Combined Sewer Overflow Program

Long-Term Control Plan

Volume 4
Phase 1 Flow Monitoring Report

2008–2009

RESTORE OUR WATERS
SEATTLE PUBLIC UTILITIES
COMBINED SEWER OVERFLOW REDUCTION

December 2010

SEATTLE PUBLIC UTILITIES
LONG-TERM CONTROL PLAN

VOLUME 4

PHASE 1 FLOW MONITORING REPORT
2008–2009 WET SEASON

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Seattle, Washington

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This report has been prepared under the direction of a registered professional engineer

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LIST OF ABBREVIATIONS

ADS	manufacturer of flow meters such as the FlowShark and Pulse
A/V	area/velocity
City	City of Seattle
CSO	combined sewer overflow
CSS	combined sewer system
DAS	Data Analysis (tool in ZFM2)
DDF	Depth-duration-frequency
DW	dry weather
DWF	dry weather flow
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
fps	feet per second
FTP	file transfer protocol
GIS	Geographic Information System
gpm	gallons per minute
LFD	low-flow diversion
LTCP	Long-Term Control Plan
MG	million gallons
mgd	million gallons per day
MH	maintenance hole
MLI	Monitor-Level Intelligence
MP	monitoring point
NPDES	National Pollutant Discharge Elimination System
PS	pump station
QAPP	Quality Assurance Project Plan
SCADA	supervisory control and data acquisition
SOP	standard operating procedure
SPU	Seattle Public Utilities
WW	wet weather
WWF	wet weather flow
ZFM2	software provided by Stantec for maintenance and analysis of flow data

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EXECUTIVE SUMMARY

This Seattle Public Utilities (SPU) Long-Term Control Plan (LTCP) Flow Monitoring Report (Report) documents the results of the Flow Monitoring project conducted within 12 combined sewer overflow (CSO) basins in SPU's combined sewer system (CSS). The 2-year Flow Monitoring project began on 10/1/2008 and continued through 5/31/2010. The data documented in this report was collected during the first year of the project, 10/1/2008 through 5/31/2009; consequently, this report is Volume 4 of 5 and is not intended to determine data suitability for final model calibration. Volume 5 of this report, which was completed after the second year of flow monitoring was completed on 5/31/2010, assesses the suitability of data collected at each meter for model calibration. Volumes 4 and 5 are combined with Volume 1, a summary report, and packaged as a combined report.

The goal of the CSO LTCP is to develop and submit to the Washington State Department of Ecology (Ecology) a single plan by July 2015 that performs the project development (monitoring, modeling, and planning) and preliminary engineering for all of the City of Seattle (City)'s CSO basins. The LTCP will identify an approved list of CSO reduction projects that will be carried into design and construction in the future to meet the City's required CSO reduction targets. The goal of the LTCP Flow Monitoring project is to collect continuous rainfall depth, level, velocity, and operational data in the CSS for two wet seasons, 10/1/2008 through 5/31/2010. The collected data must accurately represent the conditions throughout the CSS. The data will be used to characterize the hydrologic and hydraulic performance of the CSS and support development of the LTCP.

Flow monitoring is the collection of simultaneous measurements of velocity and depth (which are used to compute flow), as well as rainfall and operational data, at strategic points within the system. The objectives of the LTCP Flow Monitoring project are as follows:

- Adequately and accurately characterize the hydrologic and hydraulic performance of the CSS by collecting rainfall depth, level, velocity and operational data.
  - Hydrologic performance is defined as the hydrologic response of a subcatchment to rainfall.
  - Hydraulic performance is defined as the operating characteristics of structures and facilities in the CSS, including in-line and offline storage, HydroBrakes, gates, weirs, diversions, regulators, and pump stations.
- Capture data before, during, and after a wide range of storm events with a range of antecedent moisture conditions. In terms of recurrence intervals this objective can be defined as a minimum of three storm events of recurrence interval between 6 months and 1 year at any duration, and a minimum of two storm events of recurrence interval between 1 year and 10 years at any duration spaced throughout the wet season.
- Recommend storm events for model calibration and future flow monitoring in the event that the desired storms do not occur during the project monitoring period.

The CSO basins included in the LTCP Flow Monitoring project are approximately 5,538 acres (8.65 square miles) in area and comprise 182 miles of the CSS (see Figure ES-1). To achieve the data objectives, approximately 150 temporary flow meters were installed and maintained from October 2008 to May 2009 throughout the basins. Additional data came from the following sources:

- 83 SPU-maintained permanent flow meters installed at NPDES outfalls
- supervisory control and data acquisition (SCADA) data from SPU pump stations associated with the CSO basins
- precipitation data from SPU's rain gauges (RGs) 02, 03, 05, 08, 09, 12, 15, 17, and 20.

To ensure the highest possible data quality, monitoring data were screened on a biweekly basis during the wet weather season. The screening focused on consistency and completeness of meter response. Data screeners noted anomalies, if any, which were then reviewed and resulted in action items for attention by the metering contractor if appropriate. In addition, monthly workshops were conducted to review the data for modeling suitability. These meetings focused on review of consistency of upstream and downstream meters (flow balance), flow response to rainfall, and the quality of the data for modeling purposes. These reviews resulted in removal and replacement of meters where suitable data could not be captured, and the identification of suitable and unsuitable portions of the data in locations where meter performance was challenged. Where data were still in question, detailed analysis of the monitoring site and meter response were conducted including installation of alternative flow meter technology when warranted.

Additional details on the screening activities and outcomes are contained in the monitoring plans (Volumes 2–3) and workshop presentations, which can be found in Appendix Q of Volume 5. Overall, these screening activities resulted in the collection of data that can confidently be used in model calibration.

During the first year of the project (10/1/2008 through 5/31/2009), seven rainfall events that range from less than 2.5-month to 20-year recurrence interval were identified as useful for model calibration. Of these, four had recurrence intervals generally less than 6 months. Such storms may be useful to characterize initial values of imperviousness in the sewersheds, but do not suffice for calibration of the longer winter storms, which typically generate overflows. One of the seven identified storms occurred in January 2009 preceded by considerable snowmelt. Snowmelt is difficult to accurately simulate in the models and this event may not be usable for calibration. One event in late May 2009 exhibited very high intensities in some areas of the city and low intensities elsewhere. High-intensity events may overload inlets to the CSS—limitations in the field, not perfectly represented in the model, can result in the model overestimating peak flows for such events. The late May event therefore may not be suitable for model calibration.

As a result, only two events are considered of broad application for model calibration; one in November 2008 exhibiting modest intensities but high volume, and one in early May 2009 with low antecedent rainfall, small volume, and intensities in the range of 6 months to 2 years. The project objectives require a minimum of three events with recurrence intervals between 6-months and 1-year, and two events between 1-year and 10-year recurrence with a range of antecedent conditions. The objectives were therefore not met in the first monitoring season and a second season is necessary to fill in the range of storms needed and to finalize characterization of hydraulic structures. This additional data collection period (6/1/2009 to 5/31/2010) will significantly increase the accuracy of model calibration.

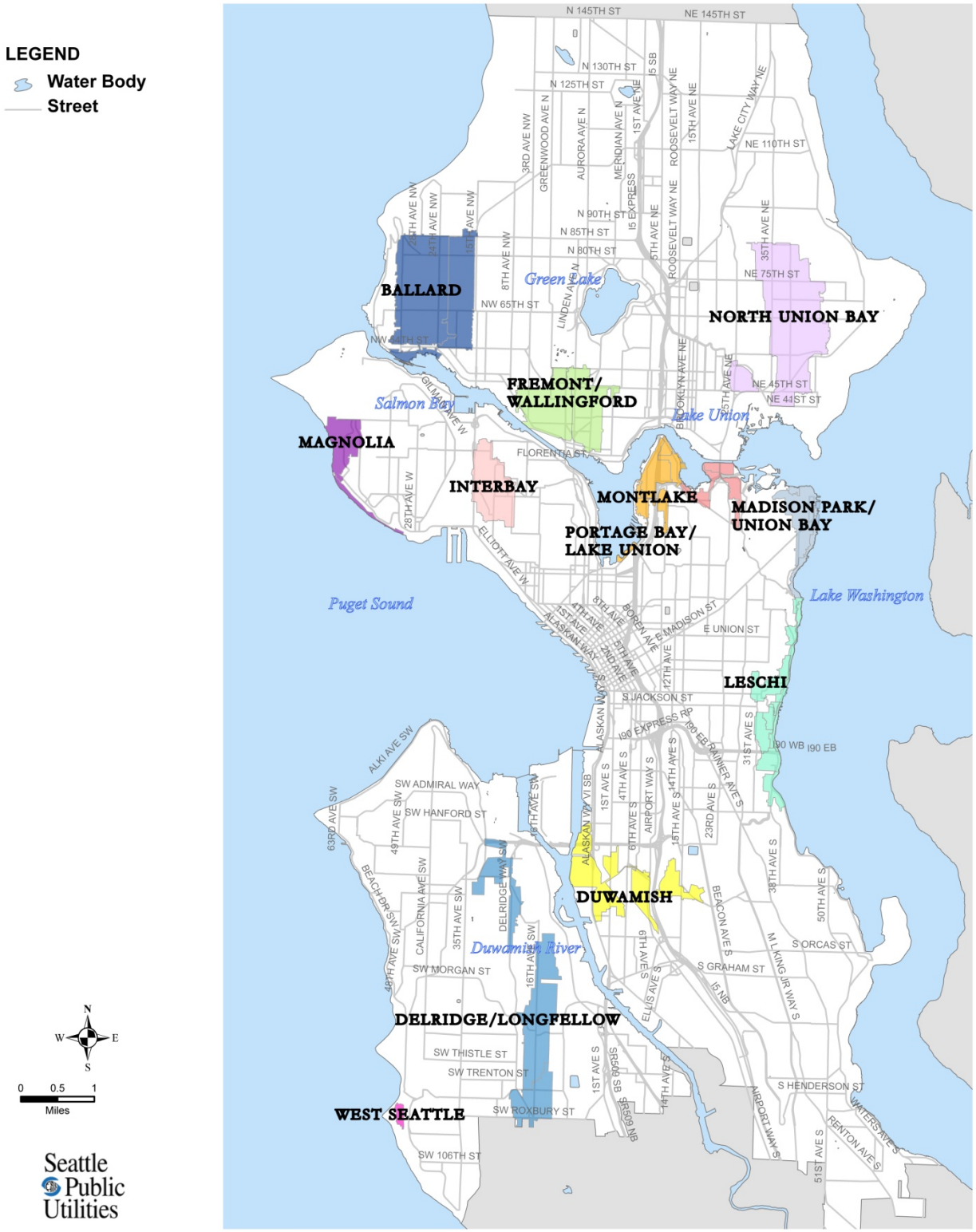

Figure ES-1. LTCP Long-Term Control Plan flow monitoring basins

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1. INTRODUCTION

Seattle Public Utilities (SPU) is currently in the process of implementing a program to reduce combined sewer overflows (CSOs). The Long-Term Control Plan (LTCP) will develop options to reduce CSOs in the most cost-effective manner. One of the requirements of the LTCP is to have accurate hydraulic models of the combined sewer system (CSS). SPU is undertaking flow monitoring of the CSS over a 2-year period to capture sufficient data to calibrate the hydraulic models. This data report covers Phase 1 of a three-part monitoring project. Phase 1 was conducted during the first wet weather season from 10/1/2008 through 5/31/2009. Phase 2 was conducted from 6/1/2009 through 9/30/2009, and Phase 3 was conducted from 10/1/2009 through 5/31/2010. The Seattle LTCP Flow Monitoring Report 2009 describes the monitoring that was undertaken, the quality of the collected data, and their suitability for use in the calibration of hydrologic and hydraulic models. Data collected for the Phases 2–3 monitoring period are discussed in a separate data report.

1.1 Goals

The goal of the CSO LTCP is to identify an approved list of CSO reduction projects that will be carried into design and construction in the future to meet the City's CSO reduction. The goal of the LTCP Flow Monitoring project is to collect continuous rainfall depth, level, velocity, and operational data in the CSS for two wet seasons, 10/1/2008 through 5/31/2010. This report summarizes Phase 1 of the monitoring from 10/1/2008 through 5/31/2009. The collected data must accurately represent the conditions throughout the CSS. The data will be used to characterize the hydrologic and hydraulic performance of the CSS and support development of the LTCP.

1.2 Monitoring Objectives

The objectives of flow monitoring are as follows:

- Adequately and accurately characterize the hydrologic and hydraulic performance of the CSS by collecting rainfall depth, level, velocity, and operational data. The adequacy and accuracy of data will be assessed using the criteria identified in Section 14.
  - Hydrologic performance is defined as the response of a subcatchment to rainfall.
  - Hydraulic performance is defined as the operating characteristics of structures and facilities in the CSS, including in-line and offline storage, HydroBrakes, gates, weirs, diversions, regulators, and pump stations.
- Capture data before, during, and after a wide range of storm events with a range of antecedent moisture conditions. In terms of recurrence intervals, this objective can be defined as a minimum of three storm events of recurrence interval between 6 months and 1 year at any duration, and a minimum of two storm events of recurrence interval between 1 year and 10 years at any duration spaced throughout the wet season.
- Recommend storm events for model calibration and future flow monitoring in the event that the desired storms do not occur during the project monitoring period.

1.3 Study Boundaries

The study area comprises 12 CSO basins located within the city of Seattle: Ballard, Delridge/Longfellow, Duwamish, Fremont/Wallingford, Interbay, Leschi, Madison Park/Union Bay, Magnolia, Montlake, North Union Bay, Portage Bay/Lake Union, and West Seattle. These basins occupy a total area of approximately 5,500 acres (8.5 square miles) and comprise a number of areas draining to an overflow point, which is designated by a National Pollutant Discharge Elimination System (NPDES) number. A CSS primarily serves these basins, which conveys wastewater and runoff from directly connected rooftops, streets, and area drains to the King County interceptor system and ultimately to the King County West Point Treatment Plant. The study boundaries include permanent flow meters at each of the NPDES sites in the basins, a network of temporary monitoring locations throughout the basins, and a network of rain gauges throughout the city. An overview of the study and the monitoring locations is shown in Figure 1-1 through Figure 1-4.

