CITY OF PORTLAND
ENVIRONMENTAL SERVICES
1120 SW Fifth Avenue, Room 1000, Portland, Oregon 97204 ▪ Nick Fish, Commissioner ▪ Michael Jordan, Director

August 31, 2016

Mr. Mark Hynson
Water Quality Specialist
Oregon Department of Environmental Quality
Water Quality Program, NW Region
700 NE Multnomah Street, Suite 600
Portland, Oregon 97232-4100

Subject: **Annual CSO and CMOM Report, FY 2016**
Columbia Boulevard Wastewater Treatment Plant NPDES Permit #101505

Dear Mr. Hynson:

Enclosed, please find two copies of the *Annual CSO and CMOM Report, FY 2016*, submitted as required in the NPDES Permit for the Columbia Boulevard Wastewater Treatment Plant. This annual report provides a comprehensive review of Portland's integrated CSO system and CMOM Program for fiscal year 2016 and addresses the material outlined in section 12.4 of the *Nine Minimum Controls Update Report*, December 2010.

If you have questions regarding this year's report, please do not hesitate to call me at (503) 823-9803.

Sincerely,

Matthew Criblez
Environmental Compliance Manager

Enclosures (Annual CSO and CMOM Report, FY 2016)

CITY OF PORTLAND | BUREAU OF ENVIRONMENTAL SERVICES

Annual CSO and CMOM Report FY 2016

REQUIRED BY NPDES PERMIT #101505

ENVIRONMENTAL SERVICES
CITY OF PORTLAND
working for clean rivers

Nick Fish, Commissioner

Michael Jordan, Director

Annual CSO and CMOM Report FY 2016

Required by NPDES Permit #101505
for CBWTP and CSO Systems

September 2016

City of Portland
Bureau of Environmental Services

REGISTERED PROFESSIONAL ENGINEER
51420PE
OREGON
July 21, 1998
ARNEL M. MANDILAG
EXPIRES: 12-31-2016

Contents

Tables

Figures

Acknowledgements

Asset Systems Management, CSO Technical Team

Issac Gardner
Arnel Mandilag
Nick McCullar
Mike Szwaya

CBWTP Operations

Mike Ciolli

Maintenance Engineering

Gary Irwin
Mary King

FOG Program

Ali Dirks
John Holtrop

Support

Dan Ashney
Gayle Bast
Amber Clayton
Alice Coker
Ivy Dunlap
Joe Dvorak
Michael Hauser
Deza Irving
Tim Kurtz
Jason Law
Gail Luthy
Linc Mann
Yarrow Murphy
Nishant Parulekar
Kevin Ramey
Josh Robben
Grant Wright

Senior Review

Steve Behrndt
Jennifer Belknap Williamson
Jan Betz
Matthew Criblez
Marveita Redding
Bill Ryan

Glossary

BOD. Biochemical Oxygen Demand

CBWTP. Columbia Boulevard Wastewater Treatment Plant

CCTV. Closed-circuit Television

CEPT. Chemically Enhanced Primary Treatment

CIP. Capital Improvement Project (or Program)

CMMS. Computerized Maintenance Management System

CMOM. Capacity, Management, Operations, and Maintenance

COOP. Continuity of Operations Plan

CSCC. Columbia Slough Consolidation Conduit

CSO. Combined Sewer Overflow, especially as it pertains to discharge events. Note that during the CSO Program's implementation, "CSO's" were being captured into the new facilities such as the Willamette CSO Tunnels and the CSCC. Technically, CSOs are no longer being "captured" after the implementation completed—rather, the water that used to produce those events is now controlled within the augmented combined sewer system, and the term *CSO* is limited once again to discharges from the combined system to receiving waters.

CSS. Combined Sewer System

DEQ. Oregon's Department of Environmental Quality

DO. Dissolved Oxygen

EPA. Environmental Protection Agency

EMC. Event Mean Concentration

EWWPT. Enhanced Wet Weather Primary Treatment

FM. Force Main

FOG. Fats, Oils, and Grease

FY. Fiscal Year (FY 2016 is July 1, 2015, through June 30, 2016)

IPS. Influent Pump Station (pumps water from the Columbia Slough Consolidation Conduit to the CBWTP)

MAO. Mutual Agreement and Order

MGD. Million Gallons per Day

NFAA. No Feasible Alternative Analysis

NMC. Nine Minimum Controls

NPDES. National Pollution Discharge Elimination System

RDII. Rainfall Derived (also, Dependent) Infiltration and Inflow

SICSO. Swan Island CSO; used to refer to the pump station pumping water stored by the Willamette River's West Side and East Side CSO Tunnels.

SPCR. Spill Protection and Citizens' Response

SRRP. Sewer Release Response Plan

SSO. Sanitary Sewer Overflow

TCWTP. Tryon Creek Wastewater Treatment Plant

TSS. Total Suspended Solids

WWTF. Wet Weather Treatment Facility

Section 1 Introduction

The Annual CSO and CMOM Report for fiscal year 2016 (FY 2016: July 1, 2015, through June 30, 2016) provides a comprehensive review of Portland's integrated combined sewer overflow (CSO) system and the Capacity, Management, Operation, and Maintenance (CMOM) Program during FY 2016. This report provides updates to the previous report submitted for FY 2015.

1.1 Changes from FY 2015 Report

For FY 2016, this report presents a focused format to concentrate on the changes and events pertinent to operations and activities during the fiscal year only. For general information on the programs presented and the regulatory background of this update, please consult the Annual CSO and CMOM Report for FY 2015 or FY 2014. Below is a summary of changes made to the format for the FY 2016 report compared to FY 2015.

- The prior section titled *CSO Events and System Performance* is now combined with information from Sections 6 *Maximization of Flow to the POTW* and 8 *CSO System and Water Quality Monitoring*.
- Elimination of Section 7 *Update of the Public Notification Program*, as there were no changes from previous fiscal years.
- Section 9 *System Reinvestment and Risk Reduction* has been renumbered to Section 6.
- The CSO Event History formerly found in Section 2.3 can now be found in Appendix A.

1.2 Programs

CSO Program. The City of Portland completed its CSO long-term control plan implementation in 2011. The City is currently proceeding with implementing its *Post-2011 Combined Sewer Overflow Facilities Plan*, published in 2010. This plan looks at ways to cost-effectively exceed the level of control specified in the 1994 Amended Stipulation and Final Order agreement with Oregon's Environmental Quality Control Commission. This additional work is necessary to handle the pressure on the combined sewer system (CSS) facilities' capabilities to control CSOs due to increased population and development.

The City completed a Monitoring and Analysis Program and submitted a report to the Oregon Department of Environment Quality (DEQ) in December 2015, as required by the Mutual Agreement and Order (MAO) WQ/M-NWR-11-073, Section 10.(4). This report was further amended in July 2016, as recommended by DEQ, to account for the wet FY 2016. This report provides information on the quality of effluent from the CBWTP, effectiveness of the Secondary Process Improvements and Chemically Enhanced Primary Treatment (CEPT) Projects, and the magnitude of sanitary area flows for consideration in an update to the CBWTP Facilities Plan, expected in December 2016 as required by the MAO.

CMOM Program. Over several years, the City of Portland has implemented a CMOM program to reduce the likelihood of sewer releases by improving the overall reliability of the sanitary and combined sewer collection systems. The *CMOM Program Report* that was submitted to DEQ on June 28, 2013, explains BES's strategies and activities for the development, reinvestment, operation, and maintenance of the system. The report was developed to comply with Condition 3.b.(1)(B) of Schedule A of the CBWTP NPDES permit.

The CMOM program specifically addresses proper operation and regular maintenance of the collection system (NMC #1). The City's wastewater collection system includes main lines, trunk lines, interceptors, pump stations, and force mains. The City is generally responsible for service laterals from the sewer main up to the curb line, while the building or private sewer laterals extending behind the curb are the responsibility of the property owner. Portland's sewer collection system consists of a network of 2,584 miles of collection system piping (1,003 miles of sanitary sewer including force mains, 911 miles of combined sewer, and 670 miles of sewer laterals) and 40,682 sewer manholes. The system also includes two wastewater treatment plants and 100 pump stations, including one new pump station brought into operation during FY 2016. There are 83 City-owned and operated pump stations, 6 pump stations owned by other public agencies that are operated and maintained by the City under satellite or easement agreements, and 11 privately-owned septic tank effluent pumping systems that are maintained by the City under agreements with the property owners.

This annual update for FY 2016 provides a review of CMOM program actions and key performance indicators, and an evaluation of the effectiveness of BES's risk-based asset management approach to collection system operation and maintenance.

1.3 Summary of CSO and CMOM Performance

1.3.1 CSO Program Achievements

FY 2016 was an extraordinarily wet year, with an average of about 53.4 inches (varying from 46 to 58 inches depending on location) falling over the combined service area. Normally, only 37-40 inches falls in any given year. Even with this amount of rain, only 5 CSOs were recorded, and all met or exceeded the permit's minimum requirements for storm return periods.

There were no significant exceedances in effluent concentrations at the CBWTP effluent outfalls. Maximum 30-day concentrations at the CBWTP effluent outfalls were 21 mg/L for biochemical oxygen demand (BOD) and 27 mg/L for total suspended solids (TSS); 30 mg/L is the permitted maximum. Peak 7-day concentrations at the same point were 23 mg/L for BOD and 31 mg/L for TSS (45 mg/L is the permitted maximum).

This fiscal year, relative to when the system became fully operational in December 2011, included some notable records and firsts during the December 5-13, 2015 event:

- The highest amount of flow delivered to CBWTP for treatment was recorded with a 1-hour peak flow of 463 million gallons per day (MGD), and instantaneous peaks of 476 MGD. (The CBWTP has been able to achieve a 1-hour peak hydraulic capacity of 450 MGD.)
- An overflow was delivered for the first time from areas at the extremities of the combined collection system, served by Sellwood OF27 and Linnton OF24. The rarity and widespread nature of the event that caused these unusual overflows was an indication of the high level of control at these areas. This event also led to a very short overflow through Kenton OF60, the first time the Columbia Slough Consolidation Conduit (CSCC) overflowed due to wet weather since it began operation in 2000. Again, the rarity of the event and the fact that this was the first time that a wet weather event caused an overflow through the CSCC indicates the high level of control at the Columbia Slough.
- Cleaning crews maintained a floatables control site other than Sheridan OF07B for the first time, due to an overflow at Sellwood OF27. Floatables were noted to be similar in composition and volume to those at another floatables control structure at Sheridan OF07B.
- The largest CSO discharged by the system was recorded at approximately 639 million gallons (MG).

The Wet Weather Treatment Facility (WWTF) with CEPT continues to operate well, having achieved 66% biochemical oxygen demand (BOD) removal and 80% total suspended solids (TSS) removal in the wet weather flow stream. Combined removal for all plant flows during wet weather events are 84% for BOD and 86% for TSS. Combined removal for all plant flows at all times are 93% for BOD and 92% for TSS.

The CBWTP received the highest volume to date of flow captured by the Willamette and Columbia Slough storage facilities (termed in previous reports as “Captured CSO”) at 10.5 billion gallons. The operators managed the integrated collection system to treat 58% of this volume through the secondary system, with 42% treated through the WWTF. There were 39 events in which flows were sent through the WWTF. The average WWTF event lasted 32 hours and discharged 112 million gallons from the WWTF. During the events, the average flow rate treated by the dry weather/secondary system was 117 MGD, exceeding the 110 MGD minimum required in the NPDES permit.

1.3.2 CMOM Program Achievements

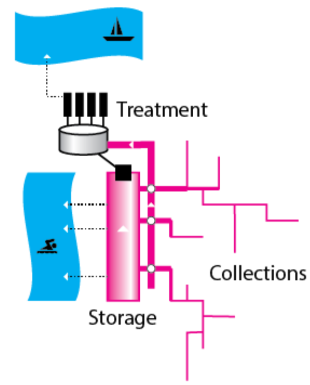
Portland's CMOM program has been designed to ensure that components of the collection system are cleaned and inspected at the right frequency and that preventive maintenance and repairs are performed to cost-effectively reduce the number of sewer releases, extend the useful life of the City's sewer infrastructure, and properly manage collection system operations. CMOM program accomplishments in FY 2016 include:

- Inspected 0.84 million feet of sewer pipe, or about 8% of the mainline sewer system
- Cleaned 1.74 million feet of sewer pipe, or about 17% of the mainline sewer system
- Completed mainline sewer repairs on 12,000 feet of pipe; 66% of the projects were in response to collection system problems
- Repaired 556 service laterals totaling about 8,300 feet of pipe; 76% of those repairs were in response to discovered problems
- Treated 253,000 feet of pipe for roots using chemical root foaming
- Completed 814 inspections of manholes considered to be at greatest risk of failure (Tier 2). No significant defects were found during these inspections.

The number of sewer releases from the City-maintained sanitary and combined sewers continued to decrease. The number of sewer releases per 100 miles of sewer was 5.2 in FY 2016, approaching BES's target of 5.0. This accomplishment is noteworthy compared to other jurisdictions with combined sewer systems of similar age and size because the City of Portland is typically responsible for sewer laterals from the main sewer to the curb, rather than just the main sewers.

Sewer emergency response crews arrived on site within the City's 2-hour response time target during all months except October and December, when response time was affected by the large number of calls associated with the severe storms on October 31 and December 7, 2015.

Section 2 Integrated CSO System Performance for FY 2016



The integrated CSO system consists of the combined sewer collection system; the CSO collection, storage, and pumping system; and the CBWTP treatment system. This section reports on the performance of the overall integrated CSO system during FY 2016.

2.1 Rainfall Patterns for the Past Fiscal Year

FY 2016 was a high rainfall year for the City of Portland. The area weighted average rainfall measured 53.4 inches over the year, compared with an annual average rainfall of 37 inches for Portland. This is 44% greater than the yearly average rainfall for the city.

During this period, three winter storms events exceeded the 4-per-winter design storms, generating CSO discharges. Two summer storms exceeded the 3-year summer storms, also generating CSO discharges.

- October 30-November 2, 2015 – Summer CSO event
- November 16-17, 2015 – Winter CSO event
- December 5-13, 2015 – Winter CSO event
- December 16-19, 2015 – Winter CSO event
- May 19, 2016 – Summer CSO event

Four other storms were large enough to have exceeded minimum storm return interval requirements for permitted CSOs. CSOs were avoided for the following events

- November 18-19, 2015 – Winter storm event
- December 1-4, 2015 – Winter storm event
- December 20-21, 2015 – Winter storm event
- January 11-14, 2016 – Winter storm event

2.1.1 Winter Storm Review

The three storms that caused CSO and exceeded the 4-per-winter NPDES Permit design depths are shown graphically in Figure 1 below. This graph is a "Depth-Duration" chart that displays the maximum depth of rainfall that occurred for the range of storm duration, from 1-hour to 48-hours. The three events that caused CSO to occur are shown with red toned lines. The three CSO events are compared to the two NPDES Winter Design Storms (4-per-winter for the Willamette River and 5-year winter for the Columbia Slough) shown with blue-tinted lines.

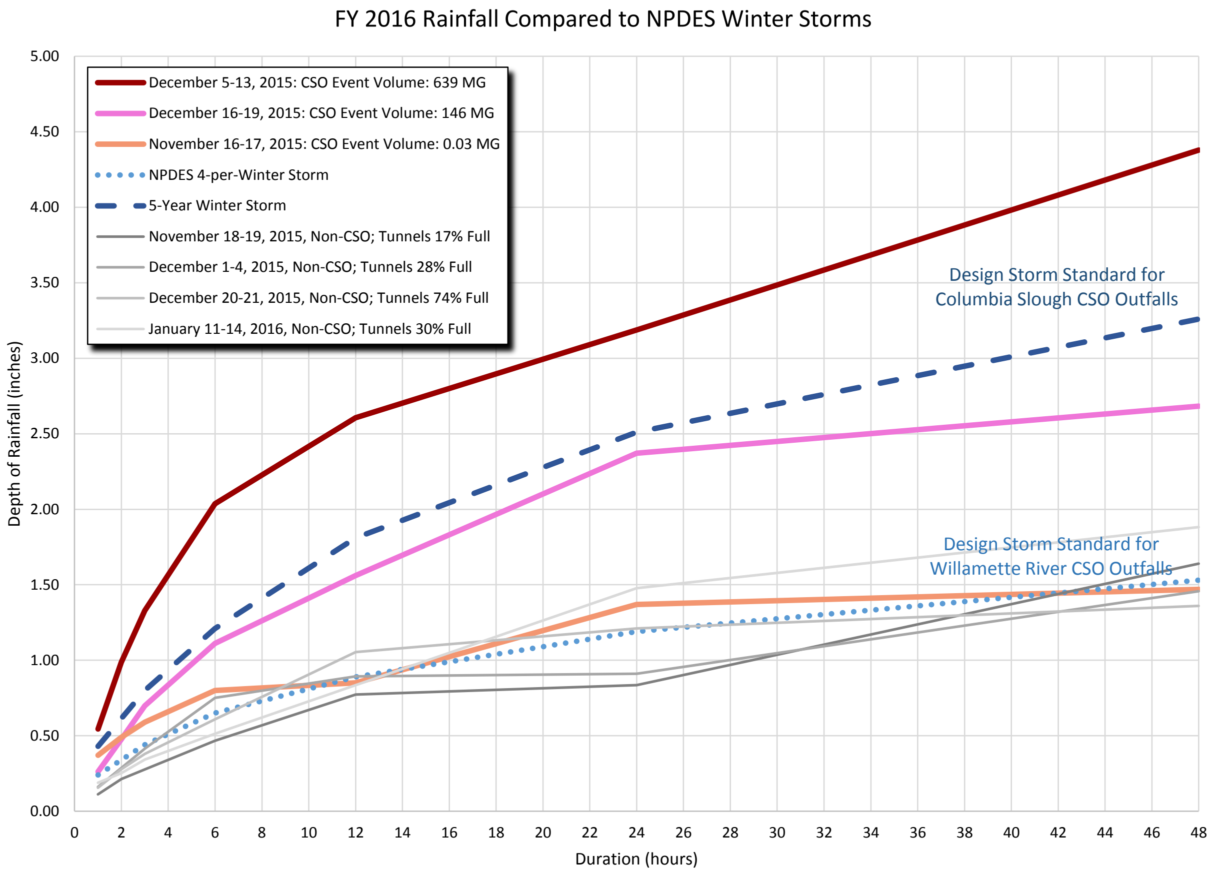


Figure 1 FY 2016 CSO Winter Storms Compared to NPDES Winter Storms

Details for the rainfall for the winter overflow events are provided in Table 1 below.

