. Past floods also threatened an electrical substation. Previous studies determined that due to topography constraints, flood-control structures such as dams cannot provide sufficient protection along Johnson creek.

The flood-management plan developed by the City's Bureau of Environmental Services, in consultation with local stakeholders, emphasizes restoring floodplain functions and riparian areas. The Lents plan addresses the City's interrelated goals of flood mitigation, and improving water quality and fish and wildlife habitat as described in the Johnson Creek Restoration Plan. The non-flood aspects of the Lents plan help address the City's responsibilities under the Endangered Species Act.

Declining water-quality and urban flooding affect municipalities throughout the U.S. Our review of riparian-restoration projects implemented by other municipalities found that, similar to Portland's Lents project, other municipalities recognize the benefits of addressing these problems by restoring or protecting riparian ecosystem services. (See Appendix 3 for a summary description of a number of these projects.) In the next subsection we discuss the major conclusions from our review of riparian-restoration projects conducted elsewhere in the context of the Lents project. Following that we describe the ecosystem services affected by the Lents project and the economic studies that we'll use to calculate the economic value of the services affected by the project. Finally, we summarize the results of an internal peer review of the data and methods described in this technical memo.

Riparian-Restoration Projects Conducted Elsewhere

Appendix 3 contains summary descriptions of riparian-restoration or wetland-related projects conducted by municipalities throughout the U.S. These projects focus on protecting or restoring services provided by riparian areas that benefit municipal residents and businesses. The affected services include flood mitigation, maintaining water quality, providing wildlife habitat and recreational or openspace amenities.

The Lents project illustrates and supports a number of the outcomes of riparian-restoration projects conducted elsewhere. These include:

- The findings from the municipal projects described in Appendix 3 and from the academic studies listed in Appendix 2 all indicate that riparian areas can provide valuable ecosystem services that benefit municipal residents, local businesses, and governments. The Lents project is a local example of riparian areas protecting residences, businesses and a major transportation corridor from flood damage.

- For many of the projects listed in Appendix 3, protecting or restoring ecosystem services was less costly or more effective than other alternatives and provided additional benefits such as wildlife habitat, flood mitigation, and recreation amenities. In the Lents example, structural flood-mitigation alternatives were not technically feasible. They also would not have provided benefits in addition to flood mitigation, such as improved air and water quality. In the next subsection we describe these additional benefits.

- Riparian-restoration projects that affect relatively small areas may yield significant benefits. Large projects, such as protecting the watersheds that provide New York City's water, can affect ecosystem services valued at billions of dollars. Smaller projects, such as restoring a mile of riparian area along an urban river, may provide a more limited range of services, but these benefits may be significant for local citizens and stakeholders. The Lents project affects a relatively small portion of Portland's riparian areas but the project will help alleviate flood damage and other related concerns associated with nuisance floods in the Lents neighborhood. At the same time, the project will generate benefits beyond flood mitigation.

Ecosystem Services Affected By the Lents Project

In this subsection we identify the ecosystem services that the Lents project will affect and describe the economic studies and other sources of information used in our analysis of the economic values of the affected services. Appendix 4 lists the economic values used in the analysis, and Appendix 5 describes the academic studies and other sources for the economic values.

Whenever we found sound and relevant local information on values, we used them. Whenever we found sound and relevant non-local information on values, we used them, either to complement the local information or to serve in its staid when we could not obtain local information. For studies conducted elsewhere we addressed the benefit-transfer implications of using results of these studies.

For each ecosystem service we describe the range of values we considered and the value or values we selected for the analysis.

Flood Management

We calculated the value of mitigating the nuisance flood based on damages caused by past flooding, as reported by Lents-area residents and businesses. In a study for the City of Portland, Woodward Clyde surveyed residents, business and City staff for information on damages associated with the February, 1996 flood (Woodward Clyde (no date)). Woodward Clyde report damages to residences, businesses, parks, roads and bridges, utilities and expenditures by the City of Portland's emergency services. Floodwaters for the 1996 flood inundated a larger area, and for a longer period of time, than do the floodwaters typical of a nuisance flood. We calculated damages for the nuisance flood by scaling down damages from the 1996 flood based on differences in peak flow and water volume between the two floods.

Records of past floods had no information on the costs associated with traffic delays caused when Johnson Creek floods Foster Road. We calculated the values of avoided traffic delays based on FEMA's calculated cost per vehicle, per hour of delay combined with traffic counts for Foster Road and the distance to alternative routes (FEMA 2003). The FEMA figure is an average of the cost of traffic delays from flooding across the US and may not necessarily represent the costs specific to the Portland area. Of note, however, is the fact that FEMA uses this figure when calculating the mitigation benefits in the Portland area of FEMA flood-management projects.

Table 5.1 lists the calculated damage to Lents area residences, businesses, and utilities, along with flood-related emergency expenditures. These damages and expenditures represent the calculated value of the flood-mitigation services provided by the Lents project. Values are reported in year 2002 dollars and accrue per flood event. We list a high and low range for the values extrapolated from the Woodward Clyde results.

Table 5.1: Flood-Mitigation Benefits of the Lents Project

Flood-Mitigation Benefit	Calculated Value, per Flood Event, in Year 2002 Dollars
Avoided Property Damage to Residences, Lower Bound	$57,961
Avoided Property Damage to Residences, Upper Bound	$75,431
Avoided Business Damage, Lower Bound	$397,211
Avoided Business Damage, Upper Bound	$516,919
Avoided Traffic Delays	$32.23 per vehicle hour of delay
Avoided Damage to Utilities, Lower Bound	$9,125
Avoided Damage to Utilities, Upper Bound	$11,875
Avoided PDX Expenditures, Lower Bound	$4,643
Avoided PDX Expenditures, Upper Bound	$6,042

Source: ECONorthwest based on material provided by the City of Portland.

An advantage of using the values reported in Table 5.1 is that, except for traffic delays, the analysis that generated the values focused on flood damage in the Lents neighborhood. In this case the study site and the policy site are one and the same. We expect that these values, adjusted for the differences in flood events between the nuisance flood and 1996 flood, will more closely represent the true flood-mitigation benefits of the Lents project than other sources of flood-mitigation benefits.

Biodiversity Maintenance

Information on the economic values of wildlife habitat provided by wetlands comes from studies conducted in Oregon and elsewhere.

The Oregon Population Survey includes questions on what Oregon residents are willing to pay to protect natural resources throughout the state. Based on an analysis of survey responses by Oregon residents, Helvoigt & Montgomery (2003) calculated the average per household willingness to pay to improve salmon runs in Oregon at $3.05 (in year 2002 dollars) per month, per household.