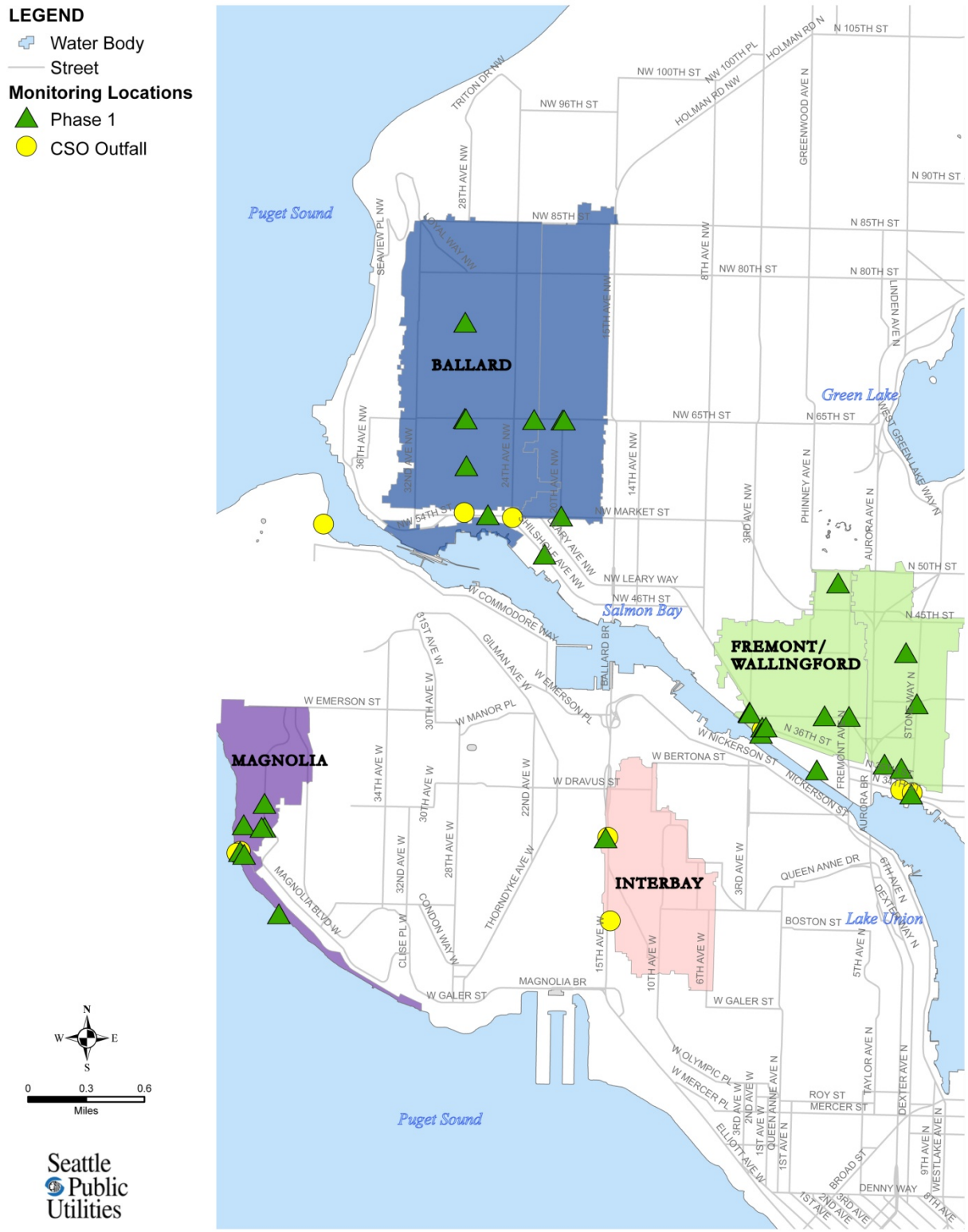

Figure 1-1. Basin overview map: Ballard, Fremont/Wallingford, Interbay, and Magnolia Basins

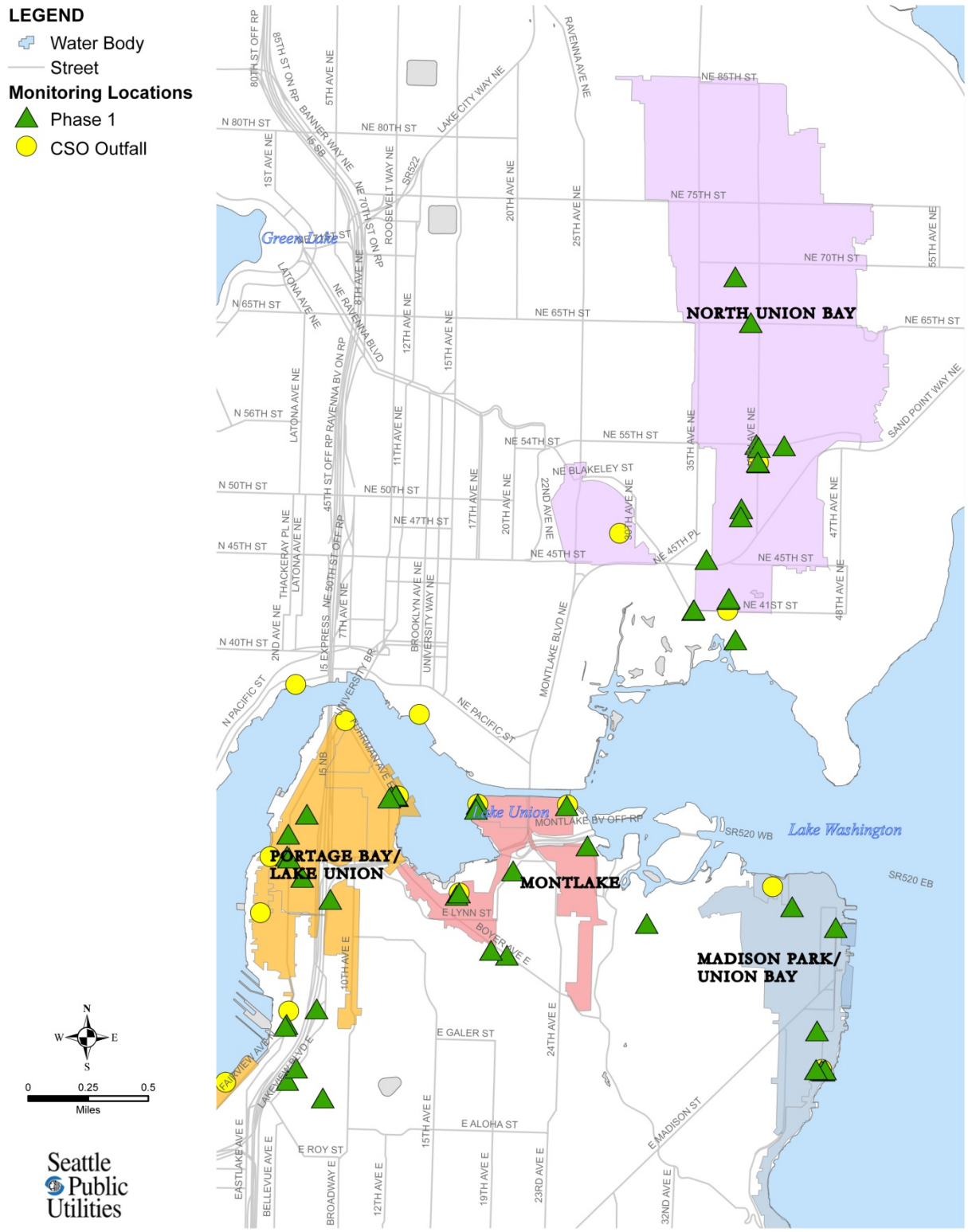

Figure 1-2. Basin overview map: Madison Park/Union Bay, Montlake, Portage Bay/Lake Union, and North Union Bay Basins

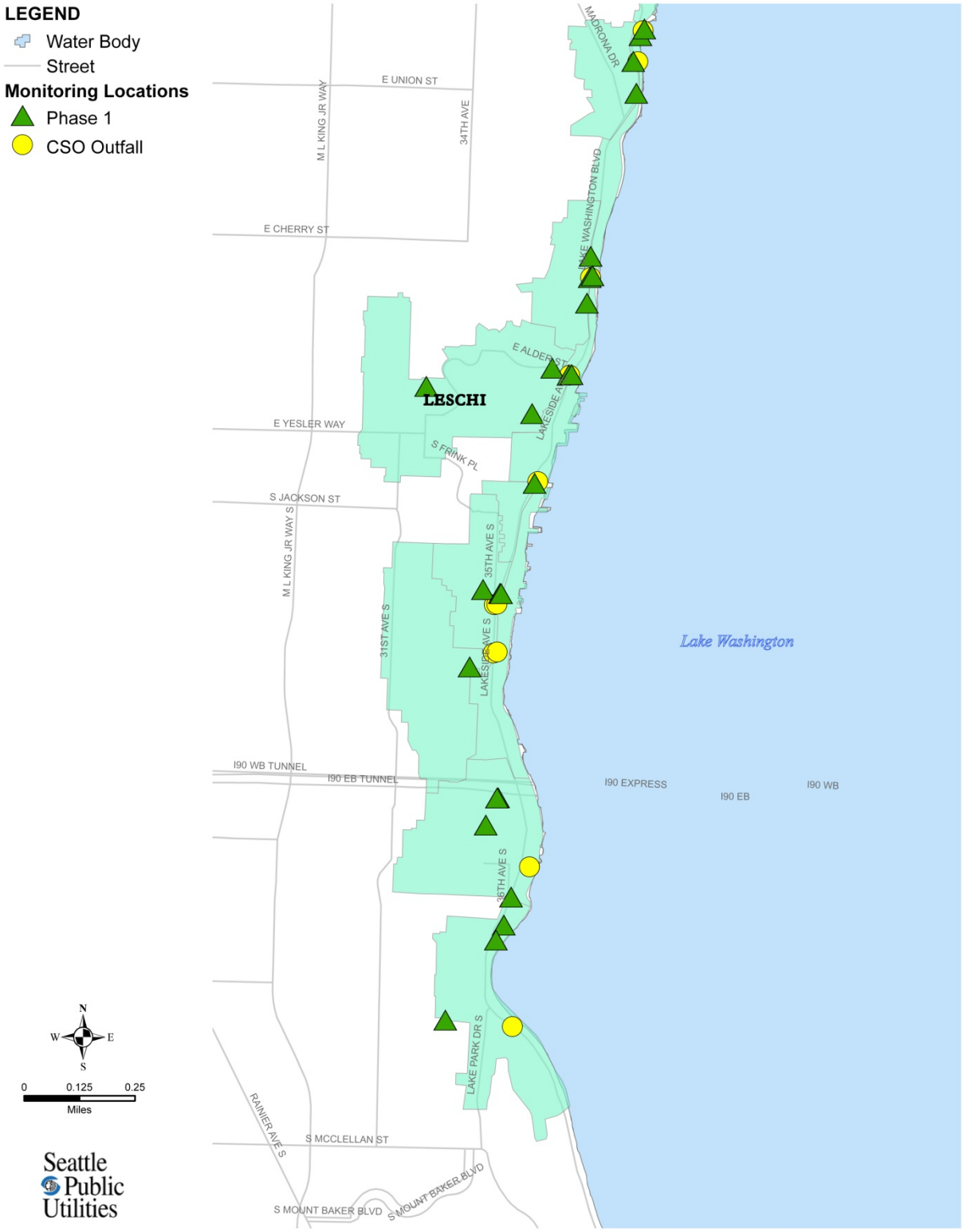

Figure 1-3. Basin overview map: Leschi Basin

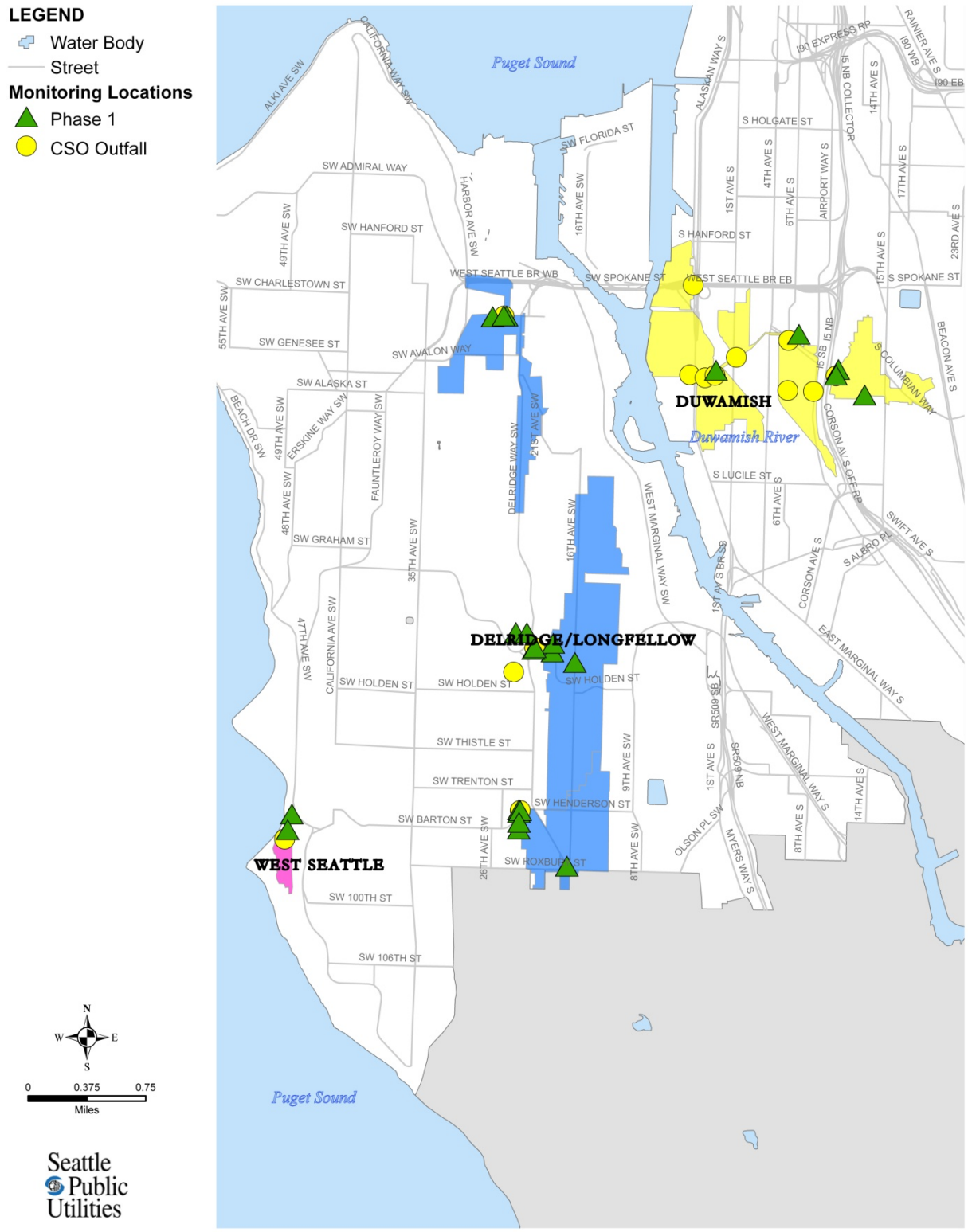

Figure 1-4. Basin overview map: Delridge/Longfellow, Duwamish, and West Seattle Basins

1.4 Report Organization

This report documents Phase 1 of data collection, from 10/1/2008 through 5/31/2009. The organization of the report is summarized below:

- **Section 1:** Introduction
- **Section 2:** Methodology
- **Section 3**: Monitoring Data
- **Section 4**: Suitability of Data for Hydrologic and Hydraulic Modeling Efforts
- **Section 5:** Conclusions

The appendices of this report contain data site sheets by basin that are meant to supply more quantitative information for each site. The data site sheets include the following information:

- purpose of each location
- site installation photos
- upstream pipe traces
- period meter installed and collecting data
- field-verified pipe diameter
- extent of scatter-of-depth and velocity data
- flow regime
- range of depth, velocity, and flow during monitoring period.