Table 1 FY 2016 Winter Storm Comparisons

Storm	Duration (hours)						Notes
	1	3	6	12	24	48	
Willamette River Winter Design Storms (inches)							
4-per-Winter Design Storm	0.24	0.44	0.65	0.89	1.19	1.53	
5 Year Winter Design Storm	0.43	0.8	1.21	1.81	2.51	3.26	
Historical Storms - Average Rainfall over Willamette CSO Basin (inches)							
November 16-17, 2015	0.37	0.44	0.8	0.85	1.37	1.47	Exceeds 4-per-Winter Design Storm 1-6 hours and 24 hours.
December 5-13, 2015	0.54	1.33	2.04	2.61	3.19	4.38	Exceeds 5 Year Winter Storm 1-48 hours.
December 16-19, 2015	0.26	0.7	1.11	1.56	2.37	2.68	Exceeds 4-per-Winter Design Storm 1-48 hours.

2.1.2 Summer Storms Review

Two storms exceeded the NPDES Permit 3-year Summer Storm. The October 30-November 2, 2015, storm is shown graphically in Figure 2 below. This graph is a “Depth-Duration” chart that displays the maximum depth of rainfall that occurred for the range of storm duration, from 1-hour to 48-hours. The event is shown with a red line. The two comparison Summer Design Storms (3-year summer for the Willamette River and 10-year summer for the Columbia Slough) are shown with blue-tinted lines. Table 2 provides rainfall details for this event. This storm was a classic atmospheric river winter storm that happened to start at the end of the summer season.

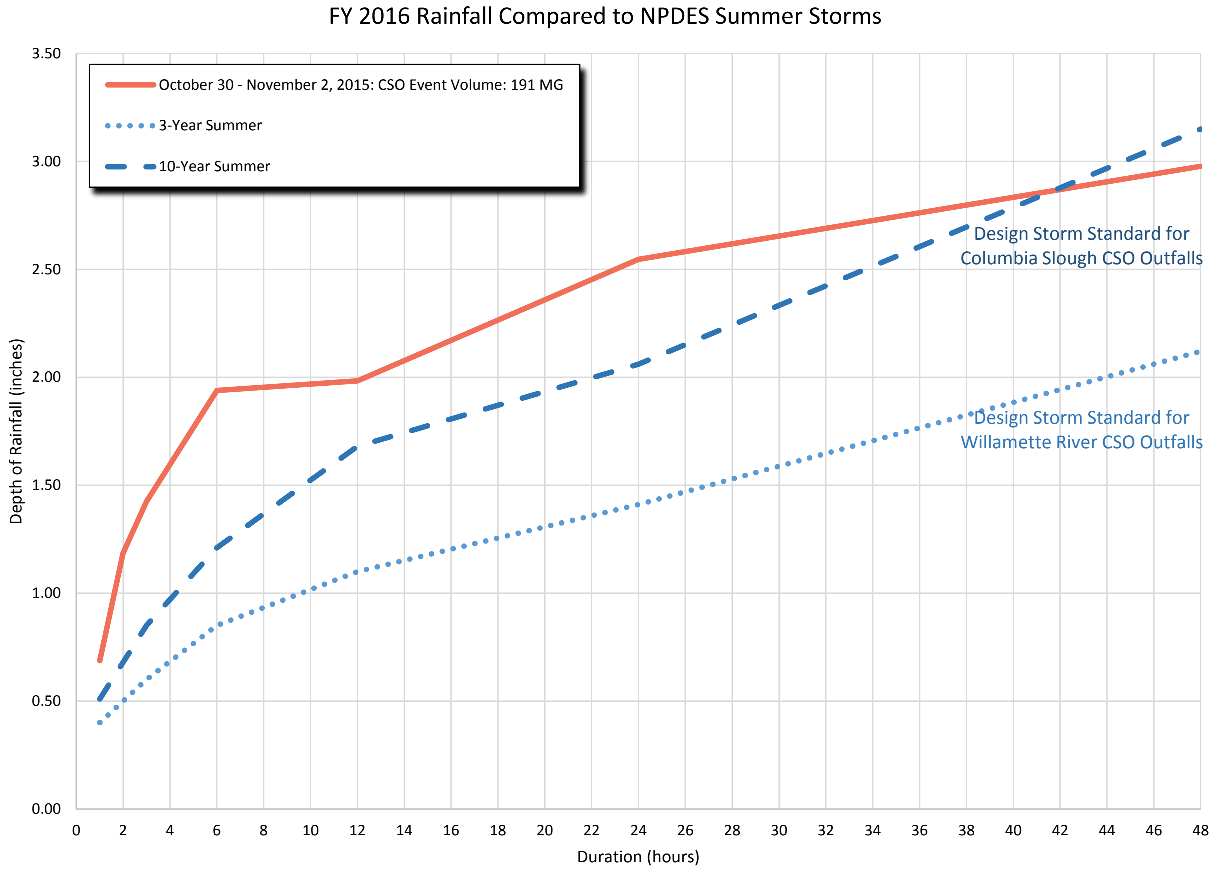


Figure 2 FY 2016 Rainfall Compared to NPDES Summer Storms

Table 2 FY 2016 Summer Storm Comparisons

Storm	Duration (hours)						Notes
	1	3	6	12	24	48	
Willamette River Summer Design Storms (inches)							
3-Year Summer	0.4	0.6	0.85	1.1	1.41	2.12	
10-Year Summer	0.51	0.85	1.21	1.68	2.06	3.15	
Historical Storms - Average Rainfall over Willamette CSO Basin (inches)							
October 30 - November 2, 2015	0.69	1.42	1.94	1.98	2.55	2.98	Exceeds 3 Year Winter Storm 1-24 hours, Exceeds 10-Year Summer Storm 48 hours.

The May 19, 2016, storm is a special case. This was a highly focused thunderstorm with intense rainfall in the east-central portion of the city. In this area, Alder Pump Station received flow levels that required activation of its storm pumps. The storm itself was much shorter than most storms that cause Willamette systemwide CSOs, and examining the effectiveness of the system requires a much shorter time scale than shown in Figure 1 and Figure 2.

May 19, 2016 storm is shown graphically in Figure 3 below. This graph displays the maximum depth of rainfall that occurred for the range of storm duration, from 5-minutes to 30-minutes. The event is shown with a red line. The two comparison Summer Design Storms (City-wide 3-year summer and SE Portland 3-year summer) are shown with blue-tinted lines. Table 3 provides rainfall details for this event.

The Alder Pump Station is currently under construction to increase local basin capacity significantly.

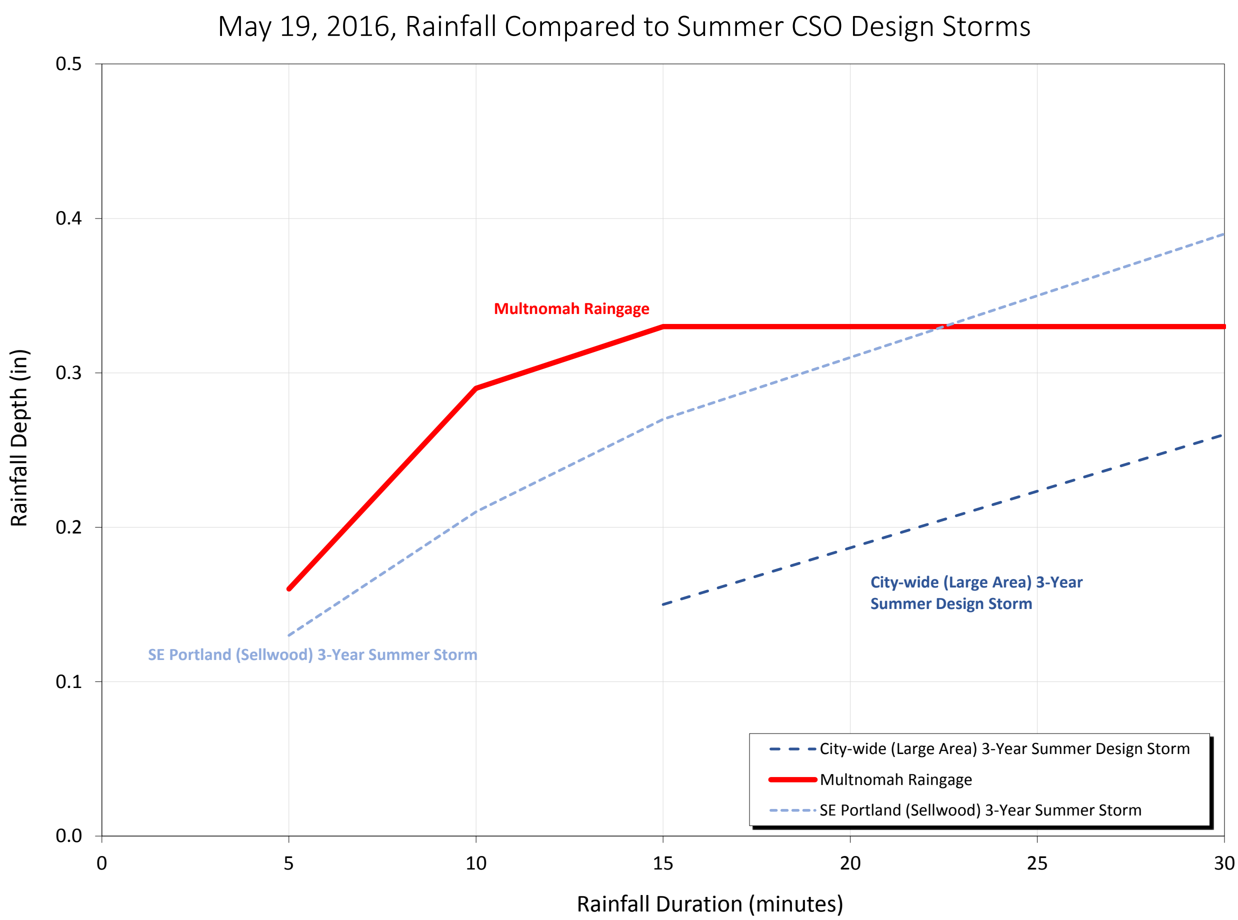


Figure 3 FY 2016 Rainfall for Events Less Than One Hour, Compared to NPDES Summer Storms

Table 3 FY 2016 Summer Storm Comparisons for Events Less Than One Hour

Storm	Duration (minutes)				Notes
	5	10	15	30	
Willamette River Summer Design Storms (inches)					
3-Year Summer			0.15	0.26	
SE Portland (Sellwood) 3-Year Summer	0.13	0.21	0.27	0.39	
Historical Storms - Average Rainfall over Willamette CSO Basin (inches)					
May 19, 2015	0.16	0.29	0.33	0.33	Exceeds SE Portland 3-Year Winter Storm 5-15 minutes, Exceeds 3-Year Summer Storm 30 minutes.

2.2 CSO Discharges into the Willamette River and Columbia Slough

2.2.1 Discharge Events

In FY 2016, there were five separate CSO discharge events, with all five contributing discharges to the Willamette River and one contributing a discharge to the Columbia Slough. Please consult the compliance letters submitted to DEQ for details on the circumstances for the events, and for verification of frequency performance standards, as indicated by the current NPDES permit for CBWTP (#101505).

- **October 30 – November 2, 2015.** 190.5 MG discharged over 6.35 hours from the East and West Side Willamette River CSO Tunnels. This storm featured a citywide peak 2-hour intensity of 1.18 inches per hour, which is at 50-year recurrence intervals. Areas around the I-84 corridor experienced 2-3 hour intensities at 100-year recurrence intervals.

- **November 16-17, 2015.** 0.03 MG discharged over 0.17 hours from Alder Pump Station

- **December 5-13, 2015.** 638.7 MG discharged over 15.60 hours from the East and West Side Willamette River CSO Tunnels, as well as from a single outfall from the Columbia Slough Consolidation Conduit (CSCC). This storm featured citywide peak 3-hour and 6-hour intensities slightly rarer than a 25-year recurrence interval. This was the first overflow from the CSCC caused by a rainfall event since the facility began operations in October 2000.

- **December 16-19, 2015.** 145.8 MG discharged over 11.00 hours from the East and West Side Willamette River CSO Tunnels.

- **May 19, 2016.** 0.02 MG discharged over 0.18 hours from Alder Pump Station.

The entire historical record of CSOs discharged from the City's CSS facilities is provided in Appendix A.

2.2.1.1 How Well Were CSO Events Controlled?

Even though system rainfall was about 44% higher than average, the system experienced only five overflows (two in the summer, three in the winter). Total overflow discharge for the year was about 975 MG, which was about 3.1% of the total volume handled by the combined and sanitary collection systems. This equates to 96.9% volume control, exceeding the 94% level of control for which the system was designed.

2.2.1.2 Were Wet Weather Flows Maximized to the Plant?

During the three systemwide CSO events (October 30-November 2, 2015; December 5-13, 2015; and December 16-19, 2015), flows through SICSO PS were maximized to the greatest extent possible, but was limited from the theoretical maximum rates due to the CSO System Operating Plan's higher priorities of protecting the plant, preventing basement sewer backups, and preventing Columbia Slough overflows.

2.2.1.3 Was System Storage Maximized?

Two of the events were due to a local system becoming overwhelmed from local rainfall (November 16-17, 2015, and May 19, 2016). The other three events involved discharges after the tunnels were filled. For all non-CSO -sized storms (less intense than 4-per-winter or 1-per-3 summers), tunnel storage levels did not exceed more than 38% of the tunnel capacity. For the CSO-sized storms that did not overflow, tunnels peaked at 74% of the tunnel capacity. While this is higher than in past fiscal years, this statistic was achieved during the very wet mid-December 2015 period, when the tunnels did not have the best opportunity to be drained in between storms.

The October 30-November 2, 2015, and December 5-13, 2015, events were especially notable for peak levels in the Willamette tunnels reaching an unprecedented elevation of 25 ft. and 27 ft. (at SICSO PS). The overflow elevation at the tunnels are at 18 ft., and water elevations above 23 ft. are considered very rare.

2.2.2 Dry Weather Overflow Events

No dry weather overflow events from the combined system outfalls were recorded in FY 2016.

2.2.3 Control of Floatables and Debris

Cleaning crews removed debris from the OF27 floatables screening control for the first time since it became operational in December 2011. Overflows at OF27 is a rare event and is an indication of the high level of control the City currently has in place at this outfall. The largest storm of the year was enough to cause water levels at the new Sellwood CSO Pump Station to overtop the weir. The composition and quantity of the floatables was similar to that found at the Sheridan bar screen. As indicated in the 2010 Implementation of Nine Minimum Controls Update Report, these screens were intended to be self-cleaning and/or efficiently and easily cleaned by maintenance crews. Even with the large amounts of overflow during these events, the amount of floatables captured at these screens remains relatively low. Table 4 shows the cleaning performed for the three large CSO events in FY 2016.

Table 4 Floatables Control System Event Maintenance Summary

CSO Event Date(s)	Maint. Date	Location	Description of Maintenance
October 30-November 2, 2015	11/2/2015	Sheridan OF07B	Removed 5 gallons of debris consisting of leaves and sticks.
December 5-13, 2015 December 16-19, 2015	2/10/2016	Sheridan OF07B	(Attempted cleaning on 12/22/2015, but river level was too high at the time.) Removed 10 gallons of garbage, leaves, and small sticks from screen.
December 5-13, 2015	12/22/2015	Sellwood OF27	Removed 10-15 gallons of light debris, leaves, and paper

2.3 Wet Weather Treatment Performance and Effluent Quality

2.3.1 CSO Facilities Operations

The CSO System configuration experienced no major changes in FY 2016. However, its newest improvements were put to the test during an unusually wet year in which the system experienced about 45% more rainfall than average. This followed an exceptionally dry year in FY 2015. Influent volumes to CBWTP increased 20% from FY 2015, which reduced the percentage treated by the secondary system (down to 86%) and the percentage of captured CSO treated via secondary (down to 58%). However, overall BOD and TSS removal efficiencies remained stable at the plant's two outfalls, OF001 and OF003 (93% and 92% respectively, same as for FY 2015). This indicates that the plant continues to exhibit the same performance, and the increased inflow was more diluted.

Table 5 shows the total volume pumped from the two major CSO pump stations in the system, Swan Island CSO (draining the Willamette River system) and the Influent Pump Station (draining the Columbia Slough system). About 8,029 MG was pumped, compared with the 10,485 MG total wet weather flow reaching the plant (see Table 6), representing 77% of that wet weather volume. The 2,456 MG (23%) difference represents the wet weather volume reaching CBWTP via gravity, from the combined collection system.

Table 5 FY 2016 Volume Pumped from CSO Tunnels

CSO Tunnel Pumping	Total Pumped Volume (MG)
Swan Island CSO Pump Station	
Forcemain 1 (Peninsular Dry Weather)	3,093
Forcemain 2 (Peninsular Wet Weather)	477
Forcemain 3 (Portsmouth Wet Weather)	2,632
Swan Island CSO Pump Station Subtotal	6,202
Influent Pump Station Total	1,827
Total Volume Pumped to CBWTP from Tunnels	8,029

2.3.2 Wet Weather Treatment Performance for EWWPT Events

2.3.2.1 Annual CSO Treatment Characteristics

Key parameters for the treatment system's annual performance are derived from the NPDES permit for the CBWTP, which specifies annual percent removal efficiencies[1]. These parameters were based on Portland's No Feasible Alternative Analysis (NFAA) report, submitted to DEQ in 2009. Table 6 summarizes the main annual treatment performance measures for the CBWTP systems. This 5 year record provides a comparison of the performance against the average year model and permit values. Key parameters are in blue text. For FY 2016,

- Secondary treatment increased from FY 2015 to 117 MGD, 6% higher than the 110 MGD minimum required by the permit after FY 2014.
- Percent of wet weather flow treated through secondary exceeded the model target level (58% compared to 54%).
- BOD and TSS removal efficiencies for the wet weather system exceeded the permit's annual requirements: BOD removal was 66% compared to the permit's requirement of 50%, and TSS removal was 80% compared to the permit's requirement of 70%.

When evaluating wet weather treatment, BES asks three questions:

- **Were wet weather flows treated to a high quality?** *Yes.* This is according to the observed numbers in comparison with permit requirements. See Section 2.3.2.2.

[1] NPDES Permit #101505 filed with DEQ, Schedule A

- **Were flows to secondary treatment maximized?** *Yes.* See Section 2.2.1.2.
- **Were effluent limits achieved at OF001 and OF003?** *Yes.* This was the first full year of operation for the new Secondary Process Improvements, and lessons were learned from the initial startup of those improvements. The numbers indicate that the system is producing the proper annual treatment results.

These results indicate that the CSO system operations strategy continues to sustain desired performance and can handle various conditions throughout the year, especially with the dramatic increase in rainfall. Portland's use of CEPT continues to keep BOD and TSS discharges from the Wet Weather Treatment Facility at consistently reduced levels.