Specific to the analysis of the Lents project, the strength of this information is that it is local. One drawback of this calculated value is that the results are for salmon runs in Oregon and not specific to salmon runs in Johnson Creek and to residents in the area. Another challenge with using this information is identifying the appropriate number of households in the Lents area to which this value would apply. Applying the calculated per household values to too large of an area will overestimate the values associated with the policy site. Applying the values to too small an area will have the opposite effect.

The contingent valuation study by Berrens, Bergland and Adams (1993) calculates willingness to pay for an additional fish caught on the Willamette and Clackamas Rivers at $3.50 per fish (in year 2002 dollars). These calculated values are based on rivers in the local area, however, both of the study rivers are larger than Johnson Creek. Given this difference, applying these results to the Lents area may overestimate the values of fish habitat provided by the Lents project.

Woodward and Wui (2001) completed a meta-analysis of contingent valuation and travel-cost studies conducted across the US on people's willingness to pay for avian habitat provided by wetlands. They report an average value of $403 per acre of wetland, per year (in year 2002 dollars) as the value of avian habitat supported by wetlands. A meta-analysis is a benefit-transfer method that calculates the values of ecosystem services using a number of studies while controlling for differences among the study sites. A benefit of this study is that it calculates values for wildlife habitat on a per-acre basis, rather than estimating values by individual species. A drawback of this study is that it reports an average value for studies conducted across the US. This average value may be greater than or less than the true value of the improved habitat as measured in the Lents area.

The work by Koteen et al. (2002) reports non-market values for salmon across a range of salmon populations. This study has limitations including larger geographic areas, larger populations of (human) beneficiaries, and larger populations of salmonids than the policy site in Johnson Creek.[1] That is, the lower-bound values of each of these variables for most of the salmon-population data reported by Koteen et al. are much higher than the corresponding values in Johnson Creek. For these reasons, we judged this study inapplicable to estimating values in Johnson Creek.

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[1] As described above, one of the limitations of valuing the wildlife benefits associated with restoring wetlands along Johnson Creek is the lack of local estimates of this value. Farber (2002) describes the importance of collecting local information from area stakeholders using what they describe as the "small-group deliberation" technique. The technique uses a combination of the values reported in the literature with local estimates of values as described by area stakeholders. To the extent these local values are important to decisionmakers and area stakeholders, this would be an area for further research.

We calculated the impact of the Lents project on the value of improved salmon and avian habitat. We calculated the value of improved salmon habitat using Helvoigt and Montgomery's calculated value of Portlanders' willingness to pay to improve salmon habitat. This study focused on the value of salmon habitat in Portland, which includes the Lents study area. As we note above, because this study has a different scope than the Lents project, it might overestimate or underestimate the values of the Lents project.

We calculated the value of improved avian habitat in the Lents area based on Woodward and Wui's meta-analysis of the value of habitat services provided by wetlands. As we describe above in Section III, meta-analysis is a recommended benefits-transfer technique that helps control for variability across studies. We note however, that Woodward and Wui's calculated value represents an average for studies across the US and that this value may be less than or greater than the value in the Lents area.

The Lents project may have an impact on the City's expenditures associated with the Endangered Species Act (ESA). We have insufficient information at this time to determine if the Lents project will affect these expenditures, and if so, to what extent. To the extent that the Lents project will reduce the City's ESA expenditures and we are unable to quantify this effect, our analysis will underestimate the economic impacts of the project.

Cultural Resources (Amenity Values)

Information on the calculated amenity values associated with the parks and openspace portion of the Lents project comes from local studies on the impact of urban parks on property values.

Lutzenhiser & Netusil (2001) calculated the relationship between proximity to urban parks in the Portland area and residential property values using the hedonic method. They report that property values for homes within 1,500 feet of an urban park are $1,671 (in year 2002 dollars) greater than similar properties further from the park. The strength of this study is that the researchers calculated amenity values for local parks that, as they are described, are similar to the type of park that will be developed in the Lents area.

The Mahan, Polasky, Adams (2000) study also describes this same relationship but they calculated the value as the impact on property values per acre of additional wetland. They report a value of $37 per acre (In 2002 dollars) of additional wetland for properties within 1,500 feet of the wetland (See Appendix 4).

The hedonic studies described above calculate the amenity values local residents place on urban parks in the Portland area. To the extent that a park in the Lents area attracts visitors from outside the local neighborhood, the hedonic values will underestimate the full amenity or recreation values of the resource.

It is likely that a park in the Lents area will attract visitors from beyond the area bordering the park for two reasons. First, the park will be adjacent to the Springwater Corridor Trail, which attracts users from an area much larger than the Lents neighborhood.[2] Second, as described in the City's Parks and Recreation report, "Parks 2020 Vision," the Lents area is within a zone designated "park deficient." Greg Everheart of Parks and Recreation notes that the Lents area is deficient for both park acreage and park facilities. A related point is that school districts in the area are growing rapidly.[3]

For these reasons it is likely that the recreation component of the Lents area will generate recreation values in addition to the amenity values reported above for area residents. At this time the City has not yet developed a formal park proposal for the area and has not calculated park benefits or costs. The City's Parks & Recreation staff will have a better understanding of recreation benefits of the park once a formal needs assessment and park plan are developed. For the purposes of our study we calculated the number of park uses based on information in the Tetra Tech report (described below) and on use statistics for the Springwater Corridor Trail and area demographic information. See the report that accompanies this appendix for the details of this calculation.

We reviewed two sources of information on the value of recreational benefits specific to park users. The first is a study conducted by Tetra Tech for the City of Portland on the recreational benefits of upgrading Portland's Westmoreland Park (Tetra Tech no date). This study reports a standard value per unit day of recreation calculated by the US Army Corps of Engineers, and a point scale that adjusts the standard unit day and associated value to account for conditions at Westmoreland Park.[4] Tetra Tech reports a value of $4 per unit day of recreation (in 2002 dollars). The Tetra Tech report offers a recreation value for a park in Portland that, as we understand it, will have similar amenities to the park developed in the Lents area.

The second source for recreational values is a study by Costanza et al. (1989) that reports an upper and lower bound on the per-acre recreation values of wetlands. They report recreation values provided by wetlands at between $80 and $313 (in year 2002 dollars) per acre of wetland. One similarity between the Costanza et al. study site and the Lents area is that both sites involve recreation in wetland areas, which affects the type and amount of recreation access and use. The greatest difference between the studies is that the Costanza et al. study site is in a coastal area of Louisiana.

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[2] Personal communication with Janet Bebb of Portland Parks and Recreation, November 6, 2003.

[3] Personal communication with Greg Everheart of Portland Parks and Recreation, November 12, 2003.

[4] A unit day is a standard measure of recreation value. The point scale used to adjust the standard measure for local conditions includes information on factors such as: recreation experience, availability of opportunity, carrying capacity accessibility and aesthetic environment.