The data collected from all temporary sites are stored in a ZFM2 database developed by Stantec. The database also includes information such as silt/sediment measurements, field verification measurements, site maintenance, and data finalization notes for all temporary meters.

The data collected from NPDES-permitted CSO outfall monitors are stored on IntelliServe, a Web site database developed by ADS Environmental Services (ADS). The Web site contains information such as silt/sediment measurements, field verification measurements, site maintenance, and data finalization notes for all permanent meters.

The data from SPU rain gauges were collected by ADS and stored on IntelliServe. Data were also imported in the ZFM2 database for temporary meter comparison to rainfall.

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2. METHODOLOGY

This section provides an overview of the methodology used to monitor flow, rainfall, pump stations, and overflows in the CSS. More detailed information can be found in the *Quality Assurance Project Plan* (QAPP). *Long-Term Control Plan: Flow Monitoring Plan 2008–2009* (QAPP December 2009).

2.1 Monitoring Locations

This section presents a description of the different types of monitoring locations from which data were collected during the review period.

2.1.1 Permanent Monitoring Locations

The City has 90 currently active permitted CSO outfalls. The permitted outfalls have a total of 108 discharge points; for example, NPDES111 Basin has 8 overflow weirs discharging to the outfall pipe. ADS operates and maintains meters at 82 of the discharge points, utilizing 92 monitoring points (including redundant units to confirm overflow). These meters comply with the City's NDPES requirements for reporting CSO overflows to Ecology. The ADS meters cover 65 of the 90 permitted outfalls. The SPU pump station SCADA system monitors the rest of the permitted outfalls. As part of this LTCP monitoring review, 55 of the existing ADS monitoring points were reviewed for data quality.

Thirty of the permanent monitoring locations were expected to provide only depth data to identify and quantify overflow events. These meters were termed "wet weather" sites because they were used only to determine overflows. Twenty of the meters provided continuous depth and velocity information that was used to calculate both dry and wet weather flows. These meters were termed "dry weather" sites. ADS finalizes the velocity and computed flow data from these meters, which will be used in this project to characterize dry and wet weather flows within a basin and to supplement the information obtained from the temporary meters. In some of the smaller basins, the permanent meters were used to characterize the hydrology as well as structure performance. The wet weather and dry weather meters are designated in all the basin schematics in Appendix B as "DW" and "WW," respectively.

Details of the permanent meters used for this project, including their location, overflow condition, and meter type, are summarized in T-16 in the *QAPP/2008–2009 Flow Monitoring Plan, SPU CSO Reduction Program, CSO Long-Term Control Plan* (December 2009).

2.1.2 Temporary Monitoring Locations

In addition to the permanent monitoring locations, a total of 170 temporary sites were monitored. Stantec was responsible for installing and maintaining the temporary meters.

The meters were installed in locations that would divide the basins into monitoring subcatchments sufficient to characterize hydrology. Sites were also selected to provide data for the characterization of key structures (HydroBrakes, sluice gates, weirs, storage tanks, etc.) in the basins. During the course of the project, some temporary meters were removed if the project team determined that they had captured sufficient data or that the data captured were not suitable for model calibration. Hydraulic conditions at some initial sites were

found not conducive to accurate data collection. These meters were moved to alternate sites, either to capture better quality data or to characterize additional areas of the system or structures in the system.

Details of the temporary meters, including their location, meter type, and purposes, are summarized in T-17 in the Quality Assurance Project Plan (Seattle Public Utilities, July 2009).

2.1.3 SCADA Monitoring Locations

SCADA data were obtained from SPU pumping stations to supplement the calibration and verification of the model. These data consist of wet-well levels at a 1-minute data resolution and pump run time data. SCADA data were also collected from the detention tank and control structures in the Delridge/Longfellow Basin.

SPU also completed drawdown tests for the pumping stations to determine the capacities of the stations. The SCADA data and drawdown test results were used to calculate flow hydrographs for use in model calibration.

2.1.4 King County Monitoring Locations

King County maintains a network of flow meters throughout its trunk sewer system at pump stations and regulator stations. For purposes of model calibration, data from the existing King County meters associated with the LTCP monitoring basins were collected to supplement the data from temporary meters. The King County data are not assessed within this data report. Assessment of these data will be included in the final report after the Phases 2–3 monitoring period.

2.1.5 Rainfall Monitoring Locations

SPU maintains a network of rain gauges throughout the city. ADS collected the data from SPU's network and reviewed, corrected, and finalized the data monthly. Rain data are stored on the IntelliServe site. Thiessen polygons were created for the SPU rain gauges to determine which rain gauge would be used for each flow meter location. It was determined that the meter locations were located within the area covered by nine separate rain gauges. The data from these gauges were sufficient for model calibration and analysis. Data from additional gauges will be used as necessary. Figure 3-1 shows the locations of the rain gauges.

2.2 Equipment

The parameters of concern for flow monitoring of the sewer system included velocity, water surface levels, and flow rates.

Ultrasonic or pressure sensors were used to measure depth in pipes, hydraulic control structures, or detention tanks at 5-minute intervals. An ultrasonic sensor typically measures velocity. The sensor transmits a continuous ultrasonic wave and measures the frequency shift of returned echoes reflected by air bubbles or suspended particles in the flow. Specific configurations vary by site.

Flow rates can be determined using a combination of measured velocity and flow area. Water surface levels were measured directly using an ultrasonic instrument where free surface conditions existed, or by using a pressure sensor. At most sites both ultrasonic and pressure sensors were used to measure water surface levels. For this project, measuring the depth within a cross-section of flow and the average velocity within that cross-section determined the flow rates. The flow rate was calculated by multiplying the area of flow by the average velocity (continuity equation). CSOs are typically measured by applying weir equations to the measured depth over a weir.

During the Phase 1 monitoring period, site verifications were performed to ensure that the meters were accurately measuring both velocity and depth. Site gain (peak- to average-velocity ratio) and any depth

adjustments were evaluated throughout the monitoring period. Measurement quality was reviewed and validated according to the SPU Hydraulics SOP HYDR Q1100: Data Review, Assessment, Validation and Verification (Seattle Public Utilities, June 2008).

The different types of flow monitoring equipment used for this project are summarized in the following subsections.

2.2.1 ADS FlowShark

The ADS FlowShark is an area-velocity flow meter that measures depth and velocity; the continuity equation is used to calculate flow. Three types of data acquisition sensors are available for the FlowShark: an ultrasonic depth sensor, a pressure depth sensor, and a velocity sensor.

The primary depth measurement device is the ADS quad-redundant ultrasonic level sensor mounted at the top of the pipe. It operates by measuring the elapsed time for an ultrasonic signal to travel to the flow surface and back, and calculates the distance to the flow surface. This information and the programmed pipe geometry are used to compute depth of flow.

A pressure depth sensor can also be used. It measures the depth of flow by recording the difference in atmospheric pressure and water height pressure. The pressure sensor is often used as a backup measurement to the ultrasonic depth sensor. It is also used to record depth in surcharged maintenance holes (MHs) where the ultrasonic depth measurement cannot be used.

The ADS V-3 digital Doppler velocity sensor measures peak velocity in the cross-sectional area of flow. An ultrasonic carrier is transmitted upstream into the flow and is reflected by suspended particles, air bubbles, or organic matter with a frequency shift proportional to the velocity of the reflecting objects. The reflected signal is received by the sensor and processed using digital spectrum analysis to determine the peak flow velocity.

2.2.2 ADS FlowShark Pulse

During this project, ADS FlowShark Pulse meters were utilized in applications where hydraulic conditions of large pipes included low velocities. ADS FlowShark Pulse meters are suitable for a wide range of applications, but they are much more expensive than the FlowShark meters. The ADS FlowShark Pulse meters have gated cross-correlation technology with digital pattern detention to measure velocity at multiple depths in the flow profile. The meters also have an upward-looking ultrasonic sensor to directly measure depth. The ADS FlowShark Pulse meters are best suited for applications where hydraulic conditions are not suitable for general purpose meters, such as sites with large pipes and low velocity. However, the meters are prone to sedimentation, restricting their usage.

2.2.3 ISCO 2150 Area Velocity Flow Module

The ISCO 2150 Flow Module uses continuous-wave Doppler technology to measure mean velocity. The sensor transmits a continuous ultrasonic wave, and then measures the frequency shift of returned echoes reflected by air bubbles or particles in the flow.

The 2150 has an area velocity probe built on digital electronics so that the analog level is digitized in the sensor itself to overcome electromagnetic interference. A pressure sensor within the AV probe measures the level. The probe is factory-calibrated for 10-foot span at different temperatures, which eliminates drift in the level signal.

2.2.4 ISCO 2110 Ultrasonic Flow Module

The ISCO 2110 ISCO ultrasonic flow module provides non-contact liquid level measurement. The ultrasonic level sensor, mounted above the flow, transmits sounds waves that are reflected by the liquid surface. The elapsed time between the transmitted and returned signal determines the liquid level. The device then calculates flow rate using the water level and the pre-programmed pipe dimensions.

2.2.5 ISCO 4230 Bubbler

The ISCO 4230 Bubbler uses an internal air compressor to force air from a bubble tube submerged in the flow. The depth of flow is determined by measuring the pressure needed to force bubbles out of the line. The 4230 then converts the depth into a flow rate. For this project, the ISCO bubbler was used to measure depth in structures where there is a restriction on electronic signals from in-stream sensors.

2.3 Data Collection, Processing and Analysis

This section provides a description of the techniques that were employed to ensure the integrity of the data, and the procedures used by ADS and Stantec for the processing and analysis of the data.

2.3.1 Permanent Meters

During the Phase 1 monitoring period, field crews visited each monitoring location to retrieve data if remote communications were not available, verified proper meter operation, and documented field conditions. The following quality assurance steps were taken to sure the integrity of the collected data (ADS Quality Assurance and Implementation Plan, ADS Environmental Services, June 2009):

Measure power supply: A dry-cell battery pack powered the meter. Power levels were recorded and battery packs were replaced, if necessary. A separate battery provided backup power to memory, which allowed the primary battery to be replaced without the loss of data.

Maintenance: Maintenance was performed if requested by the data analyst or determined by the field crew to be needed. Maintenance tasks included sensor "scrubbing" (removal of debris) and replacement of system parts if a malfunction of a part occurred. Maintenance was both preventive and reactive for the flow meter and sensors. Maintenance records were posted to the IntelliServe site on request.

Perform confirmations and validate depth and velocity: Once equipment and sensor installation was accomplished, a member of the field crew descended into the maintenance hole to perform a field measurement of depth and velocity to confirm their agreement with the meter. Because the ADS V-3 velocity sensor measures peak velocity in the wetted cross-sectional area of flow, velocity profiles were also taken to develop a relationship between peak and average velocity in lines that meet the hydraulic criteria.

Measure silt level: During site confirmation, a member of the field crew descended into the maintenance hole and measured and recorded the depth of silt at the bottom of the pipe. These data were used to compute the true area of flow.

Confirm meter synchronization: The field crew checked the flow meter clock for accuracy. If the meter and computer time were different by more than 5 minutes, the meter was activated with the current computer time. The data for this project were also synchronized with those of the temporary flow meters.

Upload and review data: Data collected by the meter were uploaded and reviewed for comparison with previous data. Data for this project were collected remotely via wireless communication and uploaded to the ADS IntelliServe system. In the event that the signal strength did not permit remote data collection, the data

were collected as per the current ADS Contract Scope of Work. All readings were checked for consistency and screened for deviations in the flow patterns, which indicated system anomalies or equipment failure.

Flow meters were generally programmed to collect data at 15-minute intervals throughout the monitoring period unless circumstances dictated a more frequent sample rate (for example, rapidly changing flows due to pump station influence). For this project, the flow meters were programmed to collect data at 5-minute intervals to achieve high-resolution data that were suitable for model calibration.

The meter stored raw data consisting of (1) the air range (distance from sensor to top of flow) for each active ultrasonic depth sensor pair and (2) the peak velocity. If the meter was equipped with a pressure sensor, then a depth reading from this sensor was also stored. When the field personnel collected the data, the air range was converted to depth data based on the pipe height and physical offset (distance from the top of the pipe to the surface of the ultrasonic sensor) and/or the offset from a weir. The data were imported into the ADS Profile™ software, and a data analyst examined the data to verify their consistency. The data analyst also reviewed the daily field reports and site visit records to identify conditions that would affect the collected data.

The data analyst reviewed the velocity profiles and line confirmation data developed by the field personnel to identify inconsistencies and verify velocity data reliability. Velocity profiles were reviewed and an average-to-peak velocity ratio was calculated for the site. This ratio was used in converting the peak velocity measured by the sensor to the average velocity used in the continuity equation.