Table 6 CBWTP Annual Treatment Performance Summary Data[2]

CBWTP Annual Treatment Performance							
Annual Treatment Characteristics	**Average Year Model / Permit**	*No CEPT* **FY 2012**	*With CEPT* **FY 2013**	*With CEPT* **FY 2014**	*With CEPT* **FY 2015**	*With CEPT* **FY 2016**	**Trend**
Annual Rainfall Depth (inches/year)	37	46.8	40.2	40.0	33.9	53.4	
Flows to CBWTP							
Influent Volume (MG/Year)	28,300	28,800	26,625	26,549	25,760	30,665	
Dry Weather Sanitary Volume (MG/Year)	22,100	20,200	19,496	19,471	19,609	20,179	
Captured CSO Flow - Volume (MG/Year)	6,200	8,600	7,129	7,078	6,151	10,485	
Total Volume Treated Thru Secondary (MG)	25,443	25,662	24,197	24,002	23,221	26,301	
% of Plant Flow Treated Through Secondary System	90%	89%	91%	90%	90%	86%	
WWTF (EWWPT) Events							
Rate to DW / Secondary During EWWPT (MGD)	100	120	126	112	112	117	
Number of Events / Year	32	29	22	27	27	39	
WWTF Volume / Year	2,857	3,138	2,429	2,546	2,540	4,363	
Amount of Captured CSO Treated via Secondary (%)	54%	64%	66%	64%	59%	58%	
Duration of WWTF Events (hours)	919	706	668	904	591	1,241	
Calendar Days of WWTF Discharges (days)	---	66	50	65	51	92	
Blended Effluent (OF001 & 003) Treatment							
BOD Loading (pounds / year)	2,510,000	4,000,000	2,957,783	3,472,307	4,176,834	3,871,106	
BOD Average Concentration (mg/l)	27	16.6	13.3	15.7	19.4	15.1	
Total Plant BOD Removal Efficiency (%)	---	93%	95%	94%	93%	93%	
TSS Loading (pounds / year)	2,440,000	5,050,000	3,585,748	4,055,479	4,413,412	4,910,264	
TSS Average Concentration (mg/l)	27	21.0	16.1	18.3	20.5	19.2	
Total Plant TSS Removal Efficiency (%)	---	92%	94%	93%	92%	92%	
Wet Weather Treatment Facility							
BOD TO Wet Weather Facility (pounds/year)	---	2,290,000	1,638,460	2,361,933	2,414,044	3,651,168	
BOD FROM Wet Weather Facility (pounds/year)	---	1,510,000	726,541	874,387	962,545	1,258,955	
Wet Weather BOD Removal Efficiency (%)	50%	34%	56%	63%	60%	66%	
TSS TO Wet Weather Facility (pounds/year)	---	4,030,000	2,257,182	3,048,027	3,130,925	5,649,463	
TSS FROM Wet Weather Facility (pounds/year)	---	1,480,000	520,375	520,252	560,013	1,134,753	
Wet Weather TSS Removal Efficiency (%)	70%	63%	77%	83%	82%	80%	

[2] The permit average for "Rate to DW/Secondary During EWWPT (MGD)" rose to 110 MGD in 2014 (applicable for FY 2015 and onwards).

2.3.2.2 CBWTP Max-Month and Peak-Week Treatment Performance

Table 7 provides maximum 30-day treatment results for BOD and TSS. While the permit requires reporting of maximums on a calendar month basis, this evaluation uses a more stringent moving 30-day window analysis. Maximum 30-day concentrations and loadings for both BOD and TSS at the outfalls for the maximum 30-day period of the year (ending December 30, 2015) were below the permit's monthly limits.

Table 7 FY 2016 Wet Weather Max-Month (30-days maximum solids loading) Treatment Performance[3]

Parameters	Maximum Monthly (30-Day)						
	Avg Concentration During Maximum Month for Mass Loading			Mass Loading			
	Permit Monthly (mg/l)	Max 30-Day (mg/l)	30-Day Avg Flow (MGD)	Permit Monthly (lbs/day)	Max 30-Day (lbs/day)	Date of 30th Day	Notes
Columbia Boulevard WWTP - Outfalls 001 and 003 Effluent Quality							
BOD5	30	21	184	45,000	31,430	30-Dec-15	17.2 inches of rain in 30 days
TSS	30	27	184	45,000	40,651	30-Dec-15	
Secondary Biological Treatment - 100 MGD Minimum Instantaneous							
BOD5	30	20	90	22,500	15,006	3-Mar-16	5.6/6.4 inches of rain in 30 days
TSS	30	24	82	22,500	19,766	19-Mar-16	
Wet Weather / CEPT System - Intermittent Discharges							
BOD5	45	29	88	22,500	21,140	29-Dec-15	17.2 inches of rain in 30 days
TSS	45	29	88	22,500	21,026	29-Dec-15	

Table 8 provides peak 7-day treatment results for BOD and TSS. As in the previous discussion for the 30-day analysis, the permit requires reporting of peaks on a calendar week (Sunday to Saturday) basis. However, this analysis uses a more stringent moving 7-day window. Treatment performance for both 7-day BOD and TSS concentrations and loadings for the maximum period (ending December 13, 2015) were excellent, and these measures were well below the limits at the outfalls.

[3] As stated in the DMRs, Portland applies the System-Based Performance Requirements for Secondary and WWTF as in-plant guidelines. Permit compliance is required only for the combined OF001 and OF003 effluent.

Table 8 FY 2016 Wet Weather Peak-Week (7-days maximum solids loading) Treatment Performance[3]

Parameters	Peak Week (7-Day)						
	Avg Concentration During Peak Mass Loading Week			Mass Loading			
	Permit Weekly (mg/l)	Max 7-Day (mg/l)	7-Day Avg Flow (MG)	Permit Weekly (lbs/day)	Max 7-Day (lbs/day)	Date of 7th Day	Notes
Columbia Boulevard WWTP - Outfalls 001 and 003 Effluent Quality							
BOD5	45	23	298	118,800	55,907	13-Dec-15	7.8 inches of rain in 7 days
TSS	45	31	298	118,800	76,162	13-Dec-15	
Secondary Biological Treatment - 100 MGD Minimum Instantaneous							
BOD5	45	28	82	37,500	18,915	14-Feb-16	1.0/6.8 inches of rain in 7 days
TSS	45	32	82	37,500	30,392	8-Dec-15	
Wet Weather / CEPT System - Intermittent Discharges							
BOD5	65	34	165	81,300	46,249	13-Dec-15	7.8 inches of rain in 7 days
TSS	65	36	165	81,300	49,622	13-Dec-15	

2.4 Wet Weather Treatment Performance for Enhanced Wet Weather Primary Treatment (EWWPT) Events

Wet weather treatment performance is best evaluated by examining the events in which the WWTF discharged treated effluent. These events are called Enhanced Wet Weather Primary Treatment (EWWPT) events to underscore that the wet weather flow diverted from the secondary system receives CEPT.

An EWWPT event begins when the WWTF starts discharging effluent, and ends after either of the following:

- WWTF discharge has ended AND the plant inflow remains below 80 MGD for 6 hours OR
- WWTF discharge has dropped to 0 MGD and no subsequent WWTF discharge occurs for 48 hours. This condition may occur when low level rainfall keeps plant inflows up, but operations is able to keep all inflows treated through the secondary.

Table 9 summarizes the WWTF events for FY 2016. The full, detailed list of the events is in Table 10.

Table 9 FY 2016 Enhanced Wet Weather Primary Treatment Events Summary

		CBWTP Flows		WWTF Flows				WWTF Effluent			
	Events	Avg Influent During EWWPT (MGD)	Avg Secondary Flow During EWWPT (MGD)	Avg WWTF Flow (MGD)	WWTF Discharge Volume (MG)	Duration of WWTF Discharge (hrs)	Calendar Days WWTF Discharge Occurred	Event BOD Load Discharged (lbs)	Event TSS Load Discharged (lbs)	EMC BOD (mg/L)	EMC TSS (mg/L)
Total	**39**				**4,363**	**1241**	**92**	**1,258,955**	**1,134,753**		
Average/Event		**204**	**117**	**78**	**112**	**31.8**	**2.4**	**32,281**	**29,096**	**48**	**30**

Key aspects for this year's WWTF performance include:

- Volume of EWWPT events was 4.4 billion gallons. This is about 7% of the total volume received at the CBWTP for the year (30.7 billion gallons; see Table 6).
- An EWWPT event was in progress during the year for about 1200 hours (14% of the year) and 92 calendar days (a little less than 2 days per week). Treatment through the WWTF continues to be highly intermittent.
- The average event mean concentrations (EMC) for BOD of 48 mg/L and 30 mg/L for TSS were better than in FY 2015, and compare very well with expected values for the CEPT system.
- Operators maintained an average of 117 MGD of flow through secondary treatment during EWWPT events, compared to the permit requirement of 110 MGD. This rate is 57% of the average flow rate reaching the plant during an EWWPT event.
- EWWPT events lasted about 32 hours on average and typically occurred across 2.4 days.

Table 10 Enhanced Wet Weather Treatment Events - Detailed Information

		CBWTP Flows		WWTF Flows				WWTF Effluent			
Date & Time Bypass Event Started	Event #	Avg Influent During EWWPT (MGD)	Avg Secondary Flow During EWWPT (MGD)	Avg WWTF Flow (MGD)	WWTF Discharge Volume (MG)	Duration of WWTF Discharge (hrs)	Calendar Days WWTF Discharge Occurred	Event BOD Load Discharged (lbs)	Event TSS Load Discharged (lbs)	EMC BOD (mg/L)	EMC TSS (mg/L)
8/29/15 8:15	1	175	121	26	1	0.8	1	1,065	435	157	64
8/30/15 4:15	2	142	114	15	8	13.3	1	5,768	2,502	83	36
10/10/15 19:15	3	170	117	47	13	6.5	2	8,443	3,424	79	32
10/25/15 14:45	4	255	112	134	47	8.5	1	24,472	16,578	62	42
10/31/15 1:45	5	243	120	116	236	48.8	3	41,910	59,904	21	30
11/7/15 14:30	6	285	127	146	41	6.8	1	16,287	10,396	47	30
11/8/15 18:15	7	175	119	46	6	3.0	1	3,665	2,088	77	44
11/15/15 8:45	8	136	115	17	7	10.0	1	1,980	1,015	33	17
11/16/15 21:45	9	224	116	98	137	33.5	3	40,511	24,325	35	21
11/19/15 0:45	10	289	128	150	90	14.5	1	22,631	19,613	30	26
11/24/15 0:15	11	264	120	136	50	8.8	1	14,023	9,898	34	24
12/1/15 22:45	12	273	119	143	76	12.8	2	28,258	18,562	45	29
12/3/15 1:45	13	178	113	57	75	31.5	2	26,800	17,240	43	27
12/5/15 13:00	14	272	122	143	1,221	205.3	10	337,434	358,644	33	35
12/17/15 3:45	15	230	119	104	718	166.5	8	227,300	225,238	38	38
12/27/15 19:15	16	194	120	66	15	5.5	2	8,453	7,022	67	55
12/29/15 11:30	17	224	120	90	19	5.0	1	5,967	4,082	38	26
1/4/16 17:15	18	153	126	17	1	0.8	1	174	326	38	72
1/12/16 12:45	19	187	119	66	723	264.8	12	177,608	204,044	29	34
1/28/16 7:30	20	167	116	46	91	47.5	3	22,538	19,541	30	26
2/3/16 17:15	21	198	116	75	86	27.3	2	21,935	11,198	31	16
2/5/16 21:15	22	238	129	91	12	3.3	2	3,609	2,456	35	24
2/11/16 19:15	23	150	121	15	1	1.0	1	391	440	74	83
2/12/16 12:15	24	229	110	102	17	4.0	1	8,615	3,930	61	28
2/13/16 20:15	25	174	109	57	34	14.3	2	9,620	6,517	34	23
2/17/16 19:00	26	254	114	130	34	6.3	2	9,801	3,179	35	11
2/18/16 13:30	27	167	116	44	72	39.0	3	25,797	13,469	43	22
2/26/16 21:15	28	175	110	56	24	10.3	2	6,127	3,203	31	16
3/1/16 1:30	29	153	107	40	31	18.5	1	10,551	10,023	41	39
3/2/16 20:30	30	254	115	129	39	7.3	2	11,373	5,368	35	16
3/5/16 5:45	31	109	98	7	11	41.5	2	3,991	2,186	42	23
3/9/16 13:15	32	218	115	96	125	31.5	2	35,973	23,633	34	23
3/12/16 1:15	33	161	114	40	165	99.3	5	38,101	22,374	28	16
4/14/16 15:00	34	222	111	98	38	9.3	2	15,781	4,831	50	15
4/22/16 3:15	35	194	120	63	32	12.3	1	12,624	5,489	47	20
5/15/16 8:00	36	183	120	53	27	12.3	1	8,399	3,859	37	17
5/19/16 20:00	37	231	119	101	10	2.5	1	5,574	2,264	64	26
5/21/16 19:15	38	190	120	61	8	3.3	1	3,047	1,828	44	27
6/23/16 19:45	39	233	120	103	20	4.8	2	12,362	3,626	73	21
Total	**39**				**4,363**	**1,241**	**92**	**1,258,955**	**1,134,753**		
Avg/Event		**204**	**117**	**78**	**112**	**32**	**2.4**	**32,281**	**29,096**	**48**	**30**

BOD and TSS removal efficiencies compared to event volume are shown in Figure 4 (BOD) and Figure 5 (TSS). Small events tend to have higher BOD and TSS concentrations, and larger volume events have lower concentrations. The CEPT system achieves better than 50% BOD and 70% TSS removal efficiencies on an overall basis, as shown by the majority of events placing above the target efficiencies on the charts.

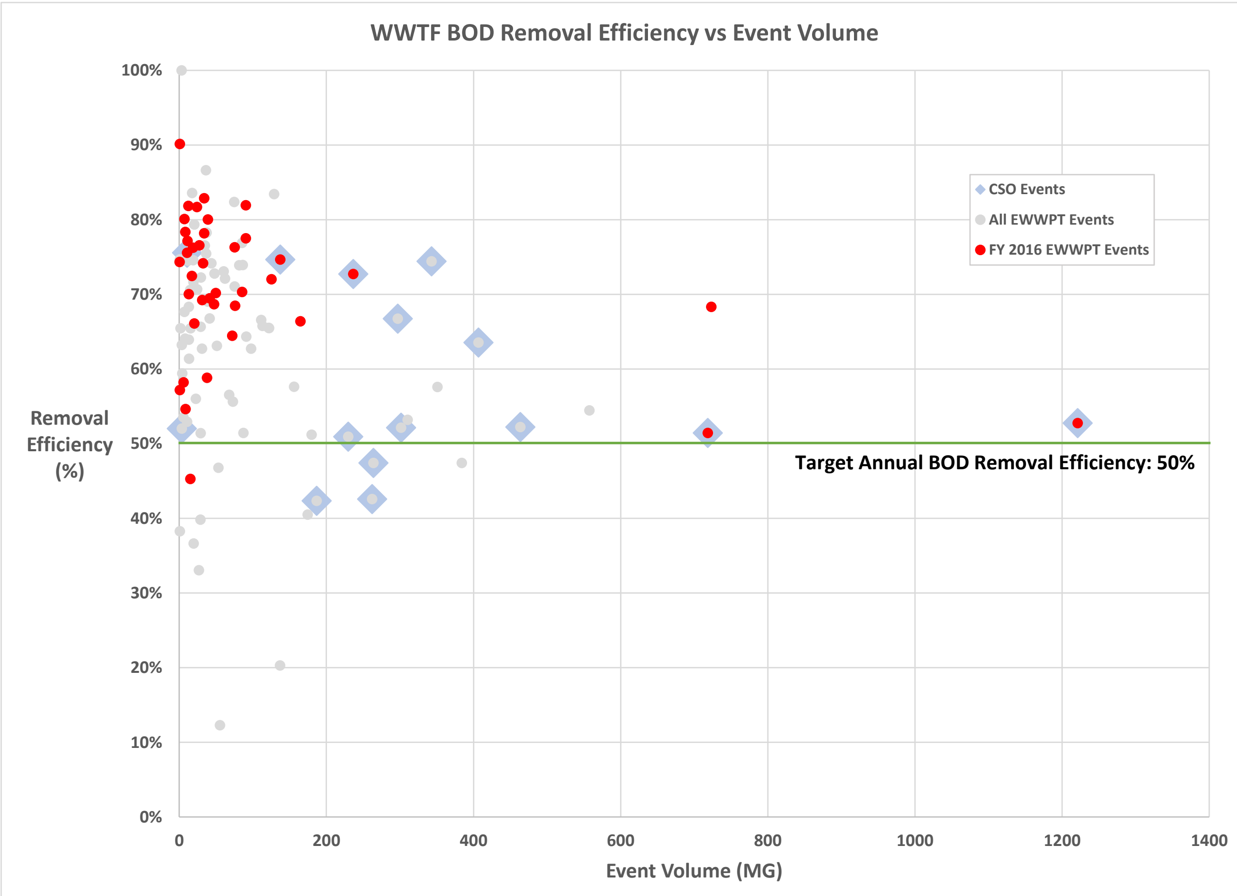


Figure 4 WWTF BOD Removal Efficiency vs. Event Volume

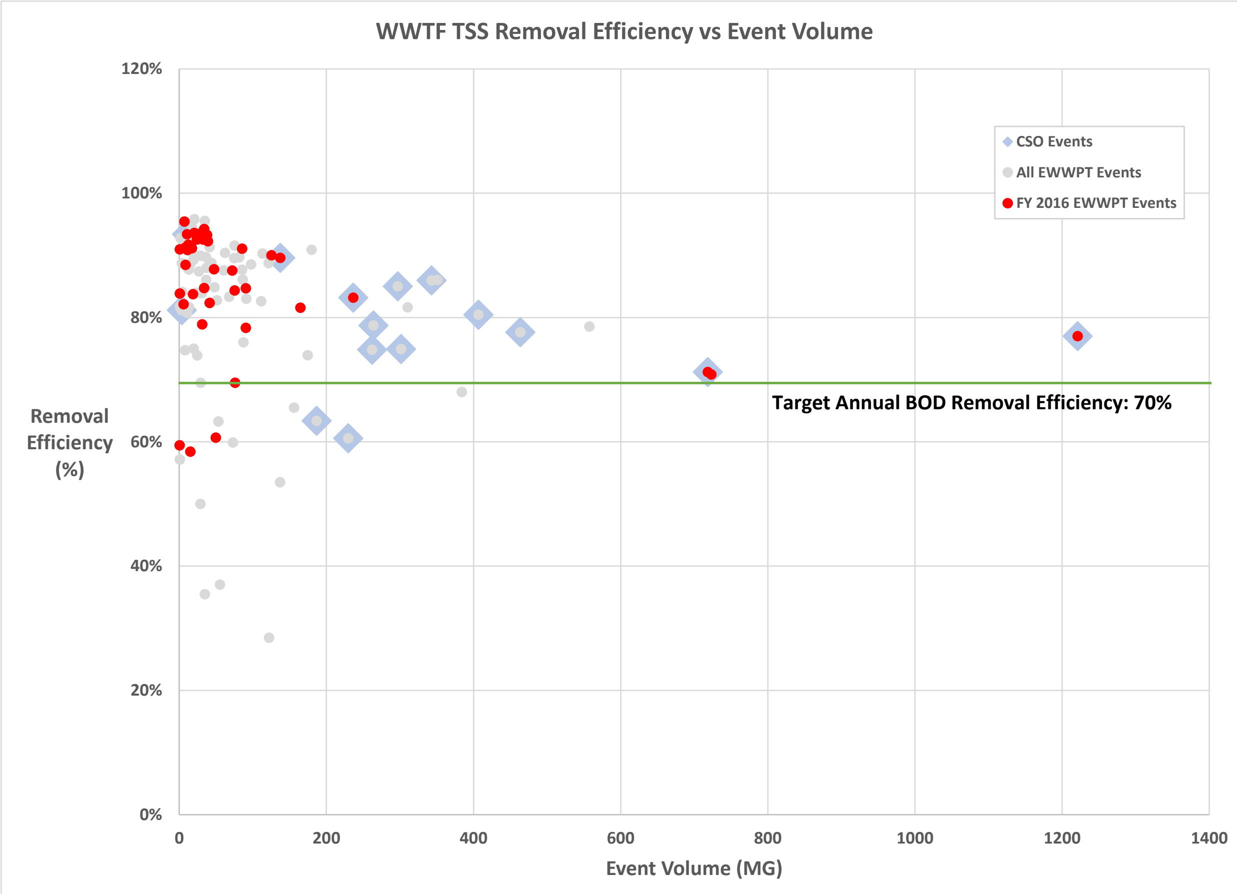


Figure 5 WWTF TSS Removal Efficiency vs. Event Volume

2.5 CSO System and Water Quality Monitoring

2.5.1 CSO Discharge Sampling

Portland obtained two more samples for FY 2016, bringing the total to 8 event samples for the current NPDES permit cycle (5 were required, if possible). Figure 6 and Figure 7 show the laboratory analysis reports for the October 30-November 2, 2015, and December 5-13, 2015, events. Both of these grab samples were collected near Outfall 36 (Alder). For details about this sampling program, please see Section 8.2 of the *FY 2015 Annual CSO and CMOM Program Report*.