Thus, the Costanza et al. study may under or overestimate the recreation benefits of the Lents project.

We calculated the amenity value of the Lents riparian restoration using the values reported in the Lutzenhiser and Netusil (2001) study and calculated the value of recreational benefits using the unit-day values reported in the Tetra Tech study. The conditions for both of these studies are similar to the Lents area and the ecosystem services addressed in the study are similar to the services that will be affected by the Lents project.

Air Quality

We found only a few sources with information on the economic values of air-quality services provided by trees and other vegetation. However, well-respected institutions produced these reports and researchers who study this topic cite these sources when reporting the value of improved air quality.

The first source is the CITYgreen 5.0 model developed by American Forests (2003). The CITYgreen model calculates the amount of air pollutants removed per unit of forested area in urban centers throughout the US. At the time of our analysis, CITYgreen did not have a model for the Portland airshed. We based our analysis on model results for the Seattle airshed.

CITYgreen calculates the value of improved air quality provided by urban trees based on the tons of pollutants removed by the trees and the avoided health-care costs of treating respiratory diseases caused by the pollutants. The CITYgreen calculated values of improved air quality include (in 2002 dollars):

- $970 per ton of carbon monoxide.
- $1,653 per ton of SO2.
- $4,519 per ton of particulate matter (PM10).
- $6,768 per ton for volatile organic compounds and ozone.

The second source is a 1992 report by the California Energy Commission (CEC) on the benefits of improved air quality. The CEC study calculates the value of improved air quality based on the avoided per-ton costs of removing pollutants. The third source is a 2003 report by the US Office of Management and Budget (OMB) on the costs and benefits of federal regulations that affect air quality and other resources. The OMB study calculates the value of improved air-quality based the health-care costs of treating ailments associated with the air pollutants. Values are reported per ton of pollutant removed.

The calculated values per ton of pollutant removed, in year 2002 dollars, from the CEC and OMB reports include:

- $1,279 per ton of carbon monoxide (CEC, 1992).
- $7,800 (OMB, 2003) to $2,271 (CEC, 1992) per ton of SO2.
- $5,572 to $1,114 per ton of NOX (OMB, 2003).

- $1,817 per ton of particulate matter (PM10) (CEC, 1992).
- $2,735 to $608 per ton of volatile organic compounds and ozone (OMB, 2003).

All of these studies have received peer review by researchers in the field, and the results apply to specific types of air pollutants. We used results of the CITYgreen model in our analysis because the model ties changes in air quality to changes in tree cover, which we can relate to the Lents projects' impact on expanded tree cover. As shown above, the Citygreen values differ from the values reported in the other studies. For carbon monoxide and SO2, the Citygreen values are lower; and for particulate matter and ozone, the Citygreen values are higher.

Water Quality

The Woodward and Wui (2001) study described above also calculated the values of water-quality services provided by wetlands. As with their analysis for the values of wildlife habitat, the researchers conducted a similar meta-analysis of studies that reported water-quality values for wetlands. The meta-analysis technique is a benefit-transfer method that controls for the differences among studies while, in this case, estimating the values of water-quality benefits provided by wetlands. They report a value of $549, in year 2002 dollars, per acre of wetland per year for water-quality services provided by wetlands. Given that this value represents an average of values from the studies conducted across the US that Woodward and Wui considered in their analysis, the true value for the Lents project may be less or greater.

Farber (1996) calculated the values of bank-stabilization services provided by wetlands in coastal Louisiana at $7,025 per acre per year (in 2002 dollars). Thibodeau and Ostro (1981) calculated the per-acre values of wetlands for runoff filtration and pollution reduction for freshwater wetlands in Massachusetts at $4,601 (2002 dollars). Considering the benefit-transfer application of these studies to the Portland area, both studies have drawbacks in that they are specific to portions of the US that are distant from Portland. In addition, the Farber study focused on coastal wetlands, rather than streamside wetlands in an urban area.

We calculated the value of water-quality services that will be provided by the Lents project using the results from Woodward and Wui. We regard the Woodward and Wui study more directly applicable to the Lents policy site than the other studies. Perhaps incidentally, the value reported by Woodward and Wui is the lowest among the studies we considered.

The Lents projects may have an impact on the City's expenditures associated with the Clean Water Act (CWA). We have insufficient information at this time to determine if the Lents project will affect these City expenditures, and if so, to what extent. To the extent that the Lents project will reduce the City's CWA expenditures and this effect is not quantified, the results of this analysis will underestimate the economic impacts of the project.

Internal Peer Review of Data and Methods

ECO submitted the data and analytical methods described in this Technical Memo for review by two of the leading researchers in the field of ecosystem economics, or the study of the value of ecosystem services. The review had three purposes:

1. Identify relevant research articles or reports not included in our literature search.
2. Comment on the data we selected for the analysis of the Lents project.
3. Comment on the analytical methods for the analysis of the economic value of ecosystem services affected by the Lents project.

Dr. Noelwah Netusil, Associate Professor of Economics at Reed College, and Dr. Catherine Kling, Resource and Environmental Policy Division Head, Professor of Economics at Iowa State University, provided the peer review. Both researchers specialize in environmental and resources economics.

- Both researchers identified articles published in academic journals that were not included in our bibliography but that may provide relevant information on the value of ecosystem services affected by the Lents project. We've considered these articles and included them in the bibliography described in Appendix 2. None of the articles affected the dataset of economic values for our analysis of the Lents project.

- The reviewers concluded that data and analytical methods described in this Technical Memo are appropriate for the analysis of the Lents project and reflect commonly-accepted standards for analyses of the economic values of ecosystem services.

- The reviewers voiced concern that the list of values reported in the tables in Appendix 4: Economic Value for the Analysis of the Lents Project, may raise questions of double counting of economic values because in some cases the tables report multiple values for a given ecosystem service. They suggested that the Technical Memo, and the follow-up report that describes the analysis of the Lents project, clearly identify and describe the economic data used in the analysis. We've edited the text of the Technical Memo and Appendix 4 to more clearly identify the data used in the analysis. The follow-up report to this Technical Memo also clearly identifies the data used in the economic analysis.