The data analyst reviewed the meter selection for which the depth sensor entity was used to calculate the final depth information. Any silt levels present at each site visit were reviewed and representative silt levels were established.

Selections for the above parameters were constant or changed during the Phase 1 monitoring period. While the data analysis process was described in a linear manner, it often required an iterative approach to complete it accurately.

2.3.2 Temporary Meters

Every 4 weeks, the crews performed level checks and velocity profile measurements. All field observations and maintenance records were translated into ZFM2 as a record, and the paperwork was scanned and organized in ZFM2. If any changes were made at the site, engineers reviewed them and made appropriate changes in the data (editing) using the Data Analysis (DAS) tool in ZFM2.

Photographs of the upstream pipe, band, and any other object of concern were taken and organized in ZFM2 for each specific site.

The flow meters were set to record data at 5-minute intervals, and data were collected every 14 days during monitoring. Numerous types of meters were installed, and each meter used its proprietary software to log the data. Thus, the data processing was slightly different for data from each of the meters.

ADS FlowShark: The two methods of collecting data from an ADS FlowShark included a remote wireless connection and an onsite serial connection. For both methods, upon successful connection the meter supplied flow data in the format of BIN files. The BIN files for the download were then transferred to the computer in Stantec's Seattle field office. The ADS Profile™ software identified the BIN files, which were then processed using the BIN file processor. The data were stored in the ADS Profile™ database, then compressed and transferred to the Stantec network server and the City of Seattle file transfer protocol (FTP) site. The data were readily available to engineers at Stantec's Cincinnati office for further processing.

The ADS Profile™ database was quickly reviewed for the current day's downloads, and the raw data were exported as text files. The exported raw data comprised the following entities: DFinal (depth), Vfinal (velocity) and Qfinal (flow). The Final Data Generator in ADS Profile™ generated the entities.

The exported raw data were then imported into the ZFM2 database, where they were compressed and uploaded onto the City of Seattle FTP site. This process was performed on a daily basis.

ADS FlowShark Pulse: The data from these meters were supplied as text files. The text files were transferred to the office and after some minimal formatting in Excel, the formatted files were imported into the ZFM2 database.

ISCO meters: The downloaded database was transferred to the office; the office personnel then exported the data as CSV files. These files were then imported into the ZFM2 database.

All data obtained from flow meters were reviewed using ZFM2 software. To account for data gaps or periods where the data were incorrect or suspect, data were edited in ZFM2. The following situations describe data gaps that were editable and corrected or filled in with data from another time period:

- **Level adjusts:** Site visits identified instances in which pipe diameters were incorrectly recorded. This usually occurred when a probe was changed or a band was moved. Following verification of the correct diameter, the raw data in ZFM2 were adjusted to account for the difference in level.
- **Daily pattern:** During dry weather, the daily pattern from another dry period was substituted where data were missing.
- **Missing velocity:** When the level data appeared to be consistent and of suitable quality, the missing velocity was filled in using the implied Manning's curve.
- **Data "pops":** Site conditions or random meter problems can cause spurious depth and velocity measurements. These data were removed from the raw data by using adjacent data as a best approximation of the correct value.
- **Peak velocity limited**: Peak velocity limits apply only to ADS FlowShark meters. Meters were usually installed with a velocity recording range of 0 to 10 feet per second (fps). It was found that certain sites exhibited peak velocities above that range, necessitating a reset of the meter electronics to measure higher velocities. The previously measured velocities restricted to 10 fps were adjusted based on subsequent data with a higher measurement range.
- **Sediment depth:** Depths of sediment at the meters were recorded at each site visit. These data, however, were not used to correct computed flows.

3. MONITORING RESULTS

3.1 Rainfall

Rainfall data were collected for the LTCP through the City's rain gauge network. Data from 9 of the 17 gauges were applicable to the NPDES basins included in the LTCP. Each of the nine gauges was assigned to an NPDES basin for review of flow monitoring results. This section describes that data, compares the gauges to each other, and compares the data to historical precipitation statistics.

The Phase 1 monitoring period was from 10/1/2008 to 5/31/2009. Unless otherwise noted, stated values are for the Phase 1 period. The long-term annual average rainfall depth at the Sea-Tac Airport gauge, which is considered the regional standard, is 37.2 inches. The long-term average for the period from October through May is 32.2 inches. During the Phase 1 monitoring period, the actual measured precipitation at Sea-Tac was 30.8 inches, indicating less than normal precipitation in this period with respect to the long-term average. Total precipitation at each of the nine gauges used in this review was less than that recorded at Sea-Tac in the same period, ranging from 23.7 inches at RG 15 to 30.5 inches at RG 17. A map of the SPU rain gauge network is presented in Figure 3-1. Figure 3-2 shows cumulative precipitation for the monitoring period for each of the LTCP rain gauges compared to that of Sea-Tac.

The monitoring period rainfall can be characterized generally as below average in volume and number of events at most gauges through February 2009. Figure 3-3 shows the monthly long-term Sea-Tac average rainfall together with the observed rainfall at RG 02 (near average for the period) and RG 15 and RG 17 (lowest and highest period volume, respectively). A significant event occurred the first two weeks of November 2008, followed by very little precipitation for the remainder of that month. December 2008 exhibited snowfall early in the month with snowmelt at the end of the month. A significant event occurred in the first week of January 2009 followed by a dry period until March. March and April 2009 were average in total rainfall, while May 2009 was well above average due to two large events.

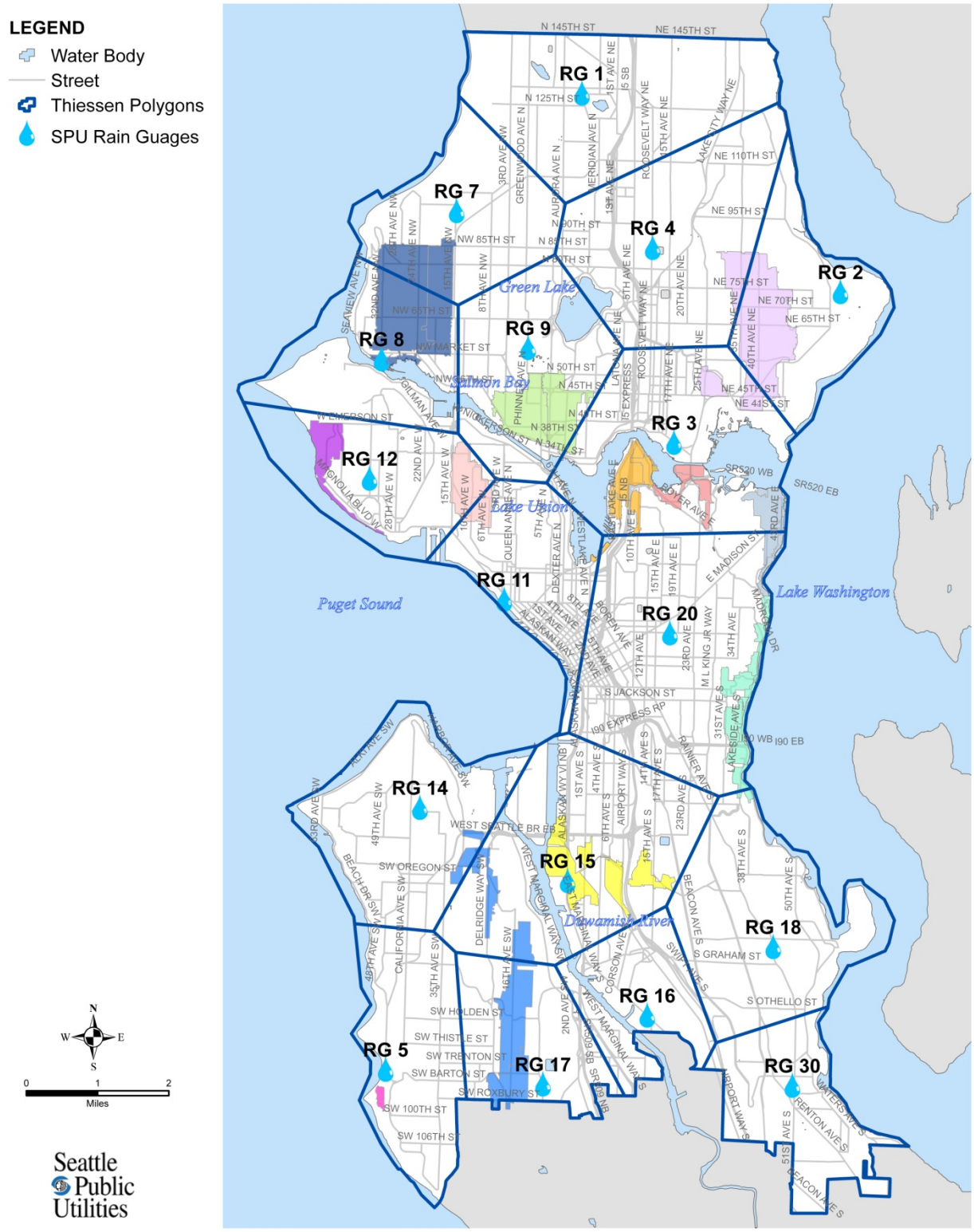

Figure 3-1. Thiessen polygons for each of the SPU rain gauges; north and south borders are the city limits

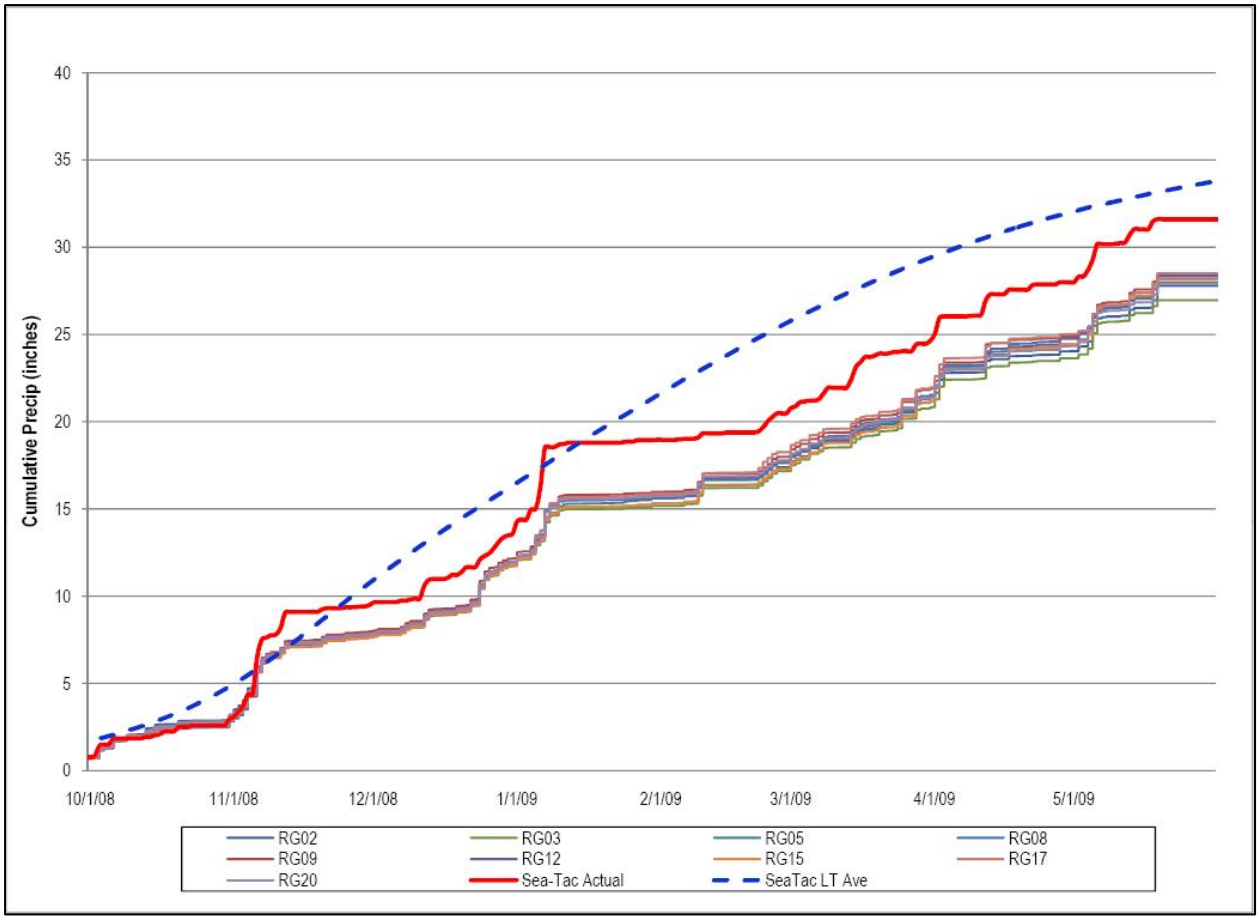

Figure 3-2. Cumulative precipitation for each of the SPU rain gauges used for the LTCP, compared to the actual precipitation and historical average at Sea-Tac Airport

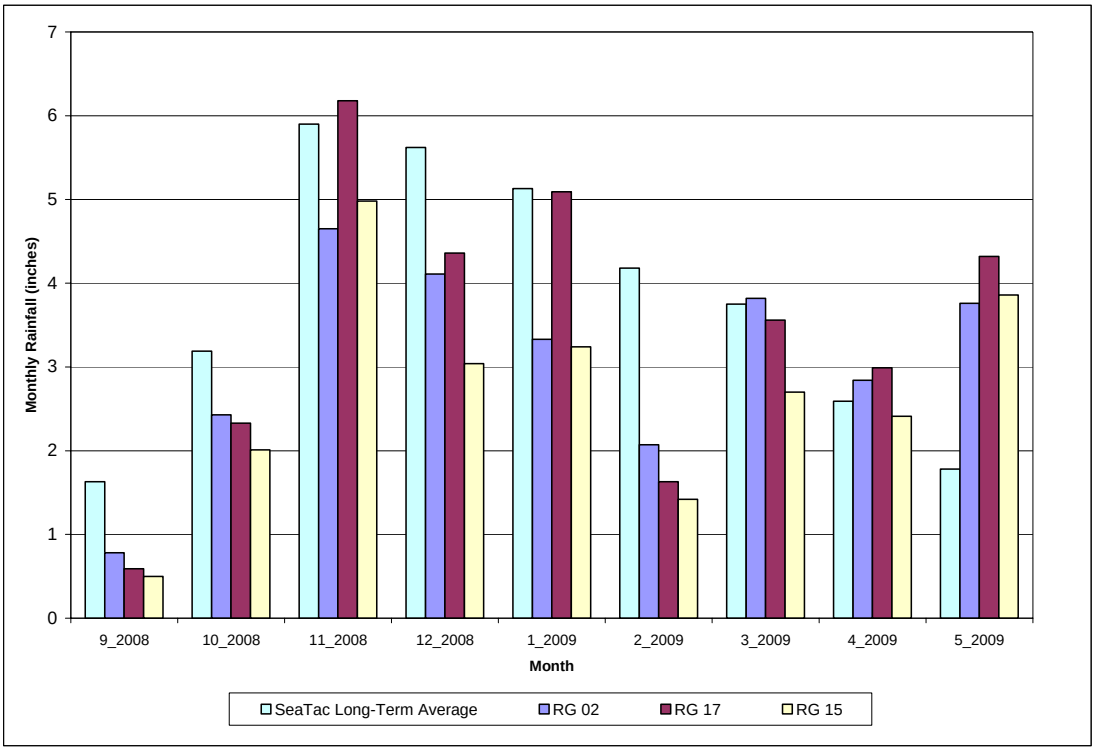

Figure 3-3. Monthly average precipitation at three SPU gauges compared to the long-term average at Sea-Tac Airport