City of Portland
Water Pollution Control Laboratory
6543 N. Burlington Ave. / Portland OR 97203 (503) 823-5600 fax (503) 823-5656
ORELAP Certification ID 4023

LABORATORY ANALYSIS REPORT

Project:	**CSO Permit**	Client:	Asset Management
Work Order:	**W15J214**	Project Mgr:	Arnel Mandilag
Received:	10/31/15 17:22		
Submitted By:	Field Operations		

Sample	Laboratory ID	Matrix	Type	Sample Collection Date Start	End	Qualifier
CSO36	W15J214-01	Stormwater	Grab	10/31/15 16:18	10/31/15 16:18	

CSO36 : W15J214-01

Analyte	Result	Units	MRL	Dil.	Batch	Prepared	Analyzed	Method	Qualifier
Microbiology									
E. coli	**>24000**	MPN/100 mL	10	1	B15J444	10/31/15 17:55	11/01/15	Colilert QT	
General Chemistry									
Total suspended solids	**182**	mg/L	2		B15K022	11/02/15	11/02/15	SM 2540D	
Total Metals									
Total Metals by ICPMS									
Copper	**24.0**	ug/L	0.200	1	B15K013	11/02/15	11/03/15	EPA 200.8	
Lead	**28.2**	ug/L	0.100	1	B15K013	11/02/15	11/03/15	EPA 200.8	

Figure 6 October 31, 2015, CSO Discharge Water Quality Sample Result - OF 36

City of Portland
Water Pollution Control Laboratory
6543 N. Burlington Ave. / Portland OR 97203 (503) 823-5600 fax (503) 823-5656
ORELAP Certification ID 4023

LABORATORY ANALYSIS REPORT

Project:	**CSO Permit**	Client:	Asset Management
Work Order:	**W15L053**	Project Mgr:	Arnel Mandilag
Received:	12/7/15 10:30		
Submitted By:	Field Operations		

Sample	Laboratory ID	Matrix	Type	Sample Collection Date Start	End	Qualifier
CSO36	W15L053-01	Stormwater	Grab	12/07/15 09:22	12/07/15 09:22	

Analyte	Result	Units	MRL	Dil.	Batch	Prepared	Analyzed	Method	Qualifier
Microbiology									
E. coli by Colilert Quantitray									
CSO36 : W15L053-01									
E. coli	**92000**	MPN/100 mL	100	1	B15L125	12/07/15 12:32	12/08/15	Colilert QT	
General Chemistry									
Total Suspended Solids									
CSO36 : W15L053-01RE1									
Total suspended solids	**123**	mg/L	2		B15L122	12/07/15	12/08/15	SM 2540D	RE1
Total Metals									
Total Metals by ICPMS									
CSO36 : W15L053-01									
Copper	**14.6**	ug/L	0.200	1	B15L133	12/08/15	12/10/15	EPA 200.8	
Lead	**19.5**	ug/L	0.100	1	B15L133	12/08/15	12/10/15	EPA 200.8	

Figure 7 December 7, 2015, CSO Discharge Water Quality Sample Result - OF 36

2.5.2 Willamette River Instream Water Quality Sampling

Figure 8 through Figure 12 show the water quality trends along the Portland stretch of the Willamette River for five parameters: zinc, lead, copper, TSS, and *E. coli*. These metals and bacteria parameters are the pollutants of concern for Portland CSO discharges. The sampling results indicate continued, similar performance as in the previous FY 2015.