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Appendix 1 Academic Journals

AGRICULTURAL ECONOMICS
AGRICULTURAL ECONOMICS RESEARCH
AMERICAN ECONOMIC REVIEW
AMERICAN ECONOMIST
AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS
APPLIED ECONOMICS
ATLANTA ECONOMIC REVIEW
AUSTRALIAN ECONOMIC PAPERS
AUSTRALIAN JOURNAL OF AGRICULTURAL AND RESOURCE ECONOMICS
BULLETIN OF ECONOMIC RESEARCH
BULLETIN OF THE OXFORD UNIVERSITY INSTITUTE OF ECONOMIC AND STATISTICS
CAMBRIDGE JOURNAL OF ECONOMICS
CANADIAN JOURNAL OF AGRICULTURAL ECONOMICS-REVUE CANADIENNE D AGROECONOMIE
CANADIAN JOURNAL OF ECONOMICS
CONTEMPORARY ECONOMIC POLICY
ECOLOGICAL ECONOMICS
ECONOMIC DEVELOPMENT QUARTERLY
ECONOMIC PLANNING
ECONOMIC POLICY
ECONOMICS OF PLANNING
ECONOMIST
ENERGY ECONOMICS
ENVIRONMENT AND DEVELOPMENT ECONOMICS
ENVIRONMENT AND PLANNING
ENVIRONMENT AND URBANIZATION
ENVIRONMENTAL & RESOURCE ECONOMICS
ENVIRONMENTAL MANAGEMENT
ENVIRONMENTAL POLLUTION
EUROPEAN ECONOMIC REVIEW
EUROPEAN REVIEW OF AGRICULTURAL ECONOMICS
FOREST POLICY AND ECONOMICS
GERMAN ECONOMIC REVIEW
INTERNATIONAL ECONOMIC REVIEW
JAPANESE ECONOMIC REVIEW
JOURNAL OF AGRICULTURAL AND RESOURCE ECONOMICS
JOURNAL OF AGRICULTURAL ECONOMICS
JOURNAL OF AGRICULTURAL ECONOMICS RESEARCH
JOURNAL OF COMPARATIVE ECONOMICS
JOURNAL OF ECONOMIC ISSUES
JOURNAL OF ECONOMIC LITERATURE
JOURNAL OF ECONOMIC PERSPECTIVES
JOURNAL OF ECONOMIC STUDIES
JOURNAL OF ECONOMIC SURVEYS
JOURNAL OF ECONOMIC THEORY
JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT
JOURNAL OF ENVIRONMENTAL MANAGEMENT
JOURNAL OF PUBLIC ECONOMICS
JOURNAL OF REAL ESTATE FINANCE AND ECONOMICS
JOURNAL OF REGULATORY ECONOMICS
JOURNAL OF RISK AND UNCERTAINTY
JOURNAL OF THE AMERICAN REAL ESTATE AND URBAN ECONOMICS ASSOCIATION

JOURNAL OF URBAN ECONOMICS
LAND ECONOMICS
LANDSCAPE AND URBAN PLANNING
LANDSCAPE ECOLOGY
NATURAL RESOURCES FORUM
NATURAL RESOURCES JOURNAL
NATURE & RESOURCES
NORTHWEST ENVIRONMENTAL JOURNAL
ORGANIZATION & ENVIRONMENT
QUARTERLY JOURNAL OF ECONOMICS
RAND JOURNAL OF ECONOMICS
REAL ESTATE ECONOMICS
REGIONAL SCIENCE AND URBAN ECONOMICS
RESOURCE AND ENERGY ECONOMICS
RESOURCES AND CONSERVATION
RESOURCES AND ENERGY
RESOURCES POLICY
REVIEW OF AGRICULTURAL ECONOMICS
RIVER RESEARCH AND APPLICATIONS
RIVERS-STUDIES IN THE SCIENCE ENVIRONMENTAL POLICY AND LAW OF INSTREAM FLOW
SCOTTISH JOURNAL OF POLITICAL ECONOMY
SOCIETY & NATURAL RESOURCES
STOCHASTIC ENVIRONMENTAL RESEARCH AND RISK ASSESSMENT
SUSTAINABLE DEVELOPMENT
SWEDISH JOURNAL OF ECONOMICS
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Municipal Projects

1. Tres Rios Project, Phoenix, Arizona

The City of Phoenix implemented the Tres Rios project to meet current and future federal water-quality discharge requirements for a wastewater treatment plant. The project created 12 acres of wetland that operate in conjunction with the existing treatment plant. Constructing the wetland was less expensive and provided additional benefits compared with expanding the treatment plant. Developing the wetland cost approximately $82 million and upgrading the existing water-treatment plant would have cost approximately $625 million. Additional benefits provided by the wetland include: wildlife habitat, environmental education, flood management, and aesthetics.

Source: International City/County Management Association and National Association of Counties. 1999. *Protecting Wetland, Managing Watersheds. Local Government Case Studies*. International City/County Management Association and National Association of Counties, Washington, DC.

2. Johnson County Streamway Park System, Kansas

The Johnson County Streamway Park System was implemented as a storm-water control program. The project created a county-wide greenways network along area streams. Creating the greenways network cost less than alternative storm-water control programs. The greenways cost $600,000 and other options would have cost $120 million. The greenways also provided recreation benefits.

Source: International City/County Management Association and National Association of Counties. 1999. *Protecting Wetland, Managing Watersheds. Local Government Case Studies*. International City/County Management Association and National Association of Counties, Washington, DC.

3. The Charles River Natural Valley Storage Project, Boston, Massachusetts.

The Charles River Natural Valley Storage Project helps control flooding by preserving 6,930 acres in 17 existing wetlands. Purchasing the land outright or purchasing preservation easements to the land cost $10 million, ten percent of the $100 it would have cost to build a dam. The City of Boston saves an estimated $17 million annually in flood damage because of the project. Additionally, an estimated 1.5 percent premium has been added to the values of homes in the area due to the flood-protection and amenity values provided by the wetlands.

Source: National Audubon Society. No date. *What's a Wetland Worth?* National Audubon Society, New York, NY.

Natural Resources Defense Council (NRDC). 1999. *Reports: Stormwater Strategies—Community Responses to Runoff Pollution.* Natural Resources Defense Council, New York, NY.

4. Staten Island Bluebelt Project, New York City, New York

The Staten Island Bluebelt project helps control stormwater using existing natural drainage systems, e.g., streams, ponds, and wetlands. A benefit/cost study indicated that the project saves $50 million over a conventional sewer-line approach.

Source: U.S. Environmental Protection Agency. June, 2001. *National Management Measures to Protect and Restore Wetlands and Riparian Ares for the Abatement of Nonpoint Source Pollution.* Appendix F. EPA number 841B01001.

5. Tualatin River, Washington County, Oregon

A study conducted by Oregon State University calculated the potential costs of restoring approximately 46 miles of riparian areas along two tributaries of the Tualatin River in Washington County, Oregon. The study calculated that the restoration program would cost $660,000. The alternative, additional dredging and water treatment, would have cost an estimated $1 million.

Source: Environmental News Network (ENN). 1996. *Riparian Restoration is cost effective, study shows.* ENN, Sun Valley, ID.

6. Wetland Reconstruction, Des Moines, Washington

The City of Des Moines, Washington reconstructed a degraded wetland area and constructed a sediment trap/pond facility. The wetlands serve the dual purpose of providing flood protection by collecting storm water runoff and acting as a preliminary filter by removing suspended solids.