3.1.1 Variations between Rain Gauges

In general, the gauges in central Seattle (RG 15 and RG 20) were the driest, and the gauges in the north and the south of the city were the wettest (Figure 3-2). In general, RG 17 experienced the highest return period for the longer-duration storms (November 2008 and January 2009), including a 20-year 3-hour classification for the January 2009 event. RG 02 experienced the lowest return period for longer-duration storms, barely exceeding a 6-month event until May 2009. Short-duration storm frequency patterns were more geographically and temporally heterogeneous, consistent with findings in *Analysis of Precipitation: Frequency and Storm Characteristics for the City of Seattle* (MGS Engineering Consultants, Inc., 2003). Depth-duration-frequency (DDF) graphs for both short and long durations can be found in Appendix A. These graphs show the difference in frequency of selected storms between the rain gauges at different durations.

3.1.2 Snowfall

Snow fell in Seattle in December 2008 and early January 2009. The Sea-Tac gauge measured a total of 17.6 inches of snow between 12/13/2008 and 1/4/2009 in four separate events. This amount of snowfall occurs infrequently during the wet season in Seattle. Simulation of the subsequent melt in a hydrological model is complicated, and generally unreliable. It is expected that the effect of the melt on soil moisture may have increased the impact of the significant rain event on 1/6/2009 and 1/7/2009 beyond what would have normally occurred. Due to the difficulty in accurately simulating the snowmelt, the January event may not be used for calibration of the models, or at least will be assigned a low weighting in the calibrations. Similarly, no events in December 2008 will be used for calibration.

3.1.3 Summary of Rain Gauge Data

From the monitoring period, seven rain event periods representing the largest events were chosen for return-period analysis. These events are listed in Table 3-1 through Table 3-3.

Summaries of rain gauge storm depths and return intervals are reported in Table 3-1 through Table 3-3. These tables report statistics for all nine rain gauges used as part of the flow monitoring, for the seven events chosen for analysis as part of the LTCP.

Table 3-1 presents the maximum rainfall volume that occurred over a 7-day period for each event, together with the total monitoring period volume at each gauge. This provides an indication of the potential effect of each event because much of the tributary area will respond to prolonged higher volume storms.

Table 3-2 presents the maximum recurrence frequency for each event at each gauge constructed by comparing the maximum rainfall depths at any duration with the short-term (5-minute to 3-hour) DDF curves. Uncontrolled CSO basins with significant impervious area respond greatly to high short-term intensities. The short-term DDF do not vary across the city.

Table 3-3 presents the maximum recurrence frequency for each event at each gauge when comparing the maximum rainfall depths at any duration in the long-term (6 hours to 168 hours or 7 days) DDF curves. The long-term DDF curves vary by rain gauge. Ecology regulations require the City of Seattle to control CSOs to the point that no more than one untreated overflow event occurs per year on average. Thus, events near a 1- to 2-year recurrence frequency are desirable to capture in the monitoring to allow model calibration in this range.

More detailed information for each rain gauge can be found in Appendix A. This information includes storm depths and return intervals for multiple durations and multiple depths, as well as DDF curves.

Table 3-1. Summary of Selected Event 7-Day Storm Depths for Each Rain Gauge

Selected events			Rain gauge number and maximum 7-day depth (inches)								
Event #	Start date	End date	RG 02	RG 03	RG 05	RG 08	RG 09	RG 12	RG 15	RG 17	RG 20
1	11/1/2008	11/7/2008	3.45	3.51	3.95	3.88	4.30	3.96	3.62	4.39	3.78
2	1/1/2009	1/7/2009	2.52	3.06	3.99	3.3	3.09	3.23	2.92	4.32	2.84
3	2/20/2009	2/26/2009	1.01	0.98	0.82	0.85	1.17	0.96	0.92	1.02	0.92
4	3/14/2009	3/20/2009	0.99	1.28	1.3	1.38	1.39	1.38	1.15	1.57	1.06
5	3/29/2009	4/4/2009	2.3	2.22	1.71	1.92	2.51	1.57	1.3	1.65	0.92
6	5/1/2009	5/7/2009	1.95	2.25	2.39	2.44	2.58	2.89	2.28	2.68	2.39
7	5/13/2009	5/19/2009	1.71	1.94	1.38	1.63	1.56	1.8	1.4	1.5	1.52
Entire period	10/1/2008	5/31/2009	27.01	27.46	27.07	26.65	29.47	27.47	23.66	30.45	24.10

Table 3-2. Maximum Recurrence Intervals for Storm Events by Rain Gauge: Short Duration (5 min to 3 hr)[a]											
Selected events			Rain gauge number and short-duration maximum return period								
Event #	Start date	End date	RG 02	RG 03	RG 05	RG 08	RG 09	RG 12	RG 15	RG 17	RG 20
1	11/1/2008	11/7/2008	< 6 mo	< 6 mo	< 6 mo	~ 1 yr	2 yr	< 6 mo	< 6 mo	6 mo	< 6 mo
2	1/1/2009	1/7/2009	< 6 mo	6 mo	~ 1 yr	2 yr	~ 1 yr	~ 1 yr	6 mo	20 yr	2 yr
3	2/20/2009	2/26/2009	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo
4	3/14/2009	3/20/2009	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo
5	3/29/2009	4/4/2009	< 6 mo	< 6 mo	6 mo	< 6 mo	~ 4 yr	< 6 mo	6 mo	6 mo	< 6 mo
6	5/1/2009	5/7/2009	~ 1 yr	~ 1 yr	~ 1 yr	6 mo	6 mo	~ 1 yr	6 mo	~ 1 yr	2 yr
7	5/13/2009	5/19/2009	~ 7 yr	20 yr	6 mo	2 yr	~ 1 yr	~ 3 yr	6 mo	~ 1 yr	2 yr

[a] *Maximum recurrence noted at any duration in the series from 5 minutes to 3 hours.*

Table 3-3. Summary of Event Long-Duration Maximum Return Periods for Each Rain Gauge (6 hr to 7 days)[a]											
Selected events			Rain gauge number and long-duration maximum return period								
Event #	Start date	End date	RG 02	RG 03	RG 05	RG 08	RG 09	RG 12	RG 15	RG 17	RG 20
1	11/1/2008	11/7/2008	1 yr	1 yr	< 1 yr	1 yr	2 yr	1 yr	1 yr	2 yr	1 yr
2	1/1/2009	1/7/2009	1 yr	2 yr	1 yr	2 yr	1 yr	2 yr	1 yr	2 yr	1 yr
3	2/20/2009	2/26/2009	< 2 mo	< 2 mo	< 2 mo	< 2 mo	<2 mo	< 2 mo	< 2 mo	< 2 mo	< 2 mo
4	3/14/2009	3/20/2009	< 2 mo	< 2 mo	< 2 mo	~ 2 mo	< 2 mo	< 2 mo	< 2 mo	< 2 mo	< 2 mo
5	3/29/2009	4/4/2009	4 mo	4 mo	4 mo	~ 2 mo	4 mo	4 mo	4 mo	4 mo	4 mo
6	5/1/2009	5/7/2009	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo	< 6 mo
7	5/13/2009	5/19/2009	6 mo	1 yr	2 mo	< 2 mo	< 2 mo	< 2 mo	< 2 mo	< 2 mo	< 2 mo

[a] *Maximum recurrence noted at any duration in the series from 6 hours to 7 days.*

3.2 Ballard Basin

The Ballard Basin, located in northwest Seattle, is more than 1,100 acres in area. The sewer system generally drains from north to south by gravity to the King County Ballard regulator for conveyance to the West Point Wastewater Treatment Plant (WWTP). The Ballard Basin contains two subcatchments, NPDES150/151 and NPDES152, which are described in the next section.

Flows from the NPDES150/151 Basin flow from north to south by gravity into the King County system just upstream from the King County Ballard regulator. Just prior to entering the King County system, flows from the NPDES152 Basin are combined with the flows from the NPDES151 Basin at MH 011-184. The northern part of the NPDES152 Basin flows into the NPDES150/151 Basin by gravity, while the flows from the southern portion of the NPDES152 Basin are collected in PS 84 and then pumped into a 36-inch trunk line for conveyance into the NPDES150/151 Basin.

Two SPU rain gauges are installed near the Ballard Basin. RG 07 is located at Whitman Middle School at 15th Avenue NW to the north of NW 90th Street, which is just past the northeast boundary of the upper portion of the NPDES150/151 Basin. RG 08 is located near the Hiram M. Chittenden Locks in the lower portion of the NPDES152 Basin. An examination of the flow monitoring data during storm events shows that these rain gauges provide an excellent representation of the timing, intensity, and spatial distribution of rainfall in the area.

Combined sewage flow was monitored by 2 permanent stations and a total of 11 temporary meters that were installed during the review period. More detailed information on Ballard monitoring locations can be found in Appendix C; a basin schematic is contained within Appendix B.

3.2.1 NPDES150/151 Basin

The NPDES150/151 Basin, located in the eastern portion of the Ballard Basin, is approximately 401 acres in area. The NPDES150 Basin extends from NW 85th Street south to NW Market Street and from 16th Avenue NW west to 22nd Avenue NW. North of NW 65th Street, the basin is fully combined, while south of NW 65th Street, the basin is partially separated. In the partially separated areas, storm drains convey street runoff and a portion of the roof runoff and other private property stormwater flow.

The NPDES150/151 CSO structure is located in MH 011-184. When wastewater in the structure reaches the level of the weir, overflows start to occur. Downstream of the overflow structure, the CSO flows are divided into two separate flow branches and separate outfalls: NPDES150 and NPDES151. Both outfalls discharge to Salmon Bay. The CSO structure is monitored both upstream and downstream of the overflow weir. The meter on the upstream side (known as the MP1 meter) records the depth in the CSO structure. The meter on the downstream side (a reverse install, known as the MP2 meter) is used to calculate the overflow rate.

One permanent meter to verify overflows monitors the basin. Five temporary monitoring locations are located in the basin.

BAL150_002-273A

BAL150_002-273A is a temporary monitoring installation that records both level and velocity. The data collected at the site are used to characterize hydrology in the northwest part of the NPDES150/151 Basin. The site was selected after reviewing an alternate location at MH 002-272.

Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during both dry and wet weather periods, and the lack of data gaps during significant wet periods. Flow balancing was performed to compare the combined flows measured at

BAL150_002-273A and BAL150_002-274A with the downstream flows collected at BAL150_011-176A (see BAL150_011-176A description). The data collected during Phase 1 are suitable for model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

BAL150_002-274A

BAL150_002-274A is a temporary monitoring installation that records both level and velocity. The data collected at the site are used to characterize hydrology for a substantial part of the northeast section of the NPDES150/151 Basin. No alternative sites were considered for this location.

Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during both dry and wet weather periods, and the lack of data gaps during significant wet periods. The results of the flow balancing analysis using the site are included with the description of BAL150_011-176A. The data collected during Phase 1 are suitable for model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

BAL150_002-349A

BAL150_002-349A is a temporary monitoring installation that records both level and velocity. The site is located upstream from BAL150_002-274A and captures flow from about one fifth of the area tributary to BAL150_002-274A. The site was selected to provide flow monitoring in one of the north-south subcatchments contributing to BAL150_002-274A. It was installed to provide an estimate of hydrologic model parameters that might be applicable to similar nearby subcatchments if BAL150_002-274A were not suitable. The data collected at the site are usable for the verification of BAL150_002-274A flow monitoring data. The site was selected after reviewing alternative locations at MHs 002-348, 002-350, 002-351, and 002-311.

Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent response of the data during storm events. The dry weather flow data are less consistent. When flow depths are less than 3 inches, the velocity-depth curve produces a lot of scatter probably due to a backup from flows entering the line just downstream from the monitoring site. The meter at BAL150_002-349A was removed on 3/31/2009 because sufficient suitable data had been collected at the site, and the downstream monitoring site at BAL150_002-274A collects suitable data for model calibration.

BAL150_011-176A

BAL150_011-176A is a temporary monitoring installation that records both level and velocity. The data collected at the site are used to characterize hydrology for most of the NPDES150/151 Basin. The site was selected after reviewing alternative locations at MHs 011-179 and 011-344.

Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during both dry and wet weather periods, and the lack of data gaps during significant wet periods. With its downstream location and high quality flow data, the site provides a very good estimation of range of flows for NPDES150/151 Basin. The data collected at BAL150_011-176A during Phase 1 are suitable for model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

Flow balancing was performed to compare the combined upstream flows measured at BAL150_002-273A and BAL150_002-274A with flows collected at BAL150_011-176A. The timing and shape of storm responses were similar at the three sites. The downstream meter recorded higher peak flows than the summation of the upstream meters by an amount that is consistent with the extra area that is tributary by BAL150_011-176A. Therefore, the flow balance suggests all three meters are functioning well.

BAL150_011-242A

BAL150_011-242A is a temporary monitoring installation that records both level and velocity. The data collected at the site are used to characterize flows downstream from the NPDES150/151 Basin and NPDES152 Basin. The site is also used to characterize system hydraulics and specifically to identify any backups from King County's Ballard siphon that would influence flows and depths upstream in the SPU system. The site was selected after reviewing an alternative location at MH 011-243.