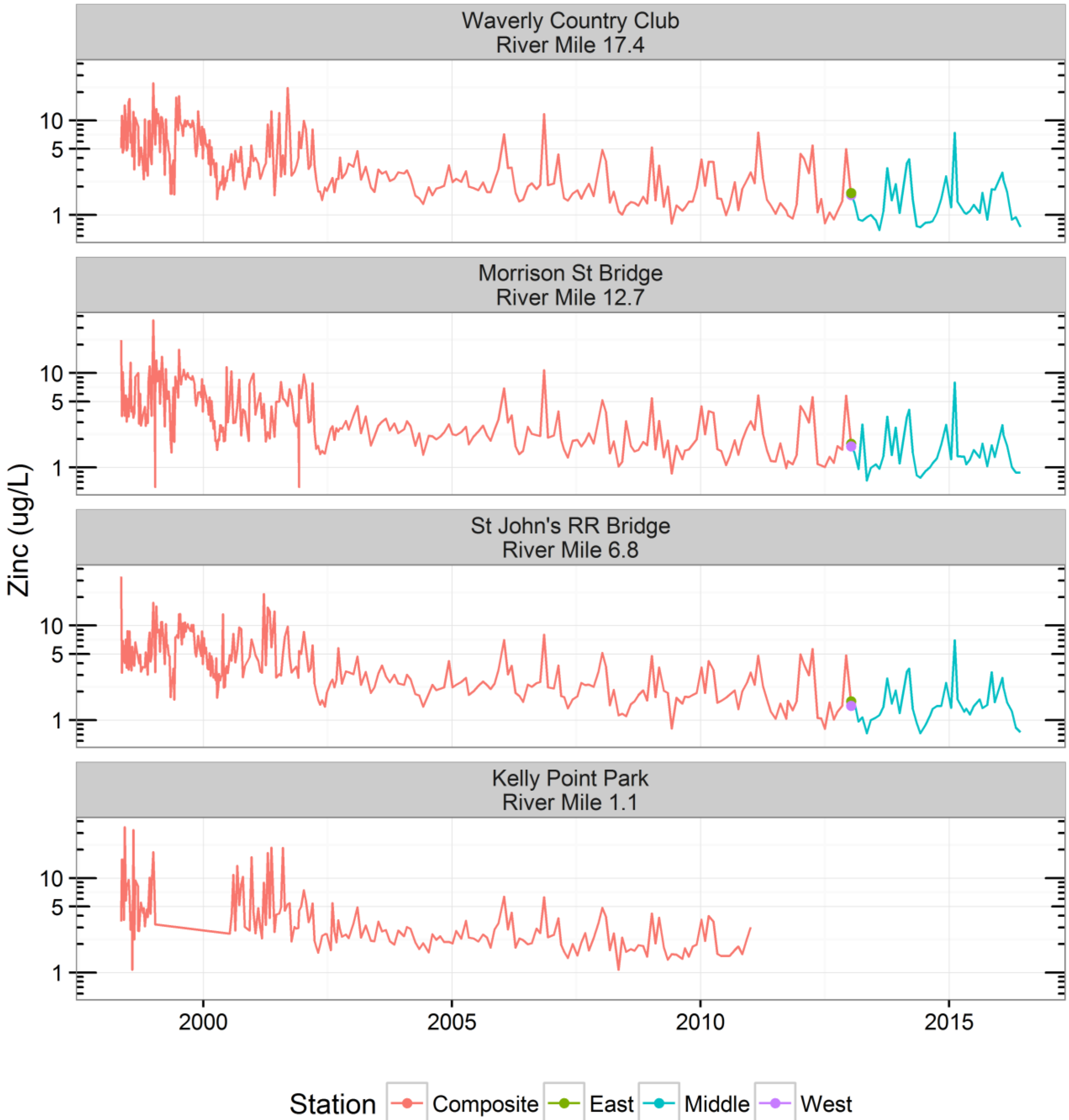


Figure 8 Willamette River Monitoring Results for Zinc

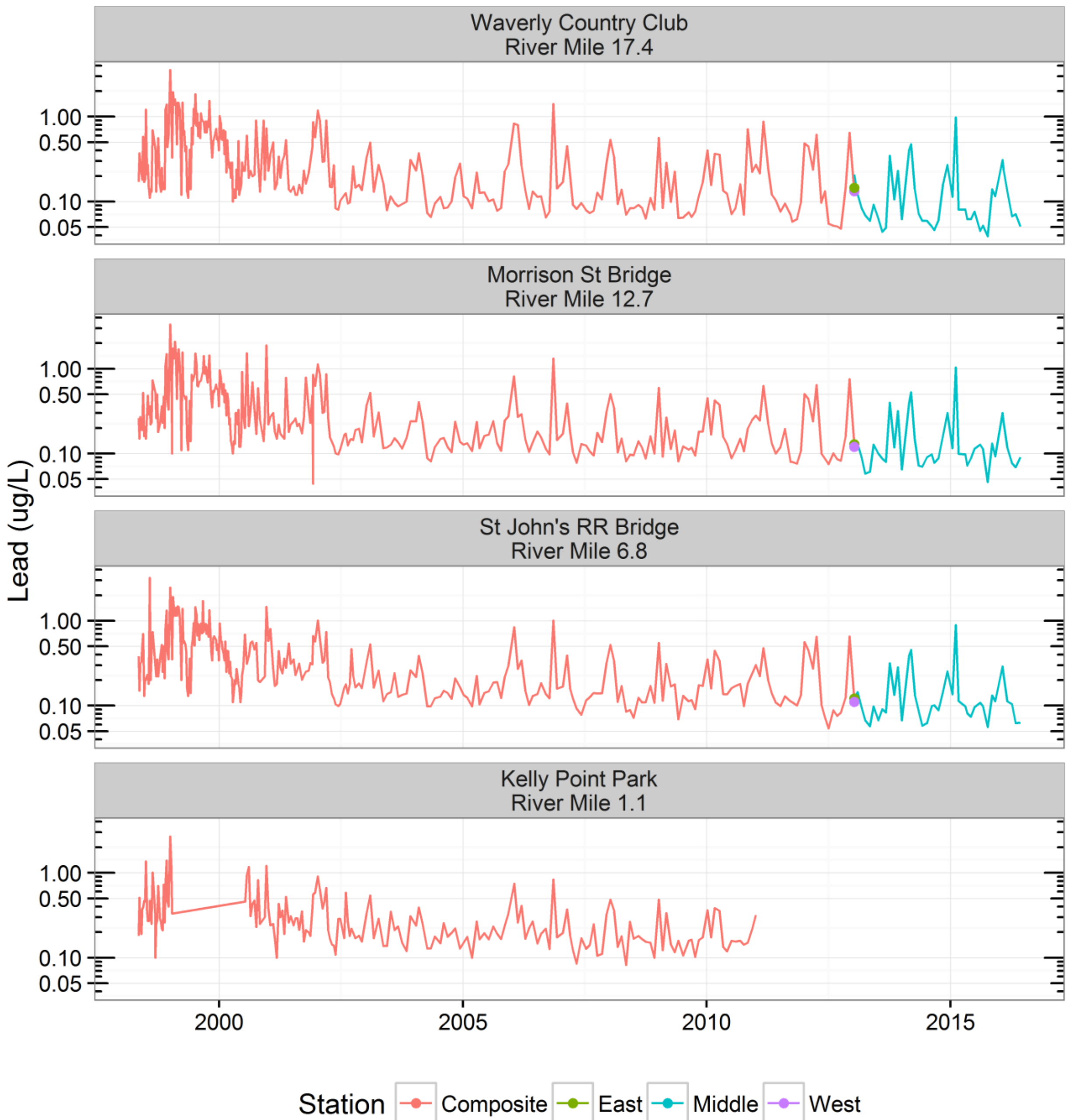


Figure 9 Willamette River Monitoring Results for Lead

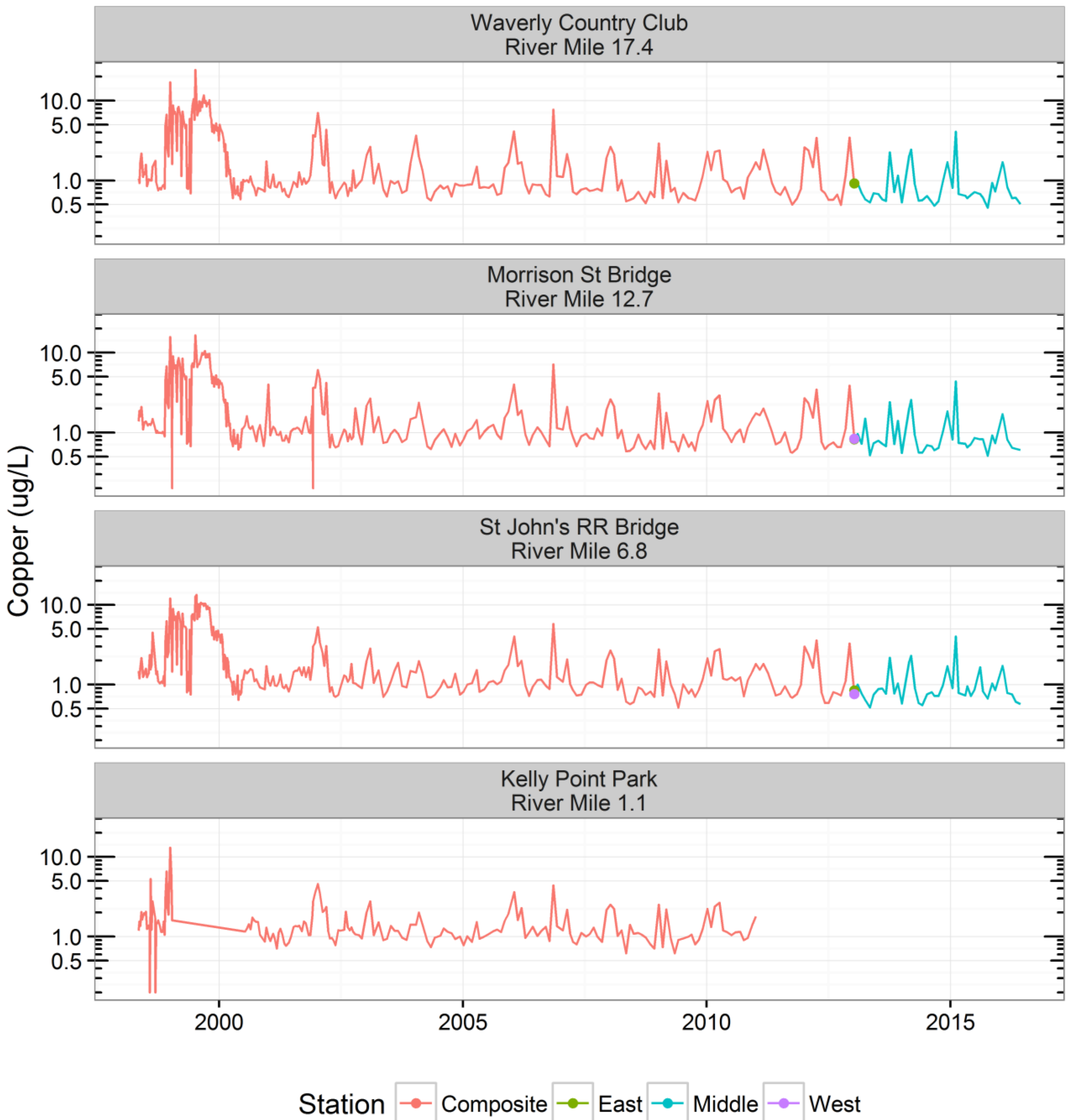


Figure 10 Willamette River Monitoring Results for Copper

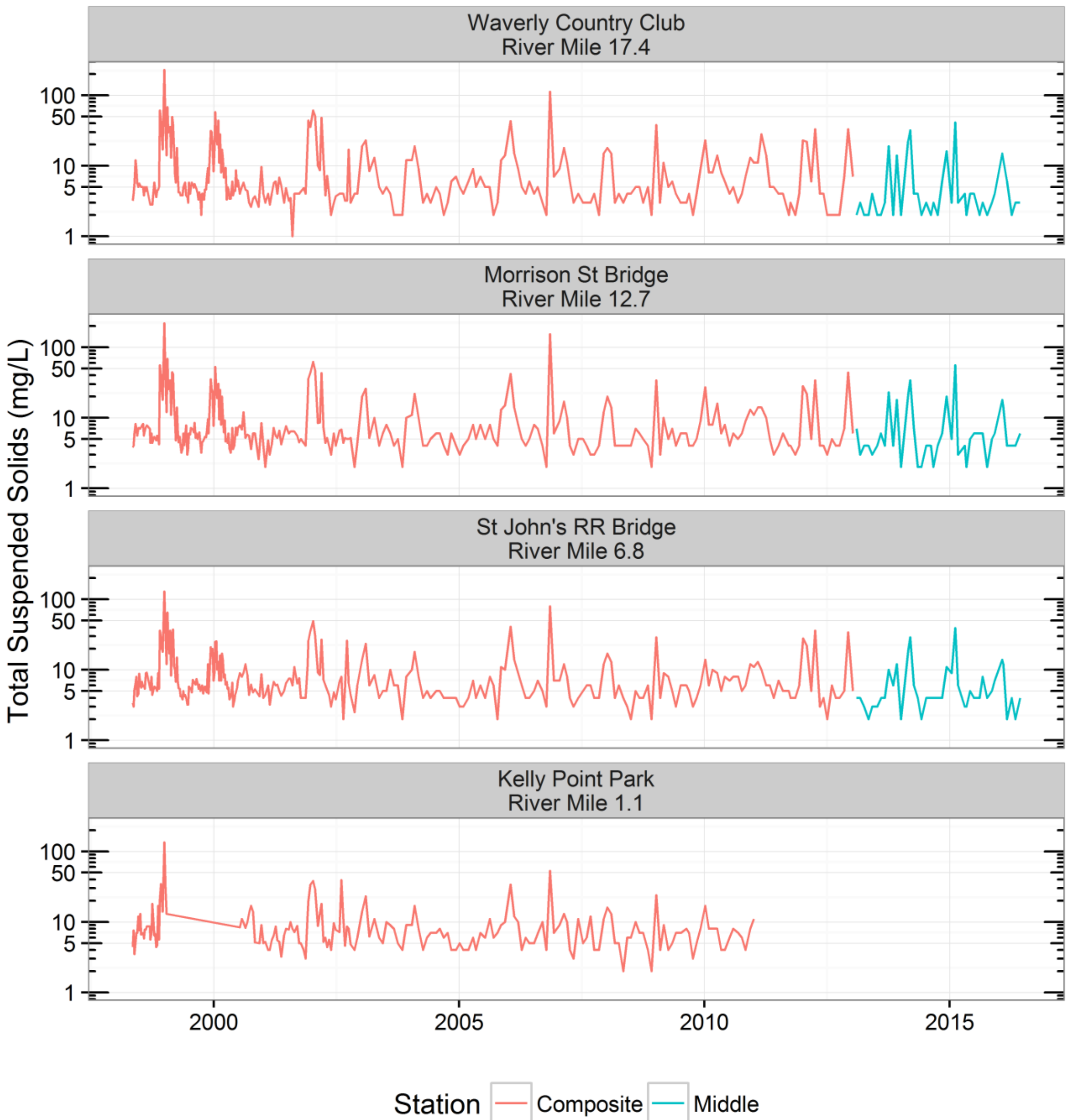


Figure 11 Willamette River Monitoring Results for TSS

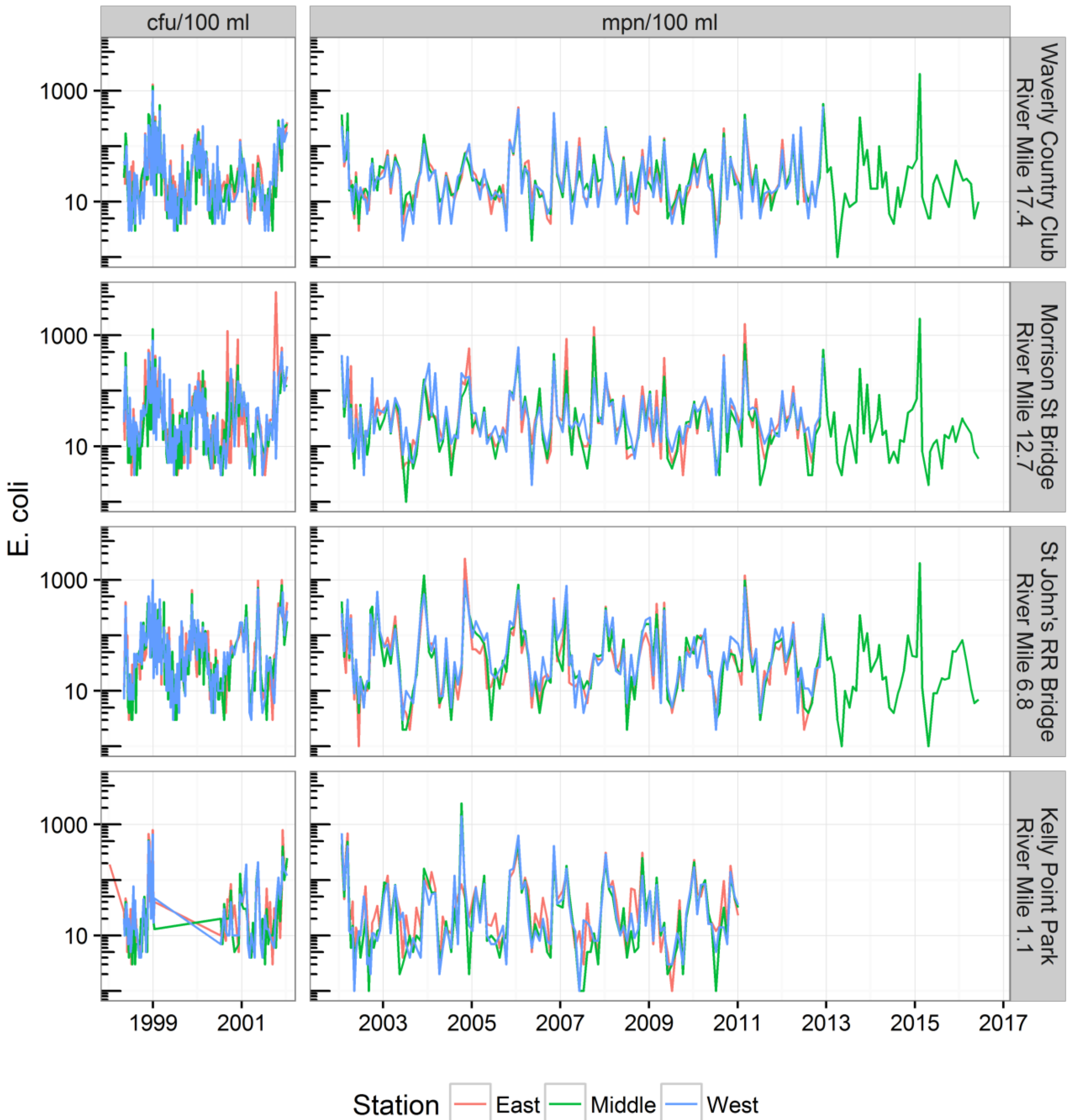
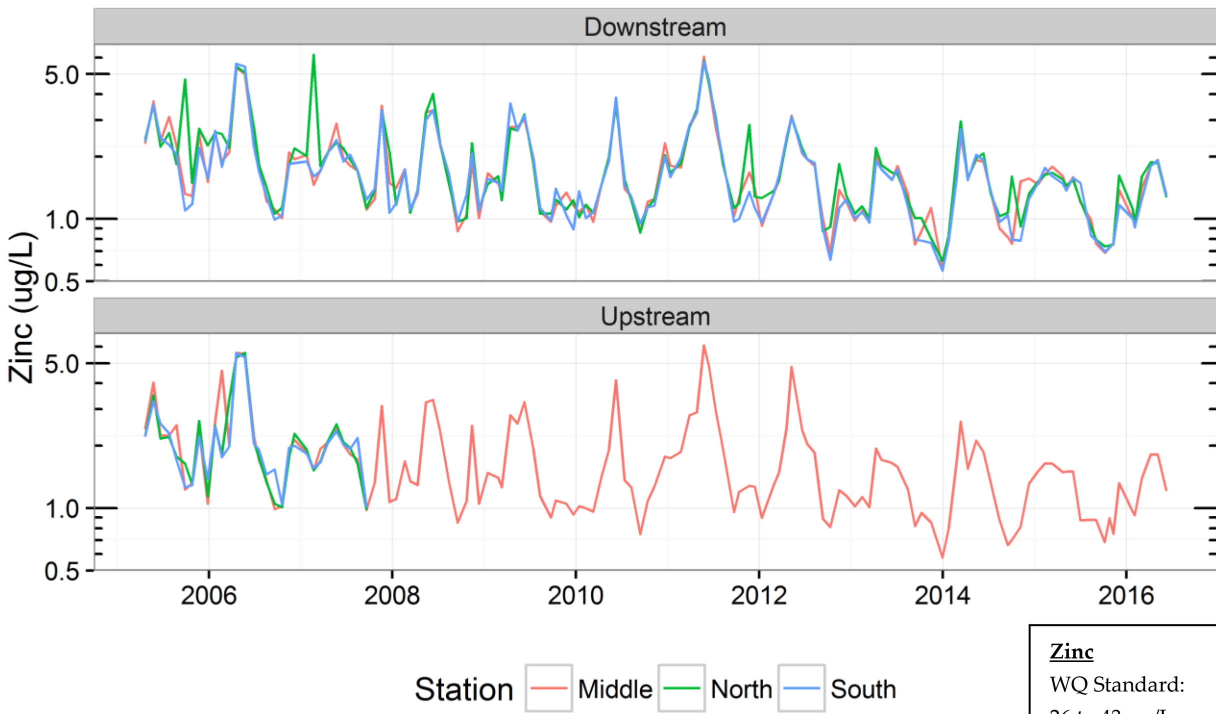


Figure 12 Willamette River Monitoring Results for E. coli

2.5.3 Columbia River Instream Water Quality Sampling

Figure 13 through Figure 17 show measurements of the main parameters of interest related to wet weather treatment and the Columbia River: Zinc, Lead, Copper, TSS, and *E. coli*. These charts compare the measurements upstream and downstream of the combined mixing zone. The charts also include the relevant numeric water quality standard for each parameter except for TSS, which is not a toxic. For the metals, the range of chronic water quality standard values is based on the measured total hardness of the river, which varies from a low of 45 to a high of 78. The charts show the reasonable range of chronic standards based on the hardness values measured in the river during the sampling period.

All parameters are well below the numeric water quality standards. There is little difference between the upstream and downstream measurements.



Zinc
WQ Standard:
26 to 43 μg/L
chronic hardness range

Figure 13 Columbia River Mixing Zone Sampling for Zinc

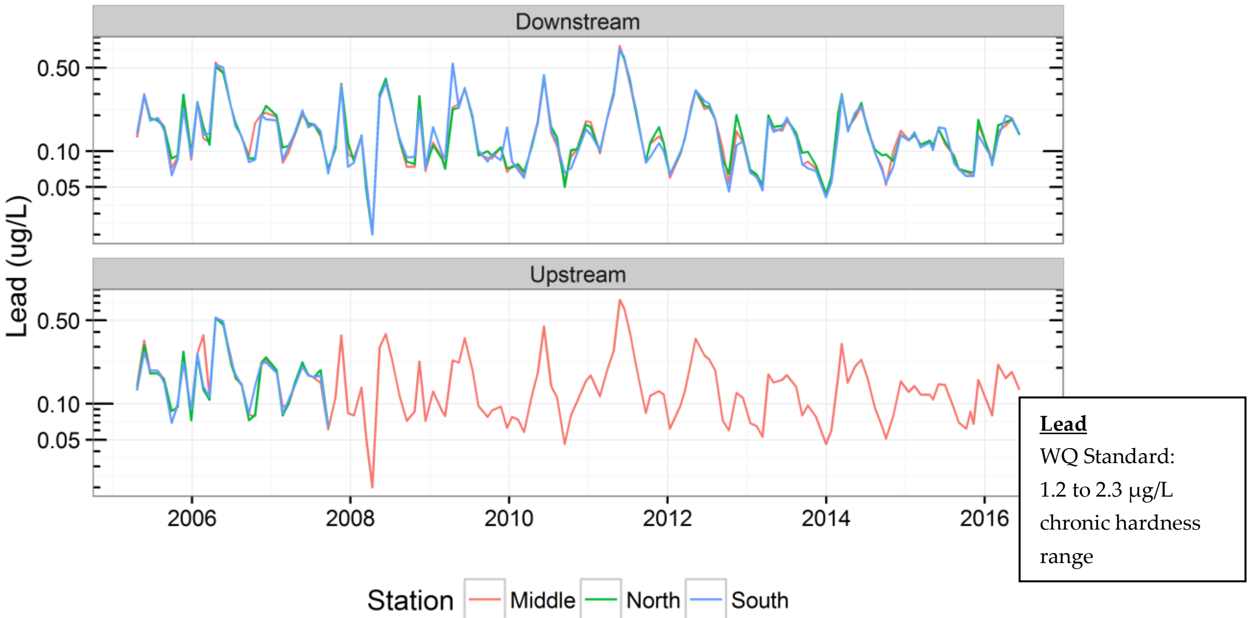


Figure 14 Columbia River Mixing Zone Sampling for Lead

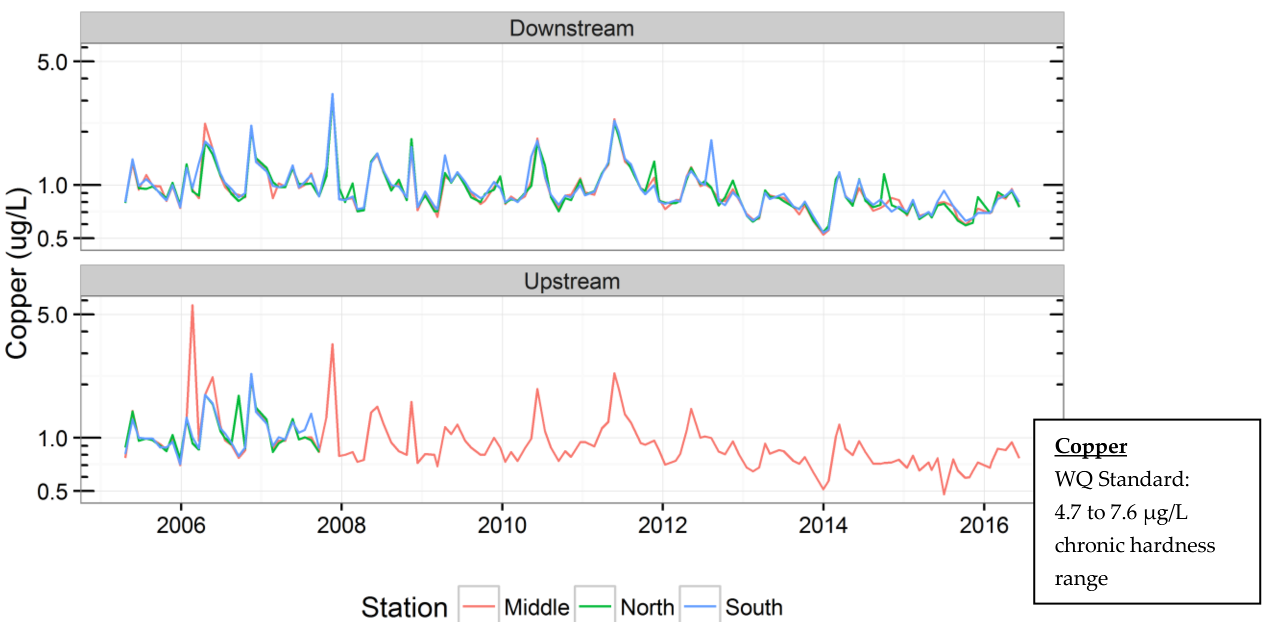
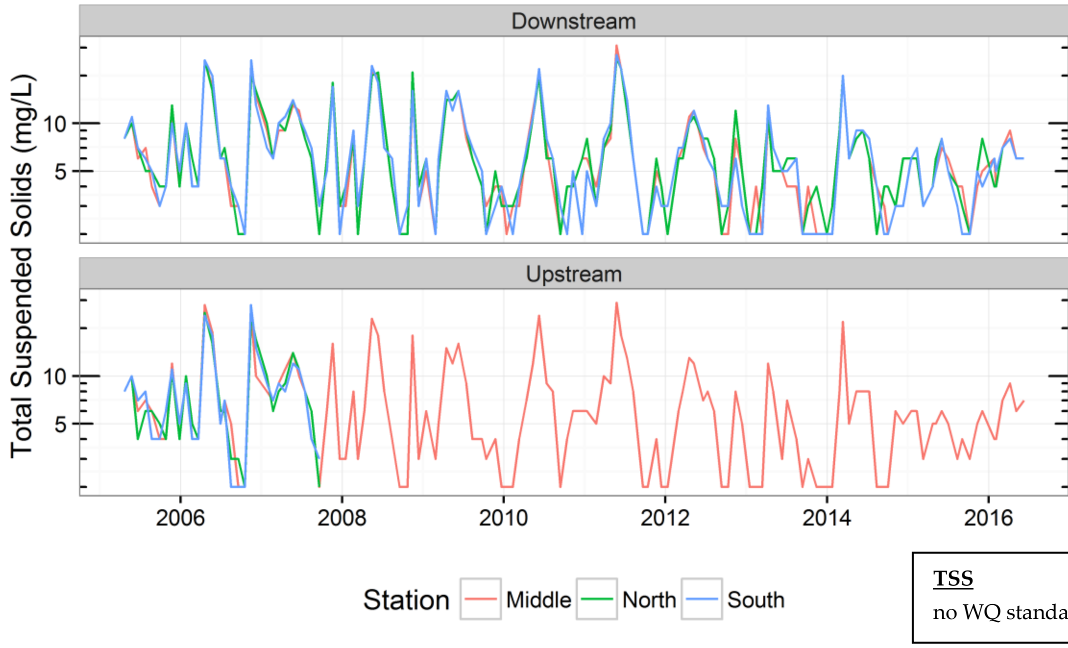
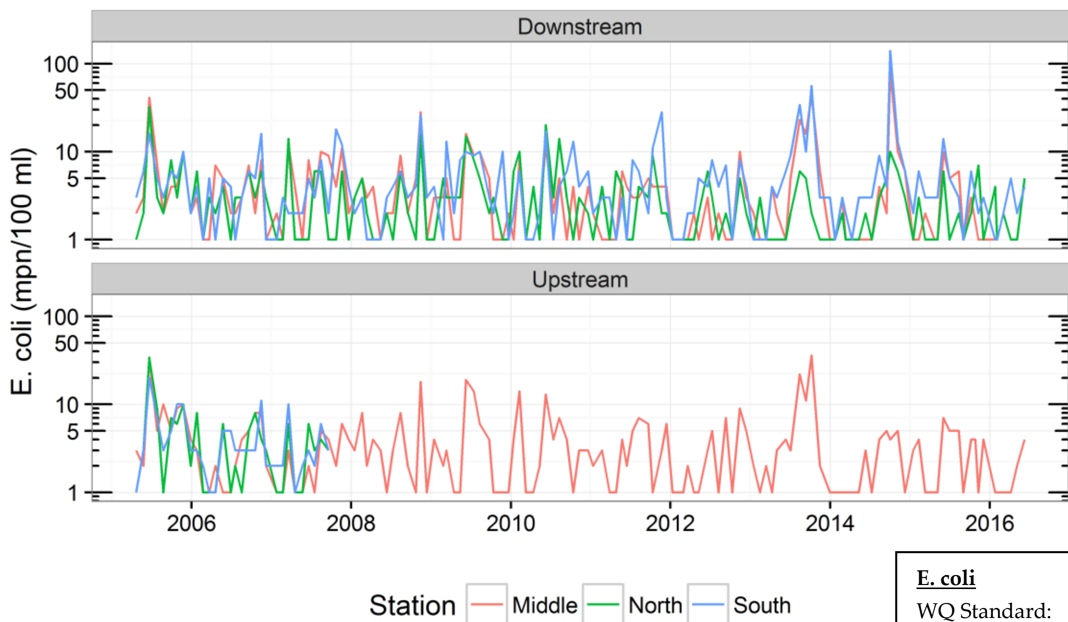


Figure 15 Columbia River Mixing Zone Sampling for Copper



TSS
no WQ standard

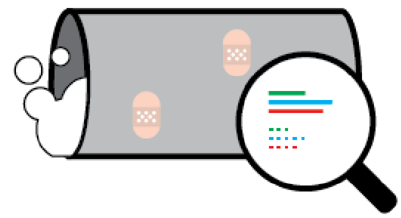
Figure 16 Columbia River Mixing Zone Sampling for TSS



E. coli
WQ Standard:
406 MPN / 100 mL

Figure 17 Columbia River Mixing Zone Sampling for E. coli

Section 3 CMOM Program Implementation



The City of Portland's CMOM program is designed to ensure that components of the collection system are cleaned and inspected at the right frequency and that preventive maintenance and repairs are performed to cost-effectively reduce the number of sewer releases, extend the useful life of the City's sewer infrastructure, and properly manage collection system operations. This annual summary for FY 2016 provides a brief overview of collection system operation and maintenance programs and practices as context for evaluation of the effectiveness of CMOM activities. Section 4 of this report includes sewer release analysis and performance.