Source: U.S. Environmental Protection Agency. 1998. *Wetlands Projects Fundd by the Clean Water State Revolving Fund (CW-SRF).* U.S. Environmental Protection Agency, Office of Wastewater, Washington, DC.

7. Winona Wetlands Purchase

The City of Port Townsend, Washington purchased an area known as the Winona Wetlands to help protect water quality in the area. The wetlands act as a critical storm-water basin and provide wildlife habitat. Development had threatened the wetlands and would have resulted in future storm-water management problems and expenditures.

Source: U.S. Environmental Protection Agency. 1998. *Wetlands Projects Fundd by the Clean Water State Revolving Fund (CW-SRF).* U.S. Environmental Protection Agency, Office of Wastewater, Washington, DC.

8. Catskills Mountains, New York

Water managers for New York City studied the costs of protecting the watersheds in the Catskills Mountains as a means of preserving the watersheds' water-quality services. The study concluded that it would cost $1.5 billion to purchase and restore the watersheds and their related water-quality services, versus $6-8 billion to build a water treatment plant and an additional $300 million per year to operate the plant.

Source: Trust for Public Land. 1997. *Protecting the Source: Land Conservation and the Future of America's Drinking Water*." Trust for Public Land. San Francisco, CA.

9. Tributary Strategies, Maryland

Maryland's Tributary Strategies found that riparian buffers were more effective than engineered approaches at reducing the nutrient content of runoff. Building suitable riparian buffers costs $671,000 per year and engineered techniques would cost $3.7 to $4.3 million per year.

Source: Palone, Roxane, and Todd Albert. 1998. *Chesapeak bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers*. Chesapeak Bay Program, Northeastern Area State and Private Forestry Group, and the USDA Forest Service. June.

9. Fairfax County, Virginia

The water utility in Fairfax County, Virginia estimates it saved approximately $57 million in stormwater costs by maintaining forest areas and riparian buffers.

Source: Palone, Roxane, and Todd Albert. 1998. *Chesapeak bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers*. Chesapeak Bay Program, Northeastern Area State and Private Forestry Group, and the USDA Forest Service. June.

10. Sterling Forest, New Jersey and New York.

Proposed development in Sterling Forest on the New Jersey-New York border would have decreased water quality so severe that a $160 million filtration plant would have been necessary. Instead, a partnership between state and private organizations purchased the forest for $65 million. The purchase consolidated 150,000 acres of contiguous forest and protected the associated recreation, amenity and wildlife values of the forest.

Source: Lerner, S. and W. Poole. 1999. *The Economic Benefits of Parks and Open Space: How Land Conservation Helps Communities Grow Smart and Protect the Bottom Line.* Trust for Public Land. San Francisco, CA.

11. Skaneateles Lake Watershed Program, Syracuse, New York.

The City of Syracuse established the Skaneateles Lake Watershed Program as part of a program of "filtration avoidance" for its water source. The City estimates that the $10 million watershed plan will save between $45 and $60 million that a water-treatment facility would have cost.

Source: Natural Resources Defense Council. 2001. *Stormwater Strategies: Community Responses to Runoff Pollution.* (www.nrdc.org).

12. Anacostia River, the District of Columbia and Maryland

Several groups are working together to restore the Anacostia River Watershed. Over the past century the river has been heavily contaminated with heavy metals, pesticides, and PCBs from industry and subjected to sewage discharges during rainfalls of over half an inch. These discharges threatened human and wildlife health in the area. The goal of the project is to restore the river to a healthy state. To accomplish this goal they are focusing on pollution reduction and the restoration of ecological integrity by increasing wetland acreage and forest coverage.

Source: Anacostia Watershed Network. 2000. *Anacostia Watershed Restoration Committee.* Anacostia Watershed Network, Washington, DC.

13. Blackstone-Woonasquatucket Rivers, Rhode Island and Massachusetts

The U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, and area non-profit organizations and businesses are working to improve water quality along the Blackstone and Woonasquatucket Rivers. Both rivers have become heavily polluted with heavy metals and dioxins over the past 200 years. Their efforts include: freshwater wetland restoration, wildlife habitat restoration, pollution reduction, and additional wastewater facilities.

Source: U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. 2003. *Urban Rivers Restoration Pilot Fact Sheet: Blackstone-Woonasquatucket Rivers and Communities, MA and RI.* (http://www.epa.gov/oswer/landrevitalization/download/factsheet_blackstone.pdf)

14. Elizabeth River, Virginia

The U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, and the Commonwealth of Virginia are all involved in projects in the Elizabeth River Basin to improve water quality. The river is currently heavily contaminated by heavy metals from industrial and military sources. Their efforts are focusing on wetlands restoration to reduce storm-water runoff and pollution.

Source: U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. 2003. *Urban Rivers Restoration Pilot Fact Sheet: Elizabeth River Basin, Virginia.* (http://www.epa.gov/oswer/landrevitalization/download/factsheet_elizabeth.pdf)

15. Fourche Creek Watershed Restoration, Arkansas

A partnership of Federal, State, and local agencies along with non-profit groups has been collaborating on restoring an urban natural area along Fourche creek. Their goals include the restoration of wetland functions, flood reduction, and wildlife and aquatic habitat restoration.

Source: U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. 2003. *Urban Rivers Restoration Pilot Fact Sheet: Fourche Creek Watershed Restoration, Arkansas.* (http://www.epa.gov/oswer/landrevitalization/download/factsheet_fourche.pdf)

16. City Creek, Utah

A partnership of the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, along with numerous local, State, and private parties has developed a master plan for restoring City Creek. The creek flows through an EPA Brownsfields Assessment Demonstration pilot and has been designated a Showcase Community. They hope to restore at least 12 acres of high value riparian habitat and 7,900 feet of daylighted and restored creek, restoring a badly damaged ecosystem and providing extensive recreation and educational opportunities in the community.

Source: U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. 2003. *Urban Rivers Restoration Pilot Fact Sheet: City Creek/Gateway District, Utah.* (http://www.epa.gov/oswer/landrevitalization/download/factsheet_citycreek.pdf)

17. South Platte River Urban Restoration Project, Denver, Colorado

The South Platte River Urban Restoration Project was implemented to coordinate local government agencies and non-profits in restoring and protecting the 10.5-mile stretch of the river that runs through the city. The goals of the project are to improve water quality, provide flood control, and to protect or enhance the ecological health of the river.

Source: South Platte River Initiative. 2000. *Long Range Management Framework.* (http://www.denvergov.org/forms/PR_SPR_Plan.pdf).