Data quality was classified as "Excellent" for the Phase 1 monitoring period, particularly during wet weather conditions. The site collects consistent and repeatable wet weather data. The wet weather data are suitable to use for model calibration. The dry weather data will not be used for model calibration because (1) the dry weather flow data showed two distinct velocity-depth relationships and (2) nearby upstream monitoring sites and local water use data together with estimated seasonal groundwater from upstream monitoring sites can provide a very good approximation of dry weather flows to the site. The velocity-depth relationship at the site changed after November 2008 storms, most likely due to the scouring of accumulated solids during the large November 2008 storm events. The dry weather hydrographs for the model nodes near BAL150_011-242A will be developed using a combination of parcel-level water use data and upstream flow monitoring data collected at BAL150_011-176A, BAL150_DWF-011184, and BAL152_011-187A. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

BAL150_DWF-011184

BAL150_DWF-011184 is a permanent monitoring installation that records both level and velocity. Meters are located on both the upstream and downstream sides of the CSO weir. The level data collected on the upstream side of the CSO weir are used to alarm for CSO events and to compute the volume of CSOs using a weir equation. Data recorded by the downstream meter are used to confirm the occurrence of overflows.

Data quality was classified as "Good" for the Phase 1 monitoring period. The level data have a consistent and repeatable pattern and lack of data gaps and are suitable for use in model calibration. However, the velocity data collected at the site will not be used for model calibration. The meter at BAL150_DWF-011184 is believed to overestimate flows based on a comparison with the upstream monitoring data at BAL150_011-176A. This may be due to the hydraulic conditions at the CSO structure where a slope break and change of flow direction affect flow velocities and depths. The depth sensor measures water levels near the entrance to the CSO maintenance hole. The velocity probe scans upstream, and it may be recording the higher velocities that occur farther upstream in the influent pipe rather than the lower velocities that occur right at the sensor.

3.2.2 NPDES152 Basin

The NPDES152 Basin, located in the western portion of the Ballard Basin, is approximately 769 acres in area. The NPDES152 Basin extends from NW 85th Street south to the waterfront, and from 22nd Avenue NW west beyond 32nd Avenue NW. North of NW 65th Street, the basin is fully combined, while south of NW 65th Street, the basin is partially separated. In the partially separated areas, storm drains convey street runoff and a portion of the roof runoff and other private property stormwater flow. South of NW Market Street and in the vicinity of the Chittenden Locks, wastewater flow is conveyed by gravity to PS 84. The pump station conveys flows to the 36-inch-diameter sewer downstream of MH 011-189.

The basin contains two CSO structures, known as NPDES152A and NPDES152B. NPDES152A, located at PS 84, is not known to produce any overflows. The NPDES152B structure (often simply referred to as NPDES152) is located in MH 011-189 and is active. When wastewater in the structure reaches the level of the weir, overflows start to occur. The CSO outfall discharges to Salmon Bay. The CSO structure is monitored both upstream and downstream of the overflow weir. The meter on the upstream side (known as

the MP1 meter) records the depth in the CSO structure. The meter on the downstream side (a reverse install, known as the MP2 meter) is used to calculate the overflow rate.

The Basins is monitored by one permanent meter to verify overflows. Seven temporary monitoring locations are located in the NPDES152 Basin.

BAL152_002-016A

BAL152_002-016A is a temporary monitoring installation that records both level and velocity. The data collected at the site are used to characterize hydrology in the northwest part of the NPDES152 Basin. The site was selected after reviewing alternative locations at MHs 002-014, 002-015, 002-018, 002-095, and 002-096.

Data quality was classified as "Good" for the Phase 1 monitoring because of the consistent and repeatable response of the data during wet weather periods and the lack of data gaps during significant wet periods. The wet weather flow data are suitable for model calibration. The dry weather data exhibit some excessive scatter in the velocity-depth relationship during low flow periods. Dry weather hydrographs will be developed by using (1) local water use data to estimate the average dry weather flow rate and (2) flow monitoring data to estimate the timing of the diurnal flow pattern. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period. Discharges from an upstream potable water flushing station connected to MH 001-006 are observed in the BAL152_002-016A flow data. Water system flushing occurs on a daily basis in the middle of the night, generally between 1:00 a.m. and 5:00 a.m. Occasionally, a second flushing occurs between 2:00 p.m. and 5:00 p.m. The daily volume of flush water varied from about 7,000 to 41,000 gallons each day during the 2008–2009 monitoring period. The daily flush volumes are generally higher in the summer months than in the winter months but not consistently so. During the flushing periods, which occurred generally 4 to 8 hours per day, the flush water flowrate into the sewer system ranged from about 0.06 mgd to 0.17 mgd. The flush water forms a significant fraction of the daily base flow and will be included in the model calibration.

BAL152_002-032A

BAL152_002-032A is a temporary monitoring installation that records both level and velocity. BAL152_002-032A is located downstream from BAL152_002-016A, and the data collected at the site are used to characterize hydrology in the northwest part of the NPDES152 Basin. The monitoring site is located at the boundary between the combined section (to the north) and the partially separated section of the NPDES152 Basin. The site was selected after reviewing an alternative location at MH 002-031.

Data quality was classified as "Good" for the Phase 1 monitoring because of the consistent and repeatable response of the data during both dry and wet weather periods, and the lack of data gaps during significant wet periods. The scatter graph has lesser resolution during low flow periods. The potable water flushing station flows (described for BAL152_002-016A above) are observable within the BAL152_002-032A flow data. The data collected during Phase 1 are suitable for model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

BAL152_002-123A

BAL152_002-123A is a temporary monitoring installation that records both level and velocity. The data collected at the site are used to characterize hydrology for a combined sewer area in the northeast part of the NPDES152 Basin. BAL152_002-123A is located downstream from the meter at BAL152_002-232A. No alternative locations were considered for the site.

Data quality was classified as "Good" for the Phase 1 monitoring because of the consistent and repeatable response of the data during wet weather periods, and the lack of data gaps during significant wet periods. The

wet weather flow data are suitable for model calibration. The meter is located in a brick sewer, and the irregularities in the pipe shape may be influencing the low flow measurements. The dry weather data exhibits some excessive scatter in the velocity-depth relationship. Dry weather hydrographs will be developed by using (1) local water use data to estimate the average dry weather flow rate and (2) flow monitoring data to estimate the timing of the diurnal flow pattern. The dry weather data collected upstream at BAL152_002-232A will be used to verify and/or supplement the development of the dry weather flow hydrographs at BAL152_002-123A. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

BAL152_002-232A

BAL152_002-232A is a temporary monitoring installation that records both level and velocity. The site was selected to provide flow monitoring in one of the north-south subcatchments contributing to BAL152_002-123A. The site was installed to provide an estimate of hydrologic model parameters that might be applicable to other nearby subcatchments if BAL152_002-123A were not suitable. The data collected at the site are usable for the verification of BAL152_002-123A flow monitoring data. The site was selected after reviewing alternative locations at MHs 002-194 and 002-195.

Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent response of the data during both dry and wet weather periods, and the lack of data gaps during significant wet periods. The low flows in particular show a very strong correlation between velocity and depth. The data collected during Phase 1 are suitable and sufficient for model calibration. The meter is recommended for removal because no additional data collection is necessary for Phases 2–3 of the wet season because the monitoring data at BAL152_002-123A downstream adequately characterizes flows in this part of the NPDES152 Basin.

BAL152_011-090A

BAL152_011-090A is a temporary monitoring installation that records both level and velocity. The data collected at the site are used to characterize hydrology for a partially separated area in the eastern part of the NPDES152 Basin. The site was selected after reviewing an alternative location at MH 011-089.

Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during both dry and wet weather periods, and the lack of data gaps during significant wet periods. The data collected during Phase 1 are suitable for model calibration. Additionally, because of its excellent data quality rating and location collecting flows in a partially separated area, the data collected at BAL152_011-090A will be useful for determining the impact of sewer separation that has occurred on private property within the NPDES152 Basin. The meter is recommended for removal because data collected at the site during Phase 1 are sufficient for model calibration.

BAL152_011-187A

BAL152_011-187A is a temporary monitoring installation that records both level and velocity. The data collected at the site are used to characterize flows downstream from the NPDES152 Basin overflow point. The site was selected after reviewing an alternative location at MH 011-186.

Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during both dry and wet weather periods, and the lack of data gaps during significant wet periods. The data collected at this location are suitable and very useful for model calibration because the installation records all of the non-CSO flows that leave NPDES152 Basin (that is, flows that pass by the permanent meter at BAL152_DWF-011189 and flows conveyed by PS 84). It is recommended that this monitoring installation remain in place for Phases 2–3 monitoring to capture additional storms to support model calibration and/or validation, and to continue to develop the model boundary conditions for flow exiting NPDES152 Basin.

BAL152_011-213A

BAL152_011-213A is a temporary monitoring installation that records both level and velocity. The data collected at the site are used to characterize hydrology for a partially separated area tributary west of PS 84. The tributary area to this monitoring site includes commercial businesses and a part of the Hiram M. Chittenden Locks property. The site was selected after reviewing alternative locations at MHs 011-214 and 011-216.

Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. The observed flow velocities do not correlate consistently with depth, perhaps due to the influence of downstream hydraulic conditions on this low-slope pipe. The flow meter captures the dry weather flow pattern but does not show a significant wet weather response to rainfall.

The flow meter was removed on 2/3/2009, and thus was not ranked based on selected storm events. This monitoring location was replaced with a meter at BAL152_011-218A.

BAL152_011-218A

BAL152_011-218A is a temporary monitoring installation that records both level and velocity. The site is downstream from BAL152_011-213A, and the data collected at the site are used to characterize hydrology for a partially separated area tributary west of PS 84. The tributary area to this monitoring site includes commercial and industrial businesses and a part of the Hiram M. Chittenden Locks property. The site was selected to supplement data collection at BAL152_011-213A and BAL152_011-222A, and no alternative locations were evaluated.

Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. Similar to BAL152_011-213A, the observed flow velocities do not correlate consistently with depth, perhaps due to the influence of downstream hydraulic conditions on this low-slope pipe. The flow meter at BAL152_011-218A captures the pattern of dry weather flow but does not indicate a significant wet weather response to rainfall.

The flow meter was removed on 3/26/2009 after determining that the SCADA data collected downstream at PS 84 are sufficient for model calibration.

BAL152_011-222A

BAL152_011-222A is a temporary monitoring installation that records both level and velocity. The site is located to the east of PS 84, and the data collected at the site are used to characterize hydrology for the partially separated area tributary to PS 84. The tributary area to this monitoring site includes commercial and industrial businesses. The site was selected after reviewing an alternative location at MH 011-223.

Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. Similar to BAL152_011-213A and BAL152_011-218A, the observed flow velocities do not correlate consistently with depth and may be influenced by downstream hydraulic conditions. The flow meter at BAL152_011-222A captures the dry weather flow pattern but does not show a significant wet weather response to rainfall.

The flow meter was removed on 3/26/2009 after determining that the SCADA data collected downstream at PS 84 are sufficient for model calibration.

BAL152_DWF-011189

BAL152_DWF-011189 is a permanent monitoring installation that records both level and velocity. Meters are located on both the upstream and downstream sides of the CSO weir. The level data collected on the upstream side of the CSO weir are used to alarm for CSO events and to compute the volume of CSOs using a weir equation. Data recorded by the downstream meter are used to confirm the occurrence of overflows.

Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. The level data have a consistent and repeatable pattern. The level data collected at the site are suitable for calibrating the model to represent the hydraulic conditions in the vicinity of the CSO weir.

The velocity and computed flow data collected at the site will not be used for model calibration. Based on a comparison with the upstream monitoring data at BAL152_002-032A and BAL152_002-123A, the meter at BAL150_DWF-011189 is believed to overestimate flows. This may be due to the hydraulic conditions at the CSO structure where a slope break and change of flow direction affect flow velocities and depths (similar to the conditions described for BAL150_DWF-011184). Due to the potential for hydraulic conditions to affect the accuracy of flow measurements at the site, it is recommended that a temporary meter be installed in a nearby upstream location that will provide a more accurate estimate of total flow approaching the CSO weir.

3.2.3 Combined Sewer Overflows

ADS reported that 14 CSOs occurred in the Ballard Basin during the Phase 1 monitoring period; Table 3-4 lists the reported CSOs during the Phase 1 monitoring period.

Table 3-4. 2008–2009 Combined Sewer Overflows in Ballard Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
150/151	11/4/2008	0:15	4,042
	1/7/2009	2:00	19,806
	4/28/2009	0:10	3,031
	5/2/2009	0:05	4,250
	5/5/2009	0:15	11,347
	5/19/2009	1:00	125,830
152	11/4/2008	0:25	111,462
	12/7/2008	0:20	4,493
	1/7/2009	5:20	545,635
	2/23/2009	0:25	2,813
	3/20/2009	0:15	21,250
	4/2/2009	11:30	28,076
	4/28/2009	0:15	16,024
	5/2/2009	0:30	48,997
	5/5/2009	4:55	116,253
	5/19/2009	1:10	202,875

Figure 3-4 shows the maximum water level recorded at each of the overflow structures in the NPDES150 and NPDES152 Basins as a percentage of the weir height.

3.2.4 Facility Operations

The CSO facilities in the Ballard Basin consist of the two overflow weirs described above; it has no HydroBrakes or storage structures. One pump station (PS 84) is located in the NPDES152 Basin.

Pump Station 84

PS 84 is located in the NPDES152 Basin at 5390 28th Avenue NW. The pump station collects flows from the southern part of the NPDES152 Basin and pumps flow just upstream from monitoring location BAL152_011-187A. The pump station has two pumps connected to one 8-inch force main.

During the Phase 1 monitoring period, SCADA data were reviewed to compare wet well elevation with run times of pumps 1 and 2. Data were consistent throughout the monitoring period.