3.1 Collection System – Gravity Sewers Operation and Maintenance

BES has programs in place to ensure that gravity sewers and manholes are properly inspected, cleaned, and repaired. Closed-circuit television (CCTV) inspection activities are key for an accurate determination of the structural and operational condition of collection system assets. Cleaning helps maintain asset condition and hydraulic capacity, enhances the effectiveness of inspections, and helps to control odors. Repairing structural deterioration protects the community's infrastructure investment, can extend an asset's useful life, and reduces the potential for catastrophic failures.

3.1.1 Sewer Inspections and Cleaning

The *Collection System Inspection and Cleaning Plan* submitted to DEQ in December 2012 provides detailed information about the City's "needs-based" maintenance strategy for prioritizing maintenance, inspection and cleaning activities and expenditures. The inspection and cleaning programs contain both preventive maintenance and unplanned work.

In FY 2016, the sewer inspection program inspected 834,390 lineal feet of mainline sewer pipe, which corresponds to approximately 8% of the mainline sewer system. Sewer mainlines are inspected for general preventive maintenance, special investigations in support of the chemical root and grease management programs, in response to sewer problems, and to support asset reinvestment projects through the Capital Improvement Program (CIP). In FY 2016, approximately 3% of the work orders in the inspection program were considered unplanned work; that is, inspection work was in direct response to special sewer investigations or collection system problems. The remainder of the program was dedicated to general preventive maintenance and support of the City's CIP Sewer Rehabilitation Program. The CCTV inspection program provides the pipeline condition assessment information that is instrumental to the risk prioritization process used to drive the CIP Rehabilitation Program work.

In addition to mainline sewer inspections, the City completed nearly 7,000 service lateral inspections in FY 2016. The vast majority of these inspections were to support the mainline sewer rehabilitation program administered through the CIP.

In FY 2016, the sewer cleaning program cleaned 1,736,441 feet of sewer pipe, which corresponds to approximately 17% of the mainline sewer system. The sewer cleaning program includes preventive maintenance, accelerated cleaning in grease management areas, support for the root treatment program, special investigations related to collection system problems, and support of CIP projects.

In FY 2016, just under 97% of mainline cleaning work orders were considered planned maintenance; that is, the cleaning was performed for general preventive maintenance, to support a planned CCTV inspection, cleaning of grease management areas, and cleaning to support root treatment activities.

3.1.2 Sewer Assessment and Repairs

Maintaining the wastewater collection system in good repair is a core service BES provides to its ratepayers. The City has a well-established sewer and manhole repair program. Priority codes in Hansen[4] are assigned when work orders are created. The priority codes are used when scheduling and assigning work and to help manage the backlog of open work orders to ensure that repairs are completed according to their relative risk and consequence of failure (e.g., top priority is given to SSO- and hazard-related repairs). The *CMOM Program Report* includes descriptions of sewer repair maintenance activities and equipment.

During FY 2016, for minor urgent or emergency repairs BES relied preferentially on services from City crews for sewer cleaning, investigation, inspection, and repair. However, for larger urgent or emergency projects BES Maintenance Engineering coordinated closely with BES

[4] *Hansen* refers to Infor Public Sector, © 2016 Infor. All rights reserved. www. infor.com

Engineering Services to conduct work under the Maintenance Capital Contract Program or emergency CIP projects.

City crews completed mainline sewer repairs totaling nearly 12,000 lineal feet. Approximately 66% of these repairs were considered to be unplanned. Repairs are considered unplanned if the work is in direct response to a collection system problem, such as a sewer release or surface cavity, or if the severity of the problem is significant enough to warrant the deployment of repairs within a week. The majority of planned repairs occur from either defects identified by the preventive maintenance CCTV inspection program or when additional repairs on a line are made in conjunction with an unplanned repair. Repairs on mainline sewers are localized spot repairs where pipe sections are excavated and replaced or renewed using cured-in-place pipe (CIPP) liners.

City crews completed over 550 service lateral repairs totaling approximately 8,300 lineal feet. Approximately 76% of these repairs were unplanned. Unplanned service lateral repairs are typically in response to a sewer system problem such as a sewer backup or a positive dye test from a sewer investigation. Planned service lateral repairs generally occur in conjunction with adjacent repairs on mainline sewers. Service lateral repairs typically involve the complete replacement of the lateral and the addition of a cleanout at the curb for improved future maintenance.

3.1.3 Root Management and Control Actions

Portland is renowned for its urban forest and must balance the need to protect both trees and sewer infrastructure. During FY 2016, BES Maintenance Engineering continued to manage the chemical root control program using third-party service providers who apply dense herbicidal foam that kills roots on contact without harming trees or surface vegetation. The City's Root Control Program uses a priority ranking system so that sewers with the greatest need for chemical root treatment are addressed first. During FY 2016, 253,630 lineal feet of mainline sewer were chemically treated for roots. In addition to chemical root foaming, City crews utilize mechanical root saws to locally remove roots in support of sewer inspection and cleaning activities as well as in response to sewer system problems.

3.1.4 Grease Management and Control Actions

In FY 2016 there were five sewer releases attributable to grease from the City-maintained sewer system. This very low number emphasizes the effectiveness of the Portland's program to control fats, oils, and grease (FOG), which was described in the *City of Portland Grease Management and Control Program* document that was included in the *CMOM Program Report*. In FY 2016 a total of 65,465 lineal feet of line was cleaned in the Accelerated Grease Cleaning areas, with approximately 20% of the lines receiving more than one cleaning.

The FOG management program has continued to proactively inspect food service establishments to ensure that grease interceptors are installed correctly, in a proper state of repair, and are cleaned at the proper frequency. FOG enforcement actions in FY 2016 are summarized in Table 11.

The FOG Coordination Team continues to meet quarterly to improve FOG-related activities performed by work groups responsible for FOG inspection and compliance, maintenance engineering, sewer cleaning and maintenance, pump station operations and maintenance, and asset management and data management. Based on CCTV inspection results and similar information, the FOG Coordination Team determines areas that are cleaned at an accelerated frequency.

The Pollution Prevention Plan Review Section is an important component of BES's control of FOG. In FY 2016 the Pollution Prevention Plan Review Section required 101 food service establishments to plumb all kitchen fixtures to grease interceptors per current Oregon Plumbing Specialty Code due to new development, redevelopment, or enforcement requirements.

Table 11 FOG Enforcement Activities in FY 2016

Description	Number	Requirement
Warning Notice	348	Increase grease removal device cleaning frequency
	85	Repair or replace grease removal devices
Notice of Violation with Civil Penalties/ Cost Recovery	21	Plumb all fixtures to a grease interceptor
	6	Establish City-required cleaning frequency
	4	Make required grease interceptor repairs

3.1.5 Rainfall Derived Inflow and Infiltration Assessment and Removal

BES uses detailed hydrologic models along with extensive flow monitoring to identify and quantify sources of rainfall derived infiltration and inflow (RDII). The *I&I Reduction Status Report* submitted annually to DEQ is developed in coordination with the City of Lake Oswego to comply with Schedule C, Compliance Conditions and Schedules, of the NPDES Permit for the Tryon Creek Wastewater Treatment Plant (TCWTP).

Additionally, in April 2016, the "Phase III Report on SW DeWitt SSO Control Project, Required under Mutual Agreement and Order (MAO): WQ/M-NWR-11-091, (BES E10273)" was submitted to DEQ. BES fulfilled Phases I and II of the MAO by completing investigations, public stormwater system improvements, and construction of early action projects to improve the sanitary sewer system (both public and private). For Phase III, BES evaluated the effectiveness of the SSO controls using monitoring data over the winters of 2014 and 2015. The Technical Memorandum, dated April 27, 2016, documents RDII reduction effectiveness of 57% in the Middle Hillsdale project area and 73% in the Upper Hillsdale project area.

BES has recalibrated the Fanno Basin Hydrology and Hydraulic Model to better characterize sewer catchments with high RDII. Next steps in the Fanno basin are to perform alternatives analysis and update the recommended plan to reduce RDII.

BES is also working with Clean Water Services on a coordinated predesign to arrive at a plan to identify and address the RDII in the southern sewer basins of Portland that drain to their system. These sewer basins are Metzger, Elmwood, and Locust. BES and Clean Water Services are currently performing sewer flow monitoring and hydraulic modeling for these basins.

RDII Program projects for FY 2017 include:

Middle Hillsdale RDII Pilot Project – Laterals – this project is scheduled to bid in August 2016 and will initiate construction in the winter of 2017 to rehabilitate 170 laterals including the private portion.

3.1.6 Manhole Inspection

BES initiated implementation of the second tier of the risk-based manhole inspection in FY 2016, which was described in the *Collection System Inspection and Cleaning Plan* submitted to DEQ in December 2012. Tier 2 manhole inspections are more detailed in nature than the routine Tier 1 manhole inspections performed during inspection of associated mainline sewers. The Tier 2 manhole inspections focus on the manholes considered to be at the greatest risk of failure, prioritized by age and material. The Tier 2 manholes are primarily those constructed of brick and monolithic concrete. In FY 2016, 814 Tier 2 manhole inspections were completed. No significant defects were found during these inspections. Tier 2 inspections will continue in FY 2017 with a crew dedicated to this work.

3.1.7 December Storm Emergency

The City of Portland is accustomed to rain and has programs and procedures in place to deal with winter storms. Nevertheless, December 2015 was particularly challenging. Severe winter storms, flooding, and landslides during the period from December 6-23, 2015 resulted in a Federal disaster declaration in Multnomah and other Oregon counties. For the first time since 1996, the Incident Command Center at the Portland Bureau of Transportation was activated in response to flooding and other storm damage throughout the city. The storm began in the morning on December 5 and continued for 9 days, stopping on the night of December 13, 2015. Rainfall intensities peaked at around 1.5 to 2.3 inches in 6 hours on the morning of December 7.

Additional heavy rain occurred on December 16-19, peaking during the evening of December 17, 2015. Emergency crews and BES personnel responded during the storms and subsequently participated in damage assessment. The Federal Emergency Management Agency is providing assistance on a cost-sharing basis for emergency work and the repair or replacement of facilities damaged by the storms.

Section 4 Sewer Release Analysis and Performance

The City of Portland's *Sewer Release Response Plan* (SRRP), submitted to the Oregon Department of Environmental Quality (DEQ) in December 2011 and adopted on January 1, 2012, establishes the process for responding to sewer releases from the City's combined and sanitary sewer system and reporting to DEQ as required by the National Pollutant Discharge Elimination System (NPDES) permit. The *CMOM Program Report* further describes the organizational structure for implementing the SRRP.

BES has a long history of implementing best management practices for collection system operation and maintenance to reduce the number and severity of sewer releases. Under the CMOM program, additional emphasis is placed on understanding why releases have occurred and how to prevent future releases.

4.1 Sewer Release Tracking and Reporting

The BES Spill Protection and Citizen Response (SPCR) Section is responsible for coordination of the overall response to sewer release events, maintaining official City sewer release records, and reporting releases to DEQ. BES SPCR routinely provides SRRP training to ensure that every report of a sewer release is dispatched for immediate response and investigation, reported as required by the NPDES permit, and documented completely and accurately. Each month SPCR prepares the report of sewer releases that is submitted to DEQ with the monthly discharge monitoring report for the Columbia Boulevard Wastewater Treatment Plant.

BES maintains sewer release data within the Hansen computerized maintenance management system (CMMS), allowing service call information to be connected with follow-up actions and work history of assets. Better data controls have been added to help manage work orders, such as more specific problem codes and standardization of planned and unplanned maintenance work types. Well-defined work order priority codes are used to ensure that work related to sewer releases receives top priority. The resources the City uses for operation and maintenance planning are explained in the *CMOM Program Report*.

BES has developed a standardized list of causes to facilitate tracking and analysis of sewer releases, as shown in Table 12. Additional terminology has been developed for weather-related sewer releases, as shown in Table 13, to more directly associate these releases with the City's levels of service established through the BES Asset Management Improvement Program.

Table 12 Sewer Release Cause Descriptions

Sewer Release Cause	Description
Structural Defect	Release caused by a physical failure of the pipeline
Equipment Failure	Release directly resulting from equipment failure typically either at a pump station or during a bypass pump around
Maintenance	Release caused by a City-related maintenance activity
Weather Event	Release caused by hydraulic capacity issues associated with weather (there are three subcategories described in Table 13)
Grease	Release caused by a blockage due primarily to grease
Debris	Release caused by a soft blockage due to sediment or other material
Roots	Release caused by a blockage due primarily to roots
Water Bureau Break	Water main break that surcharges the BES collection system
Cause Unknown	A release where the investigation does not identify a specific cause

Table 13 Weather-related Sewer Release Terminology

Term	BES Definition
Hydraulically overloaded system	Rainfall less than or equal to the 5-year, 24 hour storm (the BES level of service is to prevent sewer releases to surface waters for all storm events up to a 5-year frequency)
Extreme weather	Rainfall in excess of the 5-year, 24-hour storm but less than or equal to the 25 year, 6-hour storm
Force majeure	Rainfall exceeds 25 year storm (the BES level of service is to convey sewer to prevent releases to buildings or streets up to a 25-year storm frequency)

4.2 Sewer Release Key Performance Indicators

Striving for continuous improvement is a cyclical process of evaluating current practices, identifying needed improvements, and measuring performance. BES has developed a set of key performance indicators to gauge the effectiveness of the CMOM program.

4.2.1 SSOs per Hundred Miles of Pipe

SSOs provide a good measure of the overall effectiveness of maintenance programs for controlling roots, fats, oils, and grease, structural failures, and pump station performance. By tracking SSOs per 100 miles of sewer, BES has a succinct metric for gauging overall success toward minimizing SSOs.

As of the end of FY 2016, BES owned and maintained approximately 1,914 miles of main line sanitary and combined sewers, and 670 miles of sewer laterals. The City is typically responsible for maintaining the portion of the service lateral extending from the main sewer to the curb. During FY 2016, the City experienced 134 sewer releases over the 2,584 miles of collection system, which is approximately 5.2 releases per 100 miles of sewer.

Sewer release data is updated by BES SPCR as more complete information becomes available and investigations are conducted, and thus cause totals in this report to reflect current records. A comparison with previous fiscal years is shown in Figure 18.

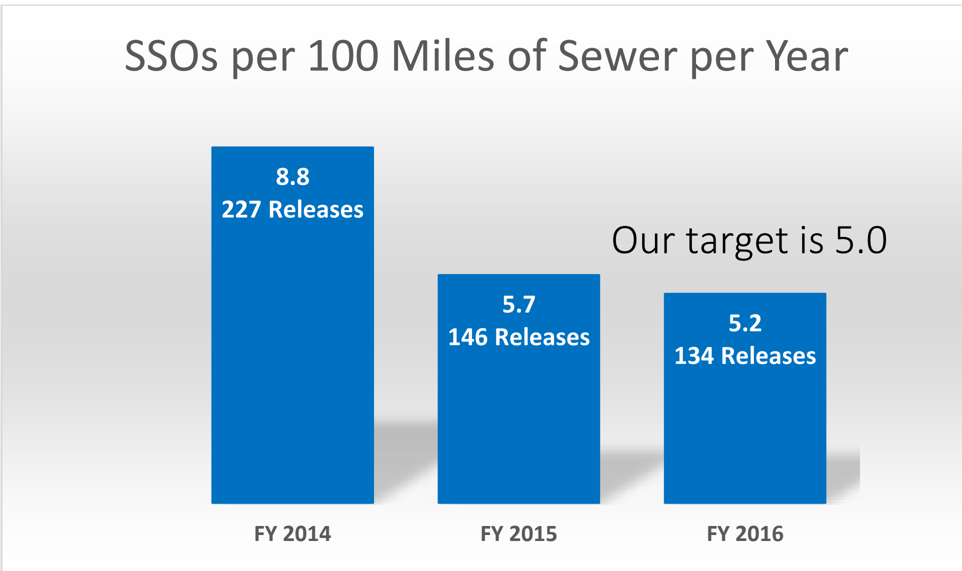


Figure 18 SSOs per Mile of Sewer

4.2.2 Response to Urgent Health and Safety-Related Service Requests

The City's goal is for a sewer emergency crew to be on site within 2 hours of receiving the initial call reporting an urgent sewer release. BES SPCR is responsible for maintaining electronic records of sewer releases, and their records are used to assess the response time of the on-site emergency crew. Under certain circumstances, such as when the caller is reporting a release that occurred in the past or is requesting to meet the City crew at a prearranged time, a sewer release is considered non-urgent, and the 2-hour on-site response goal does not apply.

Response time performance for FY 2016 is shown in Table 14. Response times were within the 2-hour response time target during all months except October and December, when response time was affected by the large number of calls associated with the severe storms on October 31 and December 7, 2015. A comparison with previous fiscal years is shown in Figure 19.