18. Urban Rivers Restoration Initiative

In July 2002, the U.S. EPA and the U.S. Army formed a partnership to address water quality issues, economic revitalization, and the public use and enjoyment of urban rivers. They selected eight rivers as pilot projects to demonstrate how coordinated government and private sector efforts can restore contaminated rivers and revitalize urban environments. (A number of these pilot-projects are described above.) This initiative acknowledges that restoring these rivers provides a range of valuable ecosystem services and economic benefits.

The eight pilot-river projects are:

- The Anacostia River in the District of Columbia and Maryland
- The Blackstone-Woonasquatucket Rivers in Rhode Island and Massachusetts
- The Elizabeth River in Virginia
- The Tres Rios area in Arizona
- The Passaic River in New Jersey
- Gawanus Canal and Bay in New York
- Fourche Creek in Arkansas
- City Creek in Utah

Appendix 4

Economic Values for the Analysis of the Lents Project

Table 1: Values of Water-Quality Services

Impact of Project	Per Year Economic Value (2002$)	Description	Source
Improved water quality	$549	per wetland acre per year based on the avoided costs of water filtration	Woodward and Wui (2001), meta-analysis, nationwide
Bank stabilization	$7,025	per wetland acre per year for property protection (buffering)	Farber (1996), Coastal wetlands - LA
Runoff filtration	$4,601	per wetland acre per year for nutrient filtering/retention (waste assimilation)	Thibodeau and Ostro (1981), freshwater wetlands - MA
Pollution Reduction	$4,605	Annualized avoided cost—per acre of wetland—of adding tertiary treatment to existing water treatment plant.	Thibodeau and Ostro (1981), freshwater wetlands - MA

Sources: As listed, with calculations by ECONorthwest

Table 2: Avoided Costs Associated With Flood-Mitigation Services in the Lents Area

Impact of Project	Economic Value (2002$)	Description	Source
Avoided flood damage: Homeowners & Renters; Lents neighborhood, Portland OR.	$57,961	Engineered flood project + riparian restoration (Lower Bound)	Woodward Clyde: Flood Damage cost estimate for Johnson Creek Flood Event (Feb 4-10, 1996). Report to City of Portland
	$75,431	(Upper Bound)	
Avoided flood damage: Businesses; Lents neighborhood, Portland OR.	$397,211	Engineered flood project + riparian restoration (Lower Bound) (per flood event)	Woodward Clyde: Flood Damage cost estimate for Johnson Creek Flood Event (Feb 4-10, 1996). Report to City of Portland
	$516,919	(Upper Bound)	
Avoided traffic delays	$32.23	Per vehicle hour of delay (per flood event)	FEMA Benefit-Cost Manual
Utilities; Lents neighborhood, Portland OR.	$9,125	Avoided interruption of service (Lower Bound)	Woodward Clyde: Flood Damage cost estimate for Johnson Creek Flood Event (Feb 4-10, 1996). Report to City of Portland
	$11,875	(Upper Bound)	
PDX Expenditures; Lents neighborhood, Portland OR.	$4,643	Avoided emergency services (lower bound)	Woodward Clyde: Flood Damage cost estimate for Johnson Creek Flood Event (Feb 4-10, 1996). Report to City of Portland
	$6,042	(Upper Bound)	

Sources: As listed, with calculations by ECONorthwest

Table 3: Amenity Values of Parks and Openspace

Impact of Project	Economic Value (2002$)	Description	Source
Increased property values	$1,671	per property within 1,500' of urban park (present value).	Lutzenhiser & Netusil (2001), Portland, Oregon
Increased property values	$37	per property per additional acre of wetland within 1,500 feet (present value)	Mahan, Polasky, Adams (2000), Portland, Oregon
Increased property values	$30	per property per additional acre of "nearest" wetland (present value)	Mahan, Polasky, Adams (2000), Portland, Oregon
Willingness to pay, voter approval of park bond	$58	per house per year for five years	Vossler et al. (2003), Corvallis, Oregon
Recreation value	$4	per unit day of recreation	Tetra Tech (no date)
Willingness to pay, contingent valuation	$80 - $313	per wetland acre for recreation (present value)	Costanza, et al. (1998), Louisiana

Sources: As listed, with calculations by ECONorthwest

Table 4: Values of Wildlife & Fish Habitat

Impact of Project	Economic Value (2002$)	Description	Source
Improved fish habitat	$3.50	Willingness to pay for an additional fish caught on the Willamette and Clackamas rivers	Berrens, Bergland, Adams (1993), Portland, Oregon
Improved avian habitat	$403	Per acre per year value of wetland for avian habitat	Woodward & Wui (2001) meta-analysis, nationwide
Improve Salmon Habitat	$3.05	WTP per month by Oregonians to improve water quality and habitat in order to help improve salmon runs in Oregon.	Helvoigt & Montgomery (2003 unpublished draft)

Sources: As listed, with calculations by ECONorthwest

Table 5: Non-market, Nonuse Values Of Salmon

Valuation Method	Location	Present Value Per Fish (2002$)	Number of Salmon
CV	California	$256,121	14,900
CV	Pacific Northwest & California	$11,808	250,000
CV	Pacific Northwest	$3,665	300,000
CV	Pacific Northwest & California	$1,543	1,000,000
CV	Pacific Northwest	$224	2,500,000

Source: Koteen, Alexander and Loomis (2002), with calculations by ECONorthwest

Table 6: Values of Improved Air Quality

Pollutant	Economic Value (2002$)	Description	Source
CO	$1,279	Avoided cost of removing one ton of CO emissions	CA Energy Comm. (1992)
	$970	Avoided health-care cost per ton of CO	American Forests (2003)
SO2	$2,271	Avoided cost of removing one ton of SO2 emissions	CA Energy Comm. (1992)
	$7,800	Avoided health-care cost per ton of SO2	U.S. OMB (2003)
	$1,653	Avoided health-care cost per ton of SO2	American Forests (2003)
NO2/NOX	$6,133	Avoided cost of removing one ton of NO2/NOX emissions	CA Energy Comm. (1992)
	$1,114	Avoided health-care cost per ton of NO2/NOX [Lower Bound]	U.S. OMB (2003)
	$5,572	Avoided health-care cost per ton of NO2/NOX [Upper Bound]	
PM10	$1,817	Avoided cost of removing one ton of PM10 emissions	CA Energy Comm. (1992)
	$4,519	Avoided health-care cost per tone of PM10.	American Forests (2003)
O3/VOC	$681	Avoided cost of removing one ton of O3/VOC emissions	CA Energy Comm. (1992)
	$608	Avoided health-care cost per tone of VOC [Lower Bound]	U.S. OMB (2003)
	$2,735	Avoided health-care cost per tone of VOC [Upper Bound]	
	$6,768	Avoided health-care cost per ton of VOC	American Forests (2003)

Sources: As listed, with calculations by ECONorthwest

Annotated Bibliography

References Cited in the Lents Project Case Study

American Forests. 2003. "CITYgreen Model 5.0. Washington, D.C. www.americanforests.org.