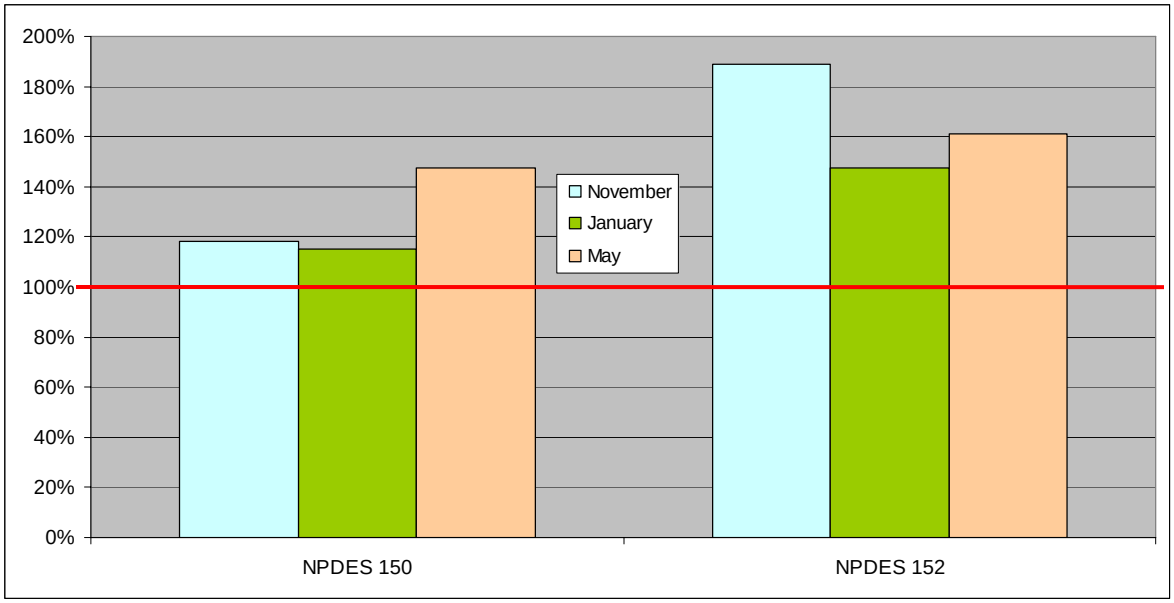

Figure 3-4. Maximum recorded levels compared to weir heights for major events

3.2.5 Recommendations for Additional Data Collection

All sites that were not removed during the Phase 1 monitoring period should remain in place throughout Phases 2–3 of the wet season monitoring period. No additional sites within the Ballard basin have been identified for Phases 2–3 of the wet weather season.

3.3 Delridge/Longfellow Basin

The Delridge/Longfellow Basin, which consists of the NPDES099, NPDES168, NPDES169, and NPDES170 Basins, is approximately 718acres in area.

The combined sewage in the NPDES099 Basin flows by gravity from south to north through permanent meter NPDES099_MH055477. Overflows from the NPDES099 Basin flow into the West Waterway at the mouth of the Duwamish River.

Combined sewage in the northern part of the NPDES168 Basin flows from north to south by gravity, and combined sewage in the southern part of the NPDES168 Basin flows from south to north by gravity. The northern and southern parts combine, then head west to permanent meter NPDES168_MH069428, and eventually enter the King County system.

The NPDES169 Basin flows east to northwest where wet weather flows are directed to CSO Facility 3. Overflows from this control facility were monitored at NPDES169_MH076367, and non-CSO flow is conveyed north to the King County system. Dry weather flows from the NPDES169 Basin are conveyed directly north to the King County system.

Combined sewage from the NPDES170 Basin flows west to CSO Facility 2, where the permanent meter DEL170_DWF-069144 monitors overflows from this control facility to the King County system. Overflows from the NPDES168, NPDES169, and NPDES170 Basins flow into Longfellow Creek, which eventually flows into the mouth of the Duwamish River at Elliott Bay.

Rainfall in the NPDES099 Basin is monitored by RG 15, which is located at the Puget Sound Clean Air Monitor Station. Rainfall in the NPDES168, NPDES169, and NPDES170 Basins is monitored by RG 17, which is located near the West Seattle reservoir.

To monitor combined sewage flow during the review period, 4 permanent stations and 20 temporary meters were installed in the Delridge/Longfellow Basin. Appendix D contains detailed information about all the sites in the Delridge/Longfellow Basin, and Appendix B contains a basin schematic.

3.3.1 NPDES099 Basin

The NPDES099 Basin, located to the south of the West Seattle Bridge near the mouth of the Duwamish River, is approximately 134acres in area. CSO Facility 34 is located in the NPDES099 Basin. The facility contains a 0.16 MG offline storage pipe, a HydroBrake, and an overflow weir.

. One permanent meter monitors NPDES099 Basin to verify overflows. Four temporary monitoring locations are located in the NPDES099 Basin.

DEL99_055-165A

DEL99_055-165A is a temporary monitoring installation that records both level and velocity. The site was installed to verify NPDES099 Basin hydrology and characterize the HydroBrake in CSO Facility 34. The site was chosen after review of alternative locations at MHs 055-163 and 055-170. The site captured a consistent diurnal dry weather flow pattern, which correlates well with the theoretical Manning's curve during storm flows. The downstream King County regulator station occasionally caused backwatering at peak flows during wet weather.

Data quality for both dry and wet weather flows was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the location of the monitoring site be maintained for the Phases 2–3 monitoring period.

DEL99_055-175A

DEL99_055-175A was a temporary monitoring installation that records both level and velocity. The flow meter was installed to measure the combined flow from the western part of the NPDES099 Basin, upstream from that basin's CSO weir and HydroBrake. The site was chosen after review of alternative locations at MH 055-476.

The storage system immediately downstream affects the site. Velocity dropouts occurred in the largest storm events as flow backed up behind the HydroBrake. For this reason, smaller storms in October 2008, February 2009, March 2009, and April 2009 were used for calibration of the site hydrology; the larger storms were used for model verification.

The DEL99_055-175A flow meter also overestimated low nighttime flows due to pooling in the pipe under dry weather conditions. This resulted in a depth reading that was high at the meter while the velocity sensor reported a higher velocity upstream from the pool. Estimates of dry weather flow need to take into account the high nighttime flow data. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. The meter was removed on 7/27/2009.

DEL99_055-223A

DEL99_055-223A is a temporary monitoring installation that records both level and velocity. The flow meter was installed to measure the combined flows from the eastern part of the NPDES099 Basin upstream from that basin's CSO weir and HydroBrake. The site was chosen after review of alternative locations at MH 055-224.

The maximum velocity was set to 15 fps on 11/24/2008, and the bidirectional velocity was activated on 12/30/2008. The site captured suitable dry weather flow data. Wet weather flows at the site were influenced by the operation of the low-flow diversion (LFD) stormwater valve installed at MH 055-476. Backwatering also occurred at peak flows during the large storm events due to the downstream HydroBrake.

Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. The LFD stormwater valve was closed on 9/16/2009 for Phases 2–3 of the periods to remove the influence of the valve on the data. It is recommended that the monitoring site be maintained for the Phases 2–3 monitoring period.

DEL99_055-473A

DEL99_055-473A is a temporary monitoring installation that records level only. The monitor was installed to measure the storage utilization in the 83-inch offline storage pipe that receives wet weather combined flows from the NPDES099 Basin. The sensor was installed approximately 3.70 inches above the bottom of the pipe.

The storage pipe was adjacent to the basin's CSO weir and HydroBrake. Wet weather flow enters the storage pipe via a 95-inch weir in the CSO chamber and drains back into the mainline through a flap gate in the weir. The site captured suitable data throughout the monitoring period. Data quality was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the monitor remain in place for the Phases 2–3 monitoring period.

NPDES99_MH055477

NPDES99_MH055477 is a permanent monitoring installation that records both level and velocity. Classified as a wet weather site, the site was not expected to provide repeatable and reliable velocity data. Level monitored at this location is used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The level data are also used to determine the characteristics of the HydroBrake immediately downstream.

Data quality was classified as "Good" for the Phase 1 monitoring period. The level sensors were not functioning in the 1/7/2009 event. It is recommended that screening of the site data continue in the Phases 2–3 monitoring period.

3.3.2 NPDES168 Basin

The NPDES168 Basin, located southeast of the NPDES099 Basin in the Longfellow Creek storm drain system, is approximately 350 acres in area. CSO Facility 2, located in the NPDES168 Basin, consists of a 1.6 MG offline storage tank, a HydroBrake, and an overflow weir.

Nine temporary monitoring locations are located in the NPDES168 Basin, one of which was removed on 11/24/2008. Two permanent meters quantify basin overflows. In addition, the SPU SCADA system monitors the site to provide real-time level in the overflow structure.

DEL168_069-280A

DEL168_069-280A is a temporary monitoring installation that records both level and velocity. The flow meter was installed to measure the combined flows from the southern and western parts of the NPDES168 Basin, upstream from that basin's CSO Facility (CSO Facility 2). The site was chosen after review of alternative locations at MH 069-278.

The site captured a consistent diurnal dry weather flow pattern, which correlates well with the theoretical Manning's curve during storm flows. The maximum velocity range was set to 15 fps on 12/15/2008. Previously collected data were corrected after establishing the correct site signature. In all wet weather events, the site captured data suitable for model calibration.

Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DEL168_069-342A

DEL168_069-342A is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the hydrology of the northern and eastern parts of the NPDES168 Basin upstream from that basin's CSO Facility (CSO Facility 2). The site served as a verification site for meter DEL168_069-346A and was chosen after review of inspections at MHs 069-346 and 069-278.

The site captured a consistent diurnal dry weather flow pattern, but with wide scatter and evidence of the meter picking multiple velocities at the same depth when flow depth was below 4 inches. Flow balancing suggested that this meter was reporting excessively high velocities.

Data quality for wet weather flow was classified as "Poor" for the Phase 1 monitoring period. The meter was removed on 11/24/2008 because it was determined that the site downstream at MH 069-346 was collecting more accurate data.

DEL168_069-346A

DEL168_069-346A is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the hydrology of the northern and eastern parts of the NPDES168 Basin upstream from that basin's CSO Facility (CSO Facility 2). The site was chosen after review of inspections at MHs 069-342 and 069-278.

The site captured a consistent diurnal dry weather flow pattern, which correlated well with the theoretical Manning's curve during storm flows. The site captured suitable data throughout the Phase 1 monitoring period. Data quality for both dry and wet weather flows was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DEL168_069-370A

DEL168_069-370A is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the hydrology of the eastern part of the NPDES168 Basin upstream from that basin's CSO Facility (CSO Facility 2). The site was chosen after review of alternative locations at MHs 069-371, 070-049, 070-225, 070-050, and 070-051.

The site captured data suitable for model calibration for all wet weather events, which correlates well with the theoretical Manning's curve during storm flows. Data quality for wet weather flow was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DEL168_069-406A

DEL168_069-406A is a temporary monitoring installation that records both level and velocity. The flow meter was installed to measure the combined flows from the NPDES168 Basin downstream from that basin's CSO Facility (CSO Facility 2). The meter was also used to characterize the HydroBrake located inside of CSO Facility 2. Rocks and debris immediately impacted the meter, originally installed in September 2008. Removing the rocks and debris took an extended period, delaying the installation until 12/15/2008. Debris was typical at the site, and weekly cleaning began in January 2009.

The site captured a consistent diurnal dry weather flow pattern. The site captured suitable data for characterization of the HydroBrake. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period because gravel and other debris frequently interfered with level and velocity readings; also, there was excessive scatter at low flows. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DEL168_069-408A

DEL168_069-408A is a temporary monitoring installation that records level only. The monitor was mounted on the floor of the storage tank to measure the use of the storage tank at CSO Facility 2 in the NPDES168 Basin. The site captured suitable data throughout the entire Phase 1 monitoring period. The data also indicated leakage from the CSO chamber through the duckbill valves into the storage tank.

Data quality for all storm events was classified as "Excellent" for the Phase 1 monitoring period. The monitor should be considered for removal in the Phases 2–3 monitoring period.

DEL168_069-428A

DEL168_069-428A is a temporary monitoring installation that records level only. The monitor was installed inside the flow control chamber at CSO Facility 2 in the NPDES168 Basin. The purpose of this monitor was

to confirm the data of the permanent meters (NPDES168_MH069428 and NPDES168_B_MH069428), and to characterize the HydroBrake located in the CSO Facility (the HydroBrake provides upstream depth).

The pressure depth probe was mounted on the CSO chamber wall 12 inches above the floor. The pressure probe was determined to be reading 358.5 inches of water depth when flow overtopped the weir, allowing the storage tank to fill. At a water depth of 384.5 inches, the CSO weir overflowed. Because the chamber was regularly filled partially with debris, the probe was replaced on 4/14/2009 and mounted on the chamber wall 13 inches above the floor. The probe was also replaced in July 2009 to improve the dynamic range on the probe. Data collected from this monitor closely agreed with those reported by the permanent pressure monitor NPDES168_MH069428 in the low- to mid-level range, but tended to over-report in the high-level range. As a result, only the lower range of the data should be used to characterize the HydroBrake. The data were more accurate than those reported by the permanent meter in this range.

Data quality was classified as "Excellent" in the lower range for the Phase 1 monitoring period. The meter should be considered for removal in the Phases 2–3 monitoring period.

DEL168_069-428B

DEL168_069-428B is a temporary monitoring installation that records level only. The monitor was installed inside the flow control chamber at CSO Facility 2 in the NPDES168 Basin. The purpose of this meter was to confirm the permanent meter (NPDES168_MH069428) data for the high-level range.

This depth-only monitor was installed to confirm the permanent meter (NPDES168_MH069428) data at CSO Facility 2 in the NPDES168 Basin, specifically the overflows from the CSO chamber into the storage tank. The ultrasonic depth probe was mounted on the CSO chamber wall and aimed at a plate level with the top of the weir to the storage tank. Data collected from this monitor closely agreed with those reported by the permanent meters NPDES168_MH069428 and NPDES168_B_MH069428. The site captured suitable data for the November 2008, January 2009, and May 2009 storms.

Data quality for all storm events was classified as "Good" for the Phase 1 monitoring period. The monitor should be considered for removal in the Phases 2–3 monitoring period.

NPDES168_MH069428

NPDES168_MH069428 is a permanent level-only monitor (pressure probe). The monitor was installed to measure the depth at the NPDES168 Basin CSO weir and then calculate the overflow volumes using a weir formula. The pressure depth probe was mounted on the wall of the CSO chamber 36.5 inches above the floor. When an overflow occurred, the site reported a depth of 381 inches. The site captured suitable data for the Phase 1 monitoring period. Data collected closely agreed with those reported by temporary monitor DEL168_069-428B. Data quality for all storm events was classified as "Excellent" for the Phase 1 monitoring period.