Table 14 SSO Response Time and Counts for FY 2016

FY 2016 Total Urgent Calls Sewer Release Calls	Number of Calls	Percent of Total
Urgent Calls with Response Time Less Than 2 Hours	397	87
Urgent Calls with Response Time 2 Hours or More	57	13
Total	454	100

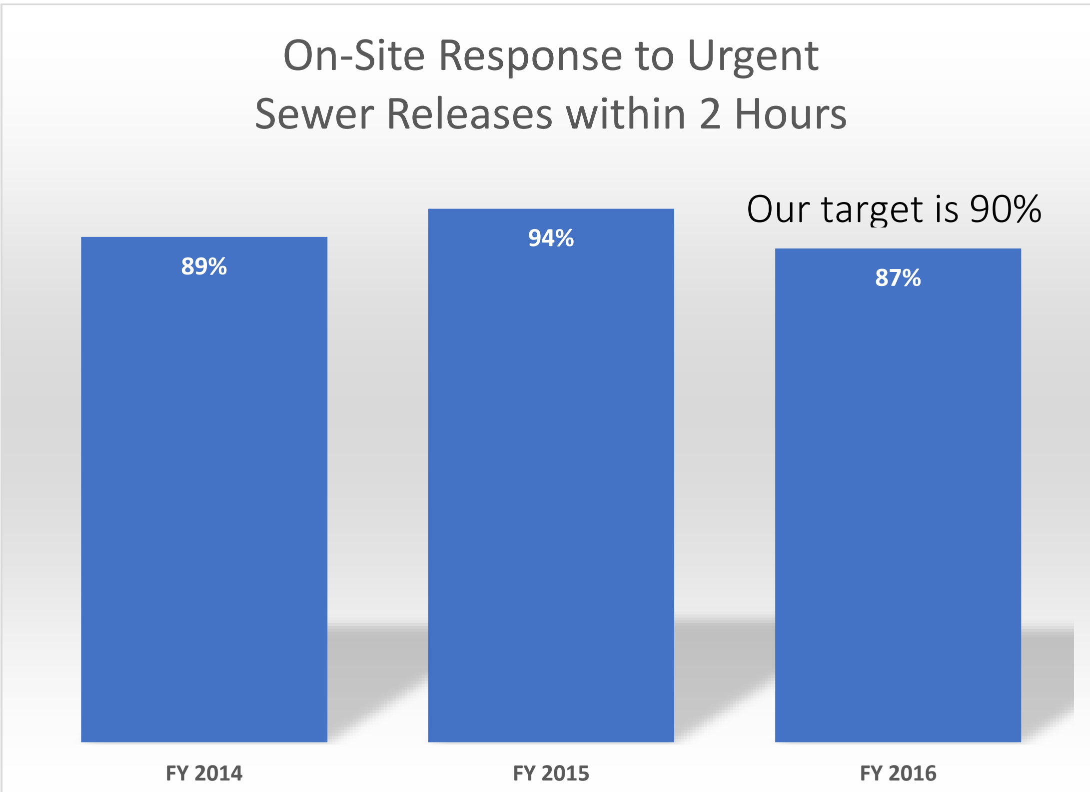


Figure 19 SSO Response Time Comparison

4.3 Analysis of Causes and Locations of Sewer Releases

During FY 2016, the City experienced 134 releases from the sanitary and combined sewer systems. There were 47 weather-related release events in FY 2016 that exceeded the design capacity of the collection system (referred to as *force majeure*) and were intentionally excluded for the purposes of analyses and tracking trends, although these releases were included in reporting to DEQ.

A chart comparing the causes of releases in FY 2014 through FY 2016 is shown in Figure 20. The release data shown are for releases due to problems in the City-maintained portion of the collection system (excluding releases due to causes resulting from problems in privately-owned sewers or laterals). The locations of the sewer releases in FY 2016 are shown on the map in Figure 21.

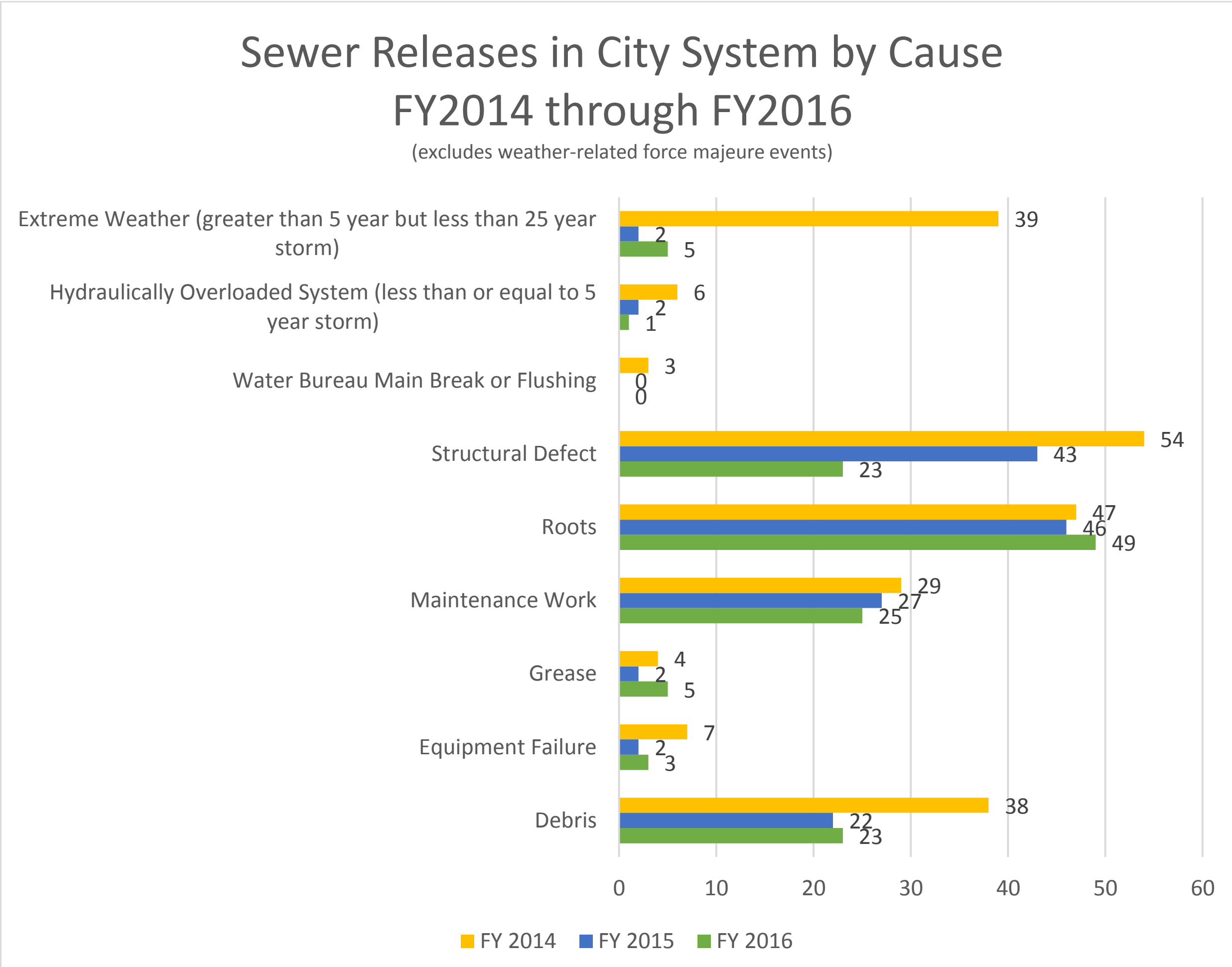


Figure 20 Comparison of Causes of Sewer Releases in FY 2014 through FY 2016

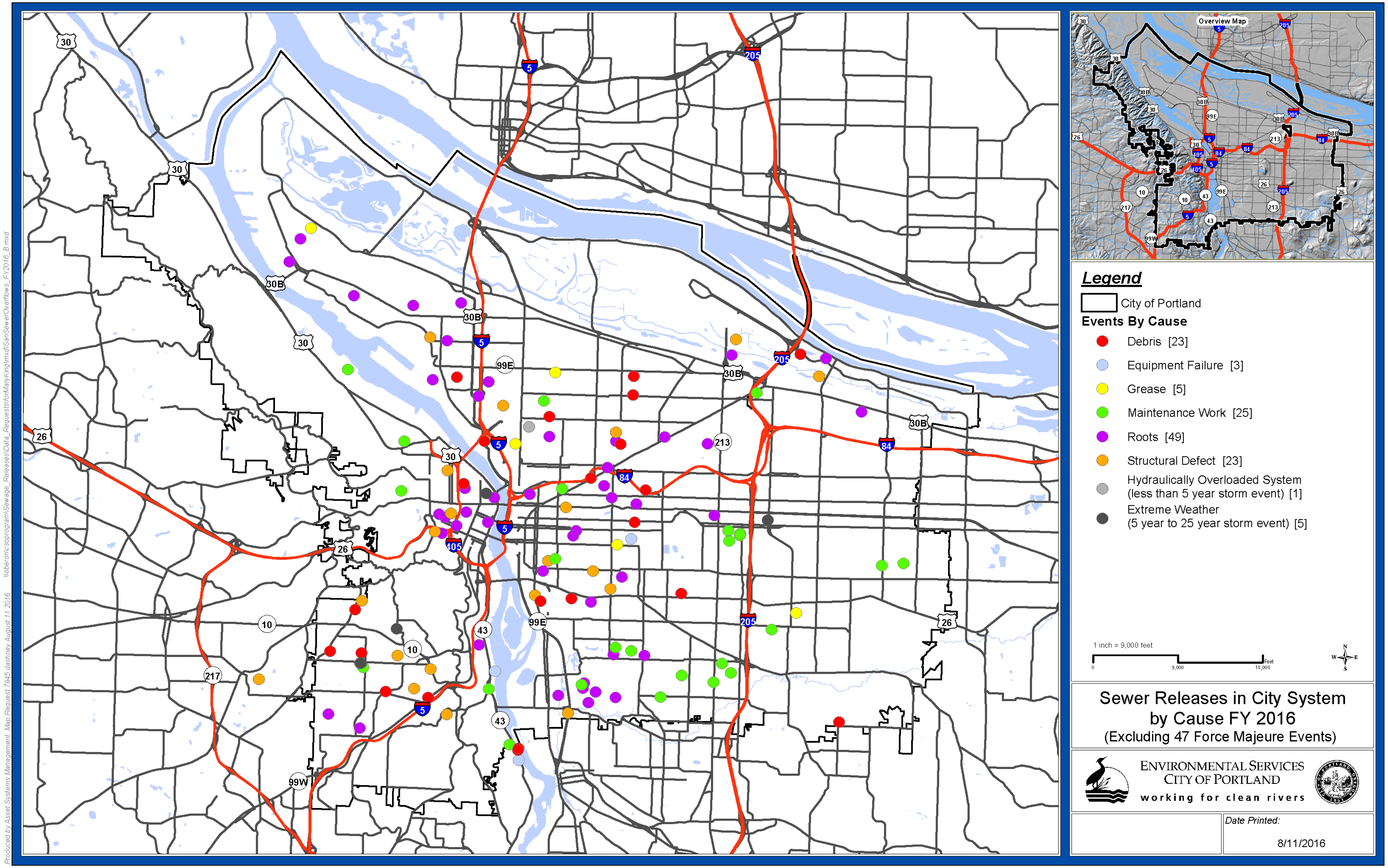


Figure 21 Sewer Releases in City System by Cause, FY 2016

Several factors may explain the decrease in the number of releases. Compared to previous fiscal years, more releases caused by weather events exceeded the 25-year storm frequency and thus were designated *force majeure*, and intentionally excluded, as previously noted. Compared to 47 *force majeure* release events in FY 2016, there was only one *force majeure* release event in FY 2014 and 15 in FY 2015. The majority were associated with the October 31 and December 7, 2015, storms. Although the severe storms, flooding, and landslides contributed to structural damage to the collection system, there were fewer releases from debris than might typically be expected due to storm debris entering the combined sewer system.

In addition to the rigorous investigatory research conducted by BES SPCR to determine the cause of sewer releases, improvements have been made to facilitate the use of the Hansen CMMS to track initial and actual problem codes on work orders. This enhanced capability provides a clearer understanding of the underlying reasons why a problem occurred or why work on (or near) an asset was required. For example, a work order may have an initial problem code "REL" for a release, or "SBU" for a sewer backup such as a plugged line. An actual problem code such as "GRS" (for grease) or "ROOTS" is also recorded on the work order and is typically based on the findings of the field crew, supervisor, or engineer.

These problem codes supplement the City's customized coding system used to characterize CCTV operators' observations and the degrees of severity (for structural defect, debris, roots, grease, etc.), as explained in the *CMOM Program Report* and the *Collection System Inspection and Cleaning Plan*. This broader array of information sources will become more useful over time, as asset histories can be more closely aligned with system performance.

Structural Defects. The number of releases from structurally defective laterals decreased from 34 in FY 2014 to 29 in FY 2015, and decreased again in FY 2016 to 10. Use of more effective lateral launch CCTV equipment has enabled City crews to become more efficient at investigating laterals. However, the work tends to be reactive in response to problems and does not match the effectiveness of preventive maintenance inspections for proactively identifying and prioritizing problems in sewer mains and manholes. Nonetheless, the risk of releases associated with structural defects should continue to decrease as the large number of sewer repair, rehabilitation, and replacement CIP projects currently in design or under construction are completed.

Maintenance. In FY 2016, there were 25 releases associated with maintenance activities, compared to 29 in FY 2014 and 27 in FY 2015. Seventeen releases were associated with sewer cleaning operations; most of these releases were "bowl water" from toilets and the volume was less than 10 gallons (one of these releases was attributed to a BES contractor jetting a line during a sewer repair project). While precautions are taken to prevent these "blow back" occurrences, some private plumbing systems lack adequate venting and the configuration of some City sewers makes it very challenging for cleaning equipment operators to work in some locations. In an ongoing effort to prevent sewer releases during cleaning operations, City sewer cleaning crews attended an 8-hour training in February 2016 that addressed proper Vactor® procedures and safety, as well as equipment maintenance and operation. Special precautions, such as using cleaning nozzles with steeper jet angles and running lower pressures, are taken in areas prone to blow back.

Eight maintenance-related releases were associated with sewer repairs. One release occurred when a City sewer repair crew encountered unstable soils during sewer lateral repair. Another was due to a crushed temporary lateral during construction conducted by a BES contractor. Three releases occurred when sewer lines were damaged during maintenance activities conducted by the City's Water Bureau, in addition to one repair conducted by the Water Bureau after a sewer repair crew hit a water line. Two releases were associated with flow-diversion activities conducted by BES contractors (one because of a pump-around failure and the other when approximately ten gallons of sewage was released out of the top port of a tanker truck during force main rehabilitation).

Debris. There were 23 releases caused by debris in FY 2016, down from 38 in FY 2014 and compared to 22 in FY 2015. Considering the severity of winter storm flows, which would typically carry storm-related debris into the combined sewer system, this low number appears to validate the effectiveness of the City's risk-based approach to sewer cleaning, which includes accelerated frequency of cleaning sewers that have a higher potential for sediment and debris accumulation. Additionally, BES has continued to conduct public outreach to try to minimize sewer backups and releases associated with disposable wipes and similar products, such as the utility bill insert at https://www.portlandoregon.gov/bes/article/578811.

Roots. During FY 2016, of the 49 releases caused by roots, 15 were in sewer mainlines and 34 were in service laterals. The majority of laterals where releases occurred in FY 2016 have been repaired by City crews using CIPP liners, or were excavated and replaced, thereby reducing the risk of future root intrusion.

4.3.1 Sewer Releases to Surface Water in FY 2016

Sewer releases to surface water occurred at nine locations in FY 2016. The circumstances of these release events are described below.

7643 SW 25th Avenue (release to Tryon Creek): During an ongoing investigation conducted as part of the Illegal Discharge Detection and Elimination Program, on July 27, 2015 BES was able to identify a defective main sanitary sewer that was leaking sewage, through the ground, to a nearby storm sewer near 7643 SW 25th Avenue. The storm sewer leads to an outfall that drains to Tryon Creek. The volume of the release was unknown but assumed to be greater than

400 gallons. City crews lined the defective main sewer on July 28 and the sewage release was stopped at that time.

10150 SW Riverside Drive (release to the Willamette River): On November 8, 2015, debris in the main sewer in SW Macadam Avenue caused flow to backup and surcharge a private manhole in a driveway. Maintenance crews estimated that approximately 1,020 gallons of sewage flowed into the river from a stormwater outfall pipe. The line segment was cleaned and the debris blockage removed on November 8, 2015. A closed circuit television (CCTV) inspection was conducted on November 10, 2015 and no structural or line condition issues were identified.

8919 SW Lancelot Lane (release to North Ash Creek): On November 18, 2015, a City field crew responded to an odor complaint and discovered a leaking sewer line at 8919 SW Lancelot Lane. The crew observed sewage seeping from the ground in a vegetated area in the backyard of that residence at the rate of about 20 gallons per minute. Sewage was observed running into nearby North Ash Creek. An emergency response was initiated to mitigate the released flow. On the evening of November 18, 2015 the City installed a pump-around system to bypass the main sewer in that area. At 9:15 a.m. on November 19, 2015, a root ball was removed from the main sewer line at that location. A CCTV inspection of the main sewer was conducted on November 19, 2015 to assess the condition of the main sewer line. No defects were observed in the sewer line. It is likely that the root ball allowed sewage to build up in the main sewer line, and, due to the topography, it allowed enough head pressure to accumulate to force fluid out of the pipe joints. Once the blockage was removed, the head pressure was reduced, and the release stopped.

2400 SW Kanan Street (release to Fanno Creek): On December 7, 2015 the sanitary sewer overflow diversion structure at SW Kanan Street overflowed for the first time since it was constructed in November 2011. This structure drains to Fanno Creek and was built to address repeated sewage releases onto the surface of SW DeWitt Street near SW 25th Avenue, under a Mutual Agreement and Order negotiated with DEQ (discussed in Section 3.1.5). The overflow released sanitary flow into Fanno Creek during the most intense rainfall period of a significant (greater than 25-year) storm that lasted 9 days. City crews responded to the site and confirmed the overflow, placed sewage release warning signs, and collected *E. coli* samples.

12008 NE Inverness Drive (release to the Columbia Slough): On December 7, 2015 during heavy rains, an underground force main near the Inverness pump station failed, releasing approximately 1-million gallons of sewage onto the ground at that address. Sewage flowed onto an adjacent property operated by a trucking company. Sewage also flowed into the nearby Columbia Slough. At 12:44 p.m. on December 7, 2015, emergency crews shut off the sewage pumps, stopping the release. The release volume was calculated from a pump rate of 500,000 gallons per hour, for two hours. A Vactor® truck was used to recover as much material as possible. The cause of the release was the failure of a coupling on an auxiliary section of a force main, which has since been repaired.

4402 SW Shattuck Road (release to Ivy Creek): On December 14, 2015, sewage was observed coming from a manhole and flowing over a highly vegetated area and into Ivy Creek, a tributary of Fanno Creek. The volume of the release was estimated at 28,500-gallons. City emergency crews responded immediately and were able to relieve the blockage at 8:00 p.m. that evening. The cause of the release was a blockage in the main sewer line. The nature of the blockage is unknown, and CCTV shows no structural issue with the sewer line.

4720 SW Lowell Court (release to Ivy Creek): On December 30, 2015, sewage from a damaged sewer line (likely due to heavy storm flows) flowed into Ivy Creek. The estimated volume was 11,250 gallons. The main sewer was repaired with PVC pipe, which stopped the release. BES plans to stabilize the soil around the sewer pipe and is currently consulting with internal staff and regulatory agencies to obtain permits to complete the work.

200 SW Carey Lane (release to a stormwater inlet that drains to the Willamette River): On March 4, 2016, sewage was observed coming from a manhole near SW Macadam Avenue at SW Carey Lane. Sewage was flowing down the roadway to a stormwater inlet that drains to the nearby Willamette River. The volume of the release was estimated at 600 gallons. City emergency crews responded immediately and determined the release was occurring at an air release valve vault on the pressure main leading from nearby Riverview pump station. The crew vactored out the vault and shut the valve, stopping the release at 7:00 p.m. The cause of the release was the blockage of an air release valve by a rag. The rag interfered with the valve's float mechanism causing the valve to remain in the open position. The air release valve is regularly inspected and maintained on a monthly basis.