American Forests developed a model that calculates the type and volume of air pollutants removed per unit of tree cover for airsheds in urban areas across the US. The model, CITYgreen 5.0, also calculates the avoided health-care costs associated with the removed pollutants.

The CITYgreen model uses ArcView, a GIS software, to map data on tree type, age, and percent canopy cover. It combines this information with data reported by government agencies and university studies that describe the amount of pollutants absorbed by age and type of tree. The final component of the model calculates the value of removing pollutants from the airshed based on the avoided health-care costs of treating respiratory-related diseases. The model calculates avoided health-care costs per ton of pollutant removed.

Berrens, R., O. Bergland, and R. M. Adams. 1993. "Valuation Issues in an Urban Recreational Fishery: Spring Chinook Salmon in Portland, Oregon." ***Journal of Leisure Research*** **25 (1): 70-83.**

The objectives of this Contingent Valuation study were (1) to test for the effects of congestion on the demand for recreational fishing in an urban setting, and (2) to determine willingness to pay for increases in fish numbers and the marginal value per fish. The study focused on the demand for recreational fishing for spring Chinook salmon on the Willamette and Clackamas Rivers in the greater Portland, Oregon area.

Bolitzer, B. and N.R. Netusil. 2000. "The Impact of Open Spaces on Property Values in Portland, Oregon." ***Journal of Environmental Management.*** **59: 185-193.**

In this study, the impact of open-space proximity and type is examined with a hedonic analysis using a data set that includes the sale price for homes in Portland, Oregon, GIS-derived data on each home's proximity to an open-space, open-space type, and neighborhood and home characteristics. Results show that proximity to an open-space and open-space type can have a statistically significant effect on a home's sale price.

California Energy Commission. 1992. *1992 Electricity Report, Air Quality*. **Sacramento, CA: California Energy Commission.**

This study analyzes air-quality issues associated with electricity production in California. The study calculated the costs of emission control for five pollutants, CO, O3, SO2, PM10, and NO2. The researchers report cost savings per-ton of pollutant prevented.

Costanza, R., S.C. Farber and J. Maxwell. 1989. "Valuation and Management of Wetland Ecosystems." *Ecological Economics*. 1: 335-361.

This study calculated the value of an acre of coastal wetland in Louisiana. The estimated total value has four parts attributed to commercial fishing, commercial trapping, recreation, and storm prevention. Researchers calculated the value of commercial fishing and trapping based on the harvest value per acre of wetland. Recreation values were calculated using the results from a travel cost model based on a 1984-85 survey of Louisiana wetlands users. The survey calculated the WTP to preserve wetlands for recreational purposes in Terrebonne Parish, Louisiana using both travel-cost and contingent-valuation methods. The storm-protection value reflects the predicted increase in damages associated with a reduction in the area of wetland buffers between urbanized areas and the coast.

Farber, S. 1996. "Welfare Loss of Wetlands Disintegration: A Louisiana Study." *Contemporary Economic Policy*. 14(January): 92-106.

This study calculated the value of projects designed to stop degradation of Louisiana coastal wetlands. Researchers calculated the value of these projects as the present-discounted value of the future stream of benefits that would be lost due to wetland degradation. The loss of critical wetlands functions means that economic processes dependent on those functions, such as commercial fishing or recreation, will no longer be possible or will require costly substitutes. The author calculated the values associated with commercial harvests of species that depend on coastal wetlands, recreation, storm protection, water treatment, and aquifer recharge.

The value of commercial harvests was based on the value of existing harvests and estimated increases in the future productivity of coastal wetlands.

The recreational value was based on the calculated willingness-to-pay for recreation and the population of the study area. The willingness-to-pay values were derived form a 1986 Army Corps of Engineers study of recreational use.

The value of avoided flood damage provided by wetlands included information on the current value of residential and commercial properties, and the cost of alternative storm protection such as constructing levees.

The authors calculated the value of water treatment provided by coastal wetlands based on the average cost savings for communities that rely on a system that combines engineered water treatment with coastal wetlands, compared with communities that relied exclusively on engineered or constructed water-treatment facilities.

The value of aquifer recharge losses equals the cost of replacing groundwater sources with the nearest surface water supply. The author calculated these values based on construction and operating costs of water pipelines.

Federal Emergency Management Agency (FEMA). 2003. FEMA Benefit-Cost Analysis Workshop. Federal Emergency Management Agency.

The FEMA manual describes how to identify and calculate economic benefits of flood-mitigation projects. FEMA defines flood-mitigation benefits as the estimated value of property and other damage avoided because of a proposed mitigation project. Local and state agencies use this information in their applications for FEMA-supported flood-mitigation grants.

The manual begins with a general description of flood-mitigation benefits and methods of calculating benefits. Individual sections of the manual address benefits specific to:

Residential, commercial, and public buildings

Critical fire, police and medical buildings

Utilities including electric power, water and wastewater

Roads and bridges.

Helvoigt, T. and C.A. Montgomery. 2003. Trends in Oregonians' Willingness to Pay for Salmon. Oregon State University, Working Paper.

The research conducted by the authors address the questions, "How important is salmon recovery to the people of Oregon and how much are they willing to pay for it?" They rely on data collected through the Oregon Population Survey from 1996 through 2002. The Survey is a biennial phone survey that measures and tracks changes in the socioeconomic characteristics of Oregonians and solicits opinions on a variety of policy issues.

The authors analyzed the survey responses for trends in attitudes of the Oregon population about salmon recovery. They also analyzed how the changing attitudes about salmon relate to changes in the state's economy and the socio-demographic make-up of the state.

Koteen, J., S.J. Alexander, and J.B. Loomis. 2002. Evaluating Benefits and Costs of Changes in Water Quality. U.S. Department of Agriculture, Forest Service. PNW-GTR-548. Portland, Oregon. July.

This report examines six water-quality parameters and their influence on water uses. The water-quality parameters are clarity, quantity, salinity, total suspended solids, temperature, and dissolved oxygen. The authors evaluate changes in these parameters and the related changes in value for municipal, agricultural, recreational, industrial, hydropower, and nonmarket uses of water. The authors analyzed changes in consumer surplus for particular activities and calculated the mean values of changes in water quality and the impact that this change in value has on water use. The authors show the nonmarket, nonuse value of salmon given changes in water quality in the Pacific Northwest and California.

Lutzenhiser, M. and N.R. Netusil. 2001. "The Effect of Open Spaces on a Home's Sale Price." *Contemporary Economic Policy*. 19(3): 291-298.