6235 SW 32nd Avenue (release to Fanno Creek): On April 1, 2016, the City responded to an odor complaint in the area of SW 33rd Avenue and SW Bertha but could not identify the source of the odor. Additional investigation was conducted, and on April 4, 2016 sewage from a sanitary sewer line at the rear of property at 6235 SW 32nd Avenue was observed coming out of a hillside in a ravine. The ravine serves as in-line detention storage of the creek, ponds water, and has a "beehive" overflow to a storm sewer that joins the main stem of Fanno Creek. City emergency crews responded to repair the damaged section of sewer line and the release was stopped at 3:00 p.m. on April 6, 2016. Due to the slope and the difficulty in accessing the site, maintenance crews hand-dug the repair. The damaged section of sewer line was removed and a 22-foot section of PVC pipe was installed as a temporary fix until engineering design can be completed and permits are obtained to replace the sanitary sewer and stabilize the slope to reduce risk to the sanitary sewer and restore the stream. During weekly follow-up sampling, an *E. coli* sample collected just below the sewer line repair on June 6, 2016 indicated that a sewage release was occurring; an emergency crew responded to the site on June 7 and immediately stopped the release by applying quick-set grout to a leaking sewer line joint.

4.4 Conclusions and Follow-Up Actions for Sewer Release Reduction

The City of Portland's CMOM program is now being fully implemented. Shifting toward risk-based operation and maintenance of the collection system should, over time, result in a positive trend toward planned, proactive maintenance and fewer sewer releases. BES continues to develop and improve the Hansen CMMS to facilitate work prioritization and asset management in the gravity collection system. Although BES's CMOM program effectively incorporates the essential elements and best management practices for proper operation and maintenance of the collection system, analysis of sewer releases in FY 2016 has highlighted several opportunities for potential improvement.

Roots in service laterals receive some degree of treatment during application of root foaming agents in sewer mainlines; however, the amount of treatment varies and is not a reliable treatment for service laterals. Typically, when City crews repair service laterals because of releases caused by roots, cleanouts at or near the curb are routinely installed to facilitate future maintenance, including chemical root treatment.

The majority of structurally-defective laterals where releases occurred in FY 2016 have been repaired by City crews using CIPP liners or were excavated and replaced. To proactively prevent sewer releases from laterals, CIP projects for replacement, repair, and rehabilitation of sewer mainlines also include inspection and repair/replacement of service laterals based on the risk of structural or operational failure. The City will continue to utilize opportunities for making cost-effective improvements to laterals.

BES anticipates that the number of releases attributable to structural defects will gradually decrease as CIP projects under construction and in design are completed. These projects to replace, repair, and rehabilitate collection system assets that pose the highest risk and consequence of failure will position the City to be better able to provide proactive rather than reactive maintenance. The methodology used for risk-based prioritization of CIP projects was presented in the *Collection System Assessment and Rehabilitation Plan* that was submitted to DEQ in December 2012.

Overall, continued implementation of the *BES System Plan—Combined and Sanitary Sewer Elements*, dated March 2012, will address condition and capacity risks in both the combined and separated sanitary sewer systems. The System Plan's consolidated system-wide approach for prioritizing reinvestment and business risk reduction through CIP projects should also reduce the potential for sewer releases.

Section 5 Maximization of Storage in the Collection Systems

One of the Nine Minimum Controls, *Maximization of Storage in the Collection Systems* ensures that combined sewage is kept within the sewer system using existing in-system storage. This optimizes the volume sent to enhanced wet weather treatment, increasing the volume treated by the higher quality secondary processes and reducing the number and volume of CSO events. While this control originally focused on keeping sewers free of blockages, removing relatively clean stormwater from the collection system contributes to maximizing available storage and conveyance capacity. The programs documented here also have the added benefits of increased visibility of these efforts and public education opportunities.

5.1 Private Development and Redevelopment

BES's Stormwater Management Manual (SWMM) applies to all development and redevelopment proposals that create or redevelop over 500 square feet of impervious area.

In FY 2016, implementation of the SWMM in combined sewer basins led to construction of stormwater facilities at 1,129 properties, managing 112 acres of private impervious area.

City staff recently revised the SWMM to include an improved organization of the manual and minor technical changes. The changes will be effective in FY 2017.

5.2 Private Property Retrofit Program

Installation of stormwater facilities on private property continues in this program. Guided by BES's 2012 Combined Sewer System Plan and its Capital Improvement Program, this program researches opportunities with private property owners to voluntarily retrofit or install on-site stormwater facilities to keep runoff out of the combined sewers. The reduced runoff helps reduce local sewer capacity problems and reduce CSO volumes. For more information, see previous Annual CSO and CMOM reports (FY 2014 and FY 2015).

For FY 2016, 2.1 acres of impervious surfaces were managed by 34 private property stormwater retrofit projects. Two examples of this year's retrofits are shown in

Figure 22 and Figure 23 below.

Figure 22 FY 2016 Example Retrofit #1

Figure 23 FY 2016 Example Retrofit #2

5.3 Ecoroofs

Ecoroofs replace conventional roofing with a layer of vegetation over a growing medium on top of a synthetic, waterproof membrane. An ecoroof significantly decreases stormwater runoff, saves energy, reduces pollution and erosion, absorbs carbon dioxide, and reduces heat island effects.

The City of Portland strongly supports the installation of ecoroofs through the City's Green Building Policy, Stormwater Management Manual, and developer floor area ratio bonuses in specific portions of the city.

As of June 2016, Portland has over 460 ecoroofs installed throughout the city, managing almost 26 acres of roof. Approximately 300 of those ecoroofs are in the combined sewer area.

During FY 2016, 3 new ecoroofs were installed in the combined sewer area, managing approximately 0.3 acres of roof. This roof area represents 250,000 gallons of rainfall to the combined system annually, and Portland's monitoring data indicate that approximately 125,000 gallons are retained by the roofs and returned to the atmosphere through evapotranspiration.

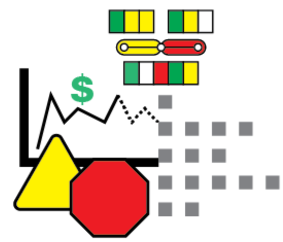
5.4 Public Right-of-Way Development and Redevelopment

As of June 2016, Portland has implemented over 1,600 green streets in the right-of-way, with approximately 910 in the combined sewer area. The Post-2011 Combined Sewer Overflow Facilities Plan identifies specifically how Portland will continue to implement both public and private stormwater controls to further reduce stormwater entering the combined sewer system and thereby increase the storage available for capturing CSO discharges.

During FY 2016, 47 new green street facilities were installed in the combined sewer area. The projects were implemented by a variety of private developers, CIP-budgeted cost-beneficial combined sewer system plan projects, and PBOT projects that required stormwater management. Collectively, these facilities manage approximately 5.2 acres of impervious area that generates 5.2 million gallons of stormwater to the combined sewer system annually. Based on the City's performance monitoring of green street facilities, these facilities will remove approximately 3.6 million gallons of runoff annually from the combined sewer system through infiltration and evapotranspiration.

Section 6 System Reinvestment and Risk Reduction

The City of Portland, Bureau of Environmental Services' asset management program focuses on assessment and mitigation of asset failure risk. The *System Plan: Combined and Sanitary Elements* (2012) recommended rehabilitation and system improvements that reduce risk. This section discusses the factors the City uses to value existing risk in the collection system and how investments guided by the *System Plan: Combined and Sanitary Elements* are effectively reducing risk to meet levels of service.



6.1 FY 2016 Reporting Methodology, Changes and Improvements

The Bureau uses CCTV inspections and computer hydrologic and hydraulic models to assess pipeline structural condition risk and capacity risk respectively. These methods support reliability-centered maintenance to keep assets functioning, and they provide information to prioritize capital reinvestment in the collection system for rehabilitation and replacement.

The general approach assigns each pipe a structural condition grade, generally identified through CCTV inspection, ranging from 1-5, with condition grade 5 being the most structurally deficient. A *remaining useful life* is assigned to a pipe based on its condition grade. This corresponds to how soon or likely a pipe is expected to fail, often referred to as the *likelihood of failure*. Additionally, the specific location and depth of the pipe and its proximity with other uses, such as streets and buildings, are used to determine a *consequence of failure* should the pipe fail before planned repairs can take place. The risk calculations associated with the combination of the likelihood and consequence of failure are used to prioritize pipe repairs. This helps ensure that pipes with the most significant near-term risk to the system are fixed first.

Hydrologic and hydraulic models are used to evaluate the existing pipe systems' ability to convey design flows in accordance with Bureau service level standards. These standards include information on minimum requirements for handling peak flows and measures to mitigate basement backup risk to customers.

The four major factors determining how system risk changes over time are:

1. **Capital Reinvestment:** Capital projects reduce risk by repairing or rehabilitating existing assets, or introducing new ones, in order to reduce capacity (level of service) risk and structural (mortality) risk in the system.

2. **Maintenance and Repair:** Maintenance staff complete targeted repairs to reduce localized structural risk or oversee emergency replacements and rehabilitation on high- risk assets.

3. **System Age:** Pipe assets are designed with an anticipated service life. As a pipe continues to age, its remaining useful life relative to its service life decreases and its potential risk of failure will increase. CCTV inspections provide a mechanism to update an asset's remaining useful based on actual pipeline condition. Updates to a pipe's remaining useful life may increase that pipe's risk, meaning that they predict a failure is more likely occur prior to the pipe's anticipated service life. Likewise, an inspection may result in decreased risk by predicting that a pipe will fail at some year beyond its anticipated service life.

4. **Unexpected changes to hydrologic conditions:** BES hydrologic models use planning information to predict future development conditions so that asset designs provide sufficient hydraulic capacity. Future conditions are largely defined by the City's currently adopted Comprehensive Plan. In some instances, actual development may significantly differ from what was projected in the Comprehensive Plan, resulting in an increase or decrease to the capacity risk of a set of assets.

The BES risk methodology calculations account for each of the risk factors identified above.

6.2 FY 2016 Activity for Risk Reduction

Risk reduction is the result of timely investment in repairing or replacing infrastructure to extend the useful life of assets. This activity may result in the reduction of likelihood of failure and/or consequences of failure.

6.2.1 Risk Change Due to Capital Improvements and Inspections

During FY 2016, the City of Portland completed 11 structural rehabilitation and capacity improvement projects within the sanitary and combined sewer collection systems. Three of these projects were exclusively lateral repairs for mitigating rainfall-derived infiltration and inflow. The other 8 projects repaired and rehabilitated 221 sanitary and combined sewer gravity mains.

CIP projects resolve both capacity and structural risk. To quantify structural risk reduction, this report uses *net structural benefit*, which compares the risk to a pipe before and after repairs or replacements are made. When a repair or replacement is completed, the pipe's condition is reset and the remaining useful life is adjusted. The net structural benefit is analyzed over time to account for the changed remaining useful life. Table 15 summarizes the reduction in risk achieved in FY 2016 through CIP projects. This risk reduction includes only the value added back to the system in terms of failure avoidance and the assets' revised remaining useful life figures.

Table 15 Risk Change Due to Capital Improvement Projects with Available Data

Type	Value
Total Risk Reduction Due to CIP Investment in Repaired/Replaced Pipe	$35,549,000

6.2.2 Risk Change Due to Maintenance Activity

Risk reduction due to maintenance activity is a result of maintenance crews performing localized repairs on sewer mains and the replacement of service laterals. Specifically, the Hansen system shows approximately 12,000 lineal feet of work on sewer main assets for the reporting period, and 427 sewer laterals replaced. Table 16 summarizes the risk reduction in FY 2016 associated with collection system maintenance and repair.

Table 16 Risk Change Due to Maintenance Activity with Available Data

Type	Value
Total Risk Reduction Due to Maintenance Activity	$10,785,000

Appendix A CSO Event History

When reporting on "how has the Portland CSO system performed," the City of Portland usually refers to the number of events and the size of overflows that have occurred since the system became fully operational in December 2011. From that standpoint, BES has validated and reported 17 permitted events from the Willamette River and Columbia Slough facilities.

Prior to December 2011, the Amended Stipulation and Final Order from DEQ required the City of Portland to eliminate the majority of overflows to the Columbia Slough by December 1, 2000. Another 16 outfalls (represented by a mix of outfalls from the West Side and East Side of the Willamette River) were controlled by December 1, 2006.

Columbia Slough CSO Events since October 2000

Table 17 presents the CSO events to the Columbia Slough since the Columbia Slough CSO system became fully operational in October 2000. The single FY 2016 event is in the bold box below. Winter events are shaded in blue, and summer events are shaded in yellow. All events were in compliance with the requirements of the NPDES permit at the time.

Table 17 Columbia Slough CSO Events since October 2000

CSO Discharge Events			Storm Characteristics			System Totals		West Side Totals	
Event #	Dates of Storm / Overflow Events	Description	6-Hour Rainfall (inches)	12-Hour Rainfall (inches)	24-Hour Rainfall (inches)	Overflow (MG)	Duration (hours)	Overflow (MG)	Duration (hours)
1	May 26, 2012	> 100-year, 30-minute storm	-	-	-	0.022	0.20	0.022	0.20
2	December 5-13, 2015	25-year, 3-6 hour storm	2.04	2.61	3.19	0.01	0.15	0.01	0.15

Willamette River CSO Events from December 2006 to December 2011

Table 18 presents the CSO events to the Willamette River since the West Side Willamette River CSO Tunnel became fully operational in December 2006 until the full Willamette system became operational in December 2011. Winter events are shaded in blue, and summer events are shaded in yellow. All events were in compliance with the requirements of the NPDES permit and the 1994 Amended Stipulation and Final Order in effect at the time.

Table 18 Willamette River CSO Events, December 2006-December 2011

CSO Discharge Events*			Storm Characteristics			System Totals		West Side Totals	
Event #	Dates of Storm / Overflow Events	Description	6-Hour Rainfall (inches)	12-Hour Rainfall (inches)	24-Hour Rainfall (inches)	Overflow (MG)	Duration (hours)	Overflow (MG)	Duration (hours)
1	Dec 14, 2006	4-per-Winter Storm	0.82	1.17	1.60	66.85	18.37	66.85	18.37
2	Jan 3, 2007	4-per-Winter Storm	0.69	1.04	1.54	5.15	4.35	5.15	4.35
3	Dec 2-3, 2007	> 5-year 24-hour Winter Storm	0.97	1.76	3.09	154.5	26.85	154.5	26.85
4	Nov 12, 2008	4-per-Winter Storm	0.76	1.02	1.38	8.1	4.1	8.1	4.1
5	Jan 1-2, 2009	5-year Winter Storm	1.12	1.52	2.73	122.60	21.58	122.60	21.58
6	May 4, 2009	3-year Summer Storm (3-6 hr duration)	0.94	1.02	1.18	5.26	1.05	5.26	1.05
7	Nov 7, 2009	2-per-Winter Storm	0.93	1.22	1.51	9.60	2.92	9.60	2.92
8	June 6, 2010	3-year Summer Storm	1.07	1.25	1.43	26.02	3.08	26.02	3.08
9	Nov 17, 2010	1-per-Winter Storm	1.03	1.56	1.77	11.48	5.58	11.48	5.58
10	Dec 8-12, 2010	5-year Winter Storm	1.43	1.52	2.34	41.82	8.92	41.82	8.92
11	Dec 28, 2010	2-per-Winter Storm	0.57	0.89	1.58	6.85	5.50	6.85	5.50
12	Jan 15-16, 2011	1-per-Winter Storm	0.94	1.21	2.13	26.27	8.92	26.27	8.92
13	Feb 27-Mar 4, 2011	1-per-Winter Storm	1.15	1.70	2.41	75.98	28.25	75.98	28.25
14	Nov 21-23, 2011	5-year Winter Storm	1.44	1.66	2.24	115.96	6.25	115.96	6.25

Willamette River CSO Events since December 2011

Table 19 presents the CSO events to the Willamette River since the Willamette River CSO Tunnel system became fully operational in December 2011. FY 2016's events are listed in the bold box below. Winter events are shaded in blue, and summer events are shaded in yellow. All events were in compliance with the requirements of the NPDES permit at the time.

Table 19 Willamette River CSO Events since December 2011

CSO Discharge Events*			Storm Characteristics			System Totals		West Side Totals		East Side Totals	
Event #	Dates of Storm / Overflow Events	Description	6-Hour Rainfall (inches)	12-Hour Rainfall (inches)	24-Hour Rainfall (inches)	Overflow (MG)	Duration (hours)	Overflow (MG)	Duration (hours)	Overflow (MG)	Duration (hours)
1	January 17-21, 2012	> 5-year 12-hour Winter Storm	1.48	2.15	2.32	304.90	10.30	86.40	10.30	218.50	10.30
2	May 26, 2012	> 100-year, 30-minute Storm	-	-	-	0.17	0.42	-	-	0.17	0.42
3	November 17-21, 2012	5-year, 24-hour Winter Storm	1.22	1.65	2.44	176.40	9.50	44.00	9.50	132.40	9.30
4	November 24, 2012	3-per Winter, 24-hour Storm	0.61	1.09	1.49	0.50	0.80	0.50	0.80	-	-
5	May 23, 2013	3-year, 12-hour Summer Storm	0.90	1.22	1.50	26.30	2.30	11.90	2.30	14.40	1.80
6	September 27-30, 2013	10-year, 24-hour Summer Storm	1.20	1.41	2.08	88.50	7.00	27.00	7.00	61.50	5.40
7	March 25-30, 2014	2-per Winter, 12-hour Storm	0.89	1.26	1.53	43.10	3.00	14.30	3.00	28.70	3.00
8	June 15-16, 2014	3-year, 30-minute Summer Storm	-	-	-	0.03	0.20	-	-	0.03	0.20
9	October 22-23, 2014	10-year, 24-hour Summer Storm	1.42	1.68	2.11	69.4	3.92	13.41	3.50	56.00	3.92
10	December 4-6, 2014	5-year, 3-hour Winter Storm	0.95	1.37	1.56	1.6	1.57	0.05	0.27	1.52	1.57
11	January 17-18, 2015	1-per Winter, 24-hour Storm	0.97	1.50	2.04	91.6	7.98	15.15	6.75	76.43	7.98
12	March 14-15, 2015	1-per Winter, 48-hour Storm	1.05	1.80	2.41	78.9	6.48	16.61	5.92	62.31	6.48
13	October 30-November 2, 2015	50-year, 2-hour storm	1.94	1.98	2.55	190.5	6.35	30.24	4.88	160.05	6.35
14	November 16-17, 2015	1-per Winter, 1-hour storm	0.80	0.85	1.37	0.03	0.17	-	-	0.03	0.17
15	December 5-13, 2015	25-year, 3-6 hour storm	2.04	2.61	3.19	638.7	15.60	134.86	13.33	503.83	15.60
16	December 16-19, 2015	1-per Winter, 3-48 hour storm	1.11	1.56	2.37	145.8	11.00	26.79	9.70	118.99	10.30
17	May 19, 2016	3-year, 30-minute Summer Storm	-	-	-	0.02	0.18	-	-	0.02	0.18

Printed on recycled paper. WT 1614