This article describes the impact on a home's sale price from proximity to different types of open space. The authors conducted a hedonic analysis using a data set comprised of single-family home sales in the city of Portland, Oregon between 1990 and 1992. Homes located within 1,500 feet of a natural-area park, where more than 50% of the park is preserved in native and/or natural vegetation, are found to experience, on average, the largest increase in sale price. The open space size that maximizes a home's sale price is calculated for each open space type. Natural-area parks require the largest acreage to maximize sale price, and specialty parks are found to have the largest potential effect on a home's sale price. A zonal approach is used to examine the relationship between a home's sale price and its distance to an open space. Natural area parks and specialty parks are found to have a positive and statistically significant effect on a home's sale price for each zone studied. Homes located adjacent to golf courses are estimated to experience the largest increase in sale price due to open space proximity, although the effect drops off quickly as distance from the golf course increases.

Mahan, B.L., S. Polasky, and R. Adams. 2000. "Valuing Urban Wetlands: A Property Price Approach." *Land Economics*. 76(1): 100-113.

This study calculated the value of wetland amenities in the Portland, Oregon metropolitan area using the hedonic property-price model. The analysis considered housing and wetland data including the sales price of a property, structural characteristics, neighborhood attributes, and amenities of wetlands and other environmental characteristics. The analysis also included distance to and size of four different wetland types: open water, emergent vegetation, scrub-shrub, and forested. Other environmental variables include proximity to parks, lakes, streams, and rivers. Results indicate that wetlands influence the value of residential property and that wetlands influence property values differently than other amenities. Increasing the size of the nearest wetland to a residence by one acre increased the residence's value by $24. Similarly, reducing the distance to the nearest wetland by 1,000 feet increased the value by $436.

Tetra Tech. No date. An analysis of the recreational benefits of upgrading Westmoreland Park. A report to the City of Portland.

Tetra Tech calculated the value of recreational benefits of upgrading Westmoreland Park using the unit-day method. This method begins with a standard value per unit-day of recreation as described by the US Army Corps of Engineers. Tetra Tech adjusted the standard value based on local considerations for Westmoreland Park of:

- Recreational experience
- Availability of recreational opportunity
- Carrying capacity of the park
- Accessibility
- Environmental amenities.

They then multiplied the adjusted value per unit day of recreation by the projected visitation to the park with and without the upgrades. The difference represents the estimated recreational value of the upgrade.

Thibodeau, F.R. and B.D. Ostro. 1981. "An Economic Analysis of Wetland Protection. "*Journal of Environmental Management*. 12: 19-30.

The authors calculated the economic benefits of wetlands in the Charles River Basin in Massachusetts. The benefits provided by wetlands include flood control, increases in nearby land value, pollution reduction, water supply, recreation and aesthetics, preservation and research, vicarious consumption and option demand, and undiscovered benefits. The authors calculated values for the first five benefits. They described the other benefits, but do not measure them.

Researchers calculated the value of flood-control functions based on the cost of property damage that would occur if the wetlands were filled. The authors used data from the US Army Corps of Engineers that predicted the annual monetary loss at various reductions in wetland storage capacity. The authors calculated the value of pollution prevention using data on construction costs of tertiary treatment facilities from the EPA and the volume of nutrients removed by wetlands, as calculated by the consulting firm Interdisciplinary Environmental Planning. For the value of the water supply provided by the wetlands, the authors relied on previous studies that calculated the average cost of obtaining well water and the difference between the cost of wetland wells and the cost of providing water from the next best source. The authors relied on data from the U.S. Fish and Wildlife Service that describes the amount of recreational activity in the wetlands and the costs and benefits per person, per year associated with wildlife-related recreation.

U.S. Office of Management and Budget, Office of Information and Regulatory Affairs. 2003. *Informing Regulatory Decisions: 2003 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities*.

The Office of Management and Budget (OMB) reviewed major federal rulemakings from the previous ten years and calculated the costs and benefits of these rules on state and local entities. OMB presented costs and benefits using a uniform format so that estimates from different agencies are comparable. OMB monetized quantitative estimates where the reporting agency had not done so. For example, converting agency projections of quantified benefits, such as, estimated injuries avoided per year, to dollars. The report lists the benefits of improved air quality per ton of air pollutant removed.

Vossler, C.A., J. Kerkvliet, S. Polasky, and O. Gainutdinova. 2003. "Externally Validating Contingent Valuation: an Open-Space Survey and Referendum in Corvallis, Oregon." *Journal of Economic Behavior and Organization*. 51: 261-277.

The authors compared the results of a CV survey with an actual referendum that would have increased property taxes to pay for open space. The authors studied whether respondents report the same decisions in non-binding surveys as they do in real elections. They studied a 1995 Corvallis, Oregon referendum on a $5 million bond issue to purchase open space.

The researchers conducted over 500 telephone interviews of Corvallis residents as close as possible prior to the date when mail-in ballots were returned so that no respondent had already voted, but the time between the survey and voting was minimized. For half the surveys, the researchers asked the open space question exactly as it appeared on the ballot, and if the respondent would vote "yes" or "no" on the measure. For the other half of the surveys, the researchers provided a brief description of the projected cost of the proposal prior to asking the ballot question itself.

They compared survey-based mean willingness to pay estimates with election-based estimates. Household WTP average $48.89 using election results, while survey-based WTP averages $75.43 excluding "undecided responses", and $49.67 treating "undecided responses" as "no". (All dollar figures are U.S. dollars.)

Woodward Clyde. No date. "Flood Damage Cost Estimate for Johnson Creed Flood Event February 4-10, 1996. A report to the City of Portland.

Woodward Clyde estimated damage along eight reaches of Johnson Creek caused by the February, 1996 flood. They interviewed residents and businesses along Johnson Creek regarding flood-related damage and interviewed City staff about emergency-related expenditures. They also contacted US West Communications and Portland General Electric for information on damages or costs attributable to the flood. They calculated damages to:

Residential, commercial and industrial properties

Parks

Roads and bridges

Utilities and emergency services.

Woodward, R.T. and Y.S. Wui. 2001. "The Economic Value of Wetland Services: A Meta-Analysis." *Ecological Economics*. 37: 257-270.

This paper assesses whether any systematic trends can be distilled from previous wetland valuation studies, and to shed light on what factors determine a wetland's value. The authors evaluate the relative value of different wetland services, the sources of bias in wetland valuation and the returns to scale exhibited in wetland values.

After reviewing 46 studies, data from 39 wetland valuation studies were identified that had sufficient commonalties to allow inter-study comparisons. The authors used two techniques to describe the valuation function, both of which are meta-analysis. The first method uses bivariate graphical and standard techniques. This provides an indication of the extent to which particular characteristics influence wetland values while also portraying the full distribution of the data. The second technique uses a standard multivariate regression of wetland values on the characteristics of both the wetlands and the studies. The independent variables are the characteristics of each study and study site.