NPDES168_B_MH069428

NPDES168_B_MH069428 is a permanent level-only monitor. The ultrasonic monitor was installed to measure the depth at the NPDES168 Basin CSO weir and then used to calculate the overflow volumes using the weir formula. The ultrasonic depth probe was mounted on the CSO chamber ceiling and aimed at the plate level with the top of the weir to the storage tank. The probe was determined to read greater than 0.0 inch of water when the storage tank overflowed. Monitor reading from the site was confirmed by monitor DEL168_069-428B and NPDES168_MH069428. The site captured suitable data for the Phase 1 monitoring period. Data quality for all storm events was classified as "Excellent" for the Phase 1 monitoring period.

NPDES168_O_MH069428

NPDES168_O_069428 is a permanent monitoring installation that records both level and velocity. The permanent flow meter was installed to measure the overflow volumes downstream from the NPDES168 Basin CSO weir. The sensors were installed in the overflow drainage line downstream from the CSO weir. The site captured suitable data for the November 2008, January 2009, and May 2009 storms.

Data quality was classified as "Good" in the Phase 1 monitoring period. The meter reported flow in periods when the other meters were not reporting depth above the CSO weir. High levels in the storm sewer immediately downstream likely affected the monitoring site. It is suspected that flow may pass over the velocity probe when the level increases in the storm sewer, storing fluid upstream from the probe. When the level in the storm sewer drops the fluid flows over the velocity probe, which generates a false overflow indication. Because of this, the meter should not be used to estimate overflows unless this situation is corrected.

SPU_069-242A

SPU_069-242A is a permanent monitoring installation that records both level and velocity. The flow meter was installed to measure the west stream of flow that joins the King County system at MH 069-184. The monitored flow consists of all flow from the NPDES168 Basin and flow collected in the area just west of the NPDES168 Basin. The meter is used to characterize NPDES168 Basin and capacity in the downstream sewers. The site was chosen after review of inspections at MHs 069-184, 069-240, 069-241, and 069-462.

The site captured a consistent diurnal dry weather flow pattern, which correlated well with the theoretical Manning's curve during storm flows. The site occasionally received backwater from the downstream King County system during peak wet weather flows, including the January 2009 storm. The maximum velocity was set to 15 fps on 12/16/2008. The site captured suitable data for the November 2008 and January 2009 storms, in addition to other smaller storms. Some velocity data were missing for the May 2009 storms, which were estimated by the Stantec data analyst using the previously established site signature.

Due to minimum data gaps and a robust site signature, data quality was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

3.3.3 NPDES169 Basin

The NPDES169 Basin, located south of the NPDES168 Basin, is approximately 184. acres in area. CSO Facility 3 is located in the NPDES169 Basin. The facility contains a 1.6 MG offline storage tank, a HydroBrake, and an overflow weir.

Two permanent meters quantify basin overflows. In addition, the site is monitored through the SPU SCADA system, which provides real-time level in the overflow structure. Eight temporary monitoring locations are located in the NPDES169 Basin.

DEL169_076-218A

DEL169_076-218A is a temporary monitoring installation that records level only. The flow meter was installed to measure the water depth in the sump of the leaping weir structure, which diverts low flow away from CSO Facility 3 directly to the King County system. The level information also indicated when wastewater flow was being diverted over the leaping weir to CSO Facility 3. The pressure depth probe was mounted on the wall of the sump. The site data indicated that the sump did not fill to capacity before high flows leaped over the weir and downstream to the offline NPDES169 Basin CSO Facility 3. The site captured suitable data for the Phase 1 monitoring period. The meter was removed between 5/18/2008 and 6/15/2008

for pipe cleaning. Data quality was classified as "Good" for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DEL169_076-232A

DEL169_076-232A is a temporary monitoring installation that records both level and velocity. The flow meter was installed to measure the combined flows from the NPDES169 Basin. The meter is just upstream from the basin's leaping weir diversion structure. The site captured a consistent diurnal dry weather flow pattern, which correlated well with the theoretical Manning's curve during storm flows. Standing waves and a hydraulic jump at approximately 4 inches in water level occurred throughout the monitoring period, which is typical for the type of clay-tiled pipes at the site. Bidirectional velocity was activated on 12/15/2008.

Flow balancing with downstream meters suggested that the meter may have been overestimating the velocity at lower depths due to the hydraulic jump. Detailed examination by Stantec indicated that the meter is likely overestimating velocity at all flow depths below about 7 inches. Data above 7 inches is considered reliable. Data quality was therefore classified as "Some Limitations" for the Phase 1 monitoring period due to the hydraulic jump, and modelers should be aware that data at depths below 7 inches should not be used in calibration. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DEL169_076-351A

DEL169_076-351A is a temporary monitoring installation that records both level and velocity. The flow meter was installed to measure flows from the eastern part of the NPDES169 Basin upstream from that basin's leaping weir diversion structure. The site was chosen after review of inspections at MHs 301-155, 302-006, 076-331, and 076-330.

The site occasionally experienced backwatering from the downstream confluence. Data gaps during 10/17/2008 to 10/27/2008, and 3/30/2009 to 4/6/2009 were caused by malfunctioning meters, which were replaced on 10/27/2008 and 4/6/2009, respectively. The data gaps did not coincide with storm events. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period due to wide data scatter at low flows, potential debris influence on the velocity reading, and the backwatering from the inflow just downstream. The data should be used with caution. The meter was removed in July 2009.

DEL169_076-351B

DEL169_076-351B is a temporary monitoring installation that records both level and velocity. The flow meter was installed to determine the amount of flow from the stormwater system being directed to the CSS during wet weather flow from the south part of the NPDES169 Basin. The meter is located at the same manhole with meter DEL169_076-351A but inside the stormwater pipe. The site is classified as a wet weather site only. The data correlated well with the theoretical Manning's curve during storm flows. The maximum velocity was set to 15 fps on 11/17/2008. The site captured suitable data for all wet weather events. Data quality was classified as "Excellent" for the Phase 1 monitoring period. The meter was removed in July 2009.

DEL169_076-362A

DEL169_076-362A is a temporary monitoring installation that records both level and velocity. The site was selected after review of inspections at MH 076-361. The flow meter was installed to measure the wet weather combined flows from the NPDES169 Basin downstream from that basin's CSO Facility 3 and HydroBrake. The data were also used to characterize the HydroBrake located in the CSO facility. Because CSO Facility 3 is an offline structure, no flow was monitored at this location during dry weather. The wet weather flow data correlated well with the theoretical Manning's curve. The site captured suitable data for the Phase 1 monitoring period. Data quality was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DEL169_076-366A

DEL169_076-366A is a temporary monitoring installation that records depth only. The monitor was installed to measure the use of the storage tank at CSO Facility 3 in the NPDES169 Basin. The pressure depth probe was mounted on the floor of the storage tank. The site captured suitable data for the Phase 1 monitoring period. Data indicated leakage from the CSO chamber through the duckbill valves. Data quality was classified as "Excellent" for the Phase 1 monitoring period. The monitor should be considered for removal in the Phases 2–3 monitoring period.

DEL169_076-367A

DEL169_076-367A is a temporary monitoring installation that records depth only. This pressure monitor was installed to confirm the permanent meters (NPDES169_MH076367 and NPDES169_B_MH076367) data at CSO Facility 3 in the NPDES169 Basin. The data were also used to characterize the HydroBrake located inside the CSO facility. The pressure depth probe, mounted on the floor of the CSO chamber, was determined to be reading 354.6 inches of water depth when the weir to the storage tank overflowed and 376 inches when the CSO weir overflowed. The high level readings from this monitor matched readings from the permanent ultrasonic monitor NPDES169_B_MH076367 exactly, and the low level readings closely agreed with those reported by monitor NPDES169_MH076367. The site captured suitable data for the Phase 1 monitoring period. Data quality was classified as "Excellent" for the Phase 1 monitoring period. The monitor should be considered for removal in the Phases 2–3 monitoring period.

DEL169_076-367B

DEL169_076-367B is a temporary monitoring installation that records pressure depth only. This ultrasonic monitor was installed to confirm the permanent meters (NPDES169_MH076367 and NPDES169_B_MH076367) data at CSO Facility 3 in the NPDES169 Basin, specifically the overflows from the CSO chamber into the storage tank. The ultrasonic depth probe was mounted on the CSO chamber ceiling and aimed at a plate level with the top of the weir to the storage tank. The monitor does not record a depth until the water level in the chamber reaches the elevation of the storage weir. The probe was determined to be reading greater than 0.0 inch of water depth when the weir to the storage tank overflowed. Data collected by this monitor closely agree with data collected by the other three monitors at the same location: DEL169_076-367A, NPDES169_MH076367, and NPDES169_B_MH076367. The site captured suitable data for the Phase 1 monitoring period. Data quality was classified as "Excellent" for the Phase 1 monitoring period. The monitor should be considered for removal in the Phases 2–3 monitoring period.

DEL169_076-370A

DEL169_076-370A is a temporary monitoring installation that records both level and velocity. The flow meter was installed to measure the wet weather combined flows from the NPDES169 Basin downstream from that basin's leaping weir diversion to the King County system. Flow did not occur during dry weather. The data correlated well with the theoretical Manning's curve during storm flows. The maximum velocity was set to 15 fps on 11/25/2008. The site captured suitable data for the November 2008, January 2009, and May 2009 storms. Data quality was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

NPDES169_MH076367

NPDES169_MH076367 is a permanent monitoring installation that records depth only. The monitor was installed to measure the depth at the NPDES169 Basin CSO weir and then calculate the overflow volumes using the weir formula. The pressure depth probe, mounted on the wall of the CSO chamber 10 inches above the floor, measured 382 inches when an overflow occurred. Data collected by this monitor showed agreement

with monitor DEL169_076-367A and monitor NPDES169_B_MH076367 at the low- to mid-level range, but slightly above the readings from those two monitors when the CSO occurred. The site captured suitable data for the Phase 1 monitoring period. Data quality was classified as "Excellent" for the Phase 1 monitoring period. The monitor should continue to be screened for the Phases 2–3 monitoring period.

NPDES169_B_MH076367

NPDES169_B_MH076367 is a permanent monitoring installation that records depth only. The monitor was installed to measure the depth at the NPDES169 Basin CSO weir and then calculate the overflow volumes using the weir formula. The ultrasonic depth probe was mounted on the ceiling of the CSO chamber and aimed at a plate 38.8 inches below the top of the CSO weir. Readings from the monitor matched readings from the temporary pressure monitor DEL169_076-367A, and is in very good agreement with the other two monitors at this location, NPDES169_MH076367 and DEL169_076-367B. The site captured suitable data for the Phase 1 monitoring period. Data quality was classified as "Excellent" for the Phase 1 monitoring period. The monitor should continue to be screened for the Phases 2–3 monitoring period.

NPDES169_O_MH076367

NPDES169_O_MH076367 is a permanent monitoring installation that records depth only. The permanent monitor was installed to measure the overflow volumes downstream from the NPDES169 Basin CSO weir. The sensors were installed in the overflow drainage line downstream from the CSO weir. The site captured suitable data for the Phase 1 monitoring period. Data quality was classified as "Good" for the Phase 1 monitoring period. The monitor should continue to be screened for the Phases 2–3 monitoring period.

SPU_069-198A

SPU_069-198A is a permanent monitoring installation that records both level and velocity. The flow meter was installed to measure the east stream of flow that joins the King County system at MH 069-184. Flow monitored at this location consists of flow from the NPDES169 Basin, flow from the NPDES170 Basin, and flow from the area just west and north of the NPDES169 Basin.

Data captured had a consistent diurnal dry weather flow pattern. The site occasionally receives backwater from the downstream King County system during peak wet weather flows. The site captured suitable data for all wet weather events. Data quality was classified as "Good" for dry weather flow and "Good" for wet weather flow for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

SPU_076-217A

SPU_076-217A is a temporary monitoring installation that records both level and velocity. The flow meter was installed to measure the dry weather flows from the NPDES169 Basin downstream from that basin's leaping weir diversion to the King County system. The site was chosen after review of inspections at MHs 076-216 and 076-215.

The site captured a consistent diurnal dry weather flow pattern, which correlated well with the theoretical Manning's curve during storm flows. Peak flow depths monitored at this location seldom exceeded 3 inches in the 8-inch pipe. During the November 2008, January 2009, and May 2009 storm events, the depth briefly reached 5 inches. Investigation showed that the cause of the low depths was the leaping weir, which was not functioning as designed. A weir plate that deflects flow into the dry weather pipe was missing, which caused additional flow to divert to the CSS control facility. The site captured suitable data for the Phase 1 monitoring period. Data quality for both dry and wet weather flows was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

3.3.4 NPDES170 Basin

The NPDES170 Basin, located due west of the NPDES168 Basin, is approximately 50 acres in area. The NPDES170 Basin contains three control structures: a 0.2 MG in-line storage pipe, a HydroBrake, and an overflow weir. One permanent meter monitors the basin to verify and compute overflows. A HydroBrake controls the outflow from a storage pipe that is from the overflow weir. No temporary monitors were in the NPDES170 Basin until September 2009. The temporary monitors were added to characterize the HydroBrake and the storage utilization.

DEL170_DWF-069144

DEL170_DWF-069144 is a permanent monitoring installation that records both velocity and level. The meter was installed in the upstream pipe and on the dry weather side of the NPDES170 Basin CSO weir. Data collected by this meter were used both for calculating the overflow volume and characterizing the HydroBrake downstream. The site captured suitable data for the Phase 1 monitoring period. Data quality was classified as "Excellent" for the Phase 1 monitoring period. SPU placed the site on the dry weather list to provide finalized velocity and flow data. The meter should continue to be screened, and velocity should be finalized for the Phases 2–3 monitoring period.

3.3.5 Combined Sewer Overflows

ADS reported that four CSOs occurred in the Delridge/Longfellow Basin during the Phase 1 monitoring period; Table 3-5 lists the CSOs reported by ADS during the Phase 1 monitoring period. A sensor failure occurred in the ADS installation at the NPDES099 Basin in the 1/7/2009–1/8/2009 event. SPU estimated the volume of overflow at the NPDES099 Basin for that event based on depths recorded in the adjacent storage tank. Depths measured at other nearby monitoring sites confirmed the occurrence of the overflow.

Table 3-5. 2008–2009 Combined Sewer Overflows in Delridge/Longfellow Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
99[a]	1/7/2009	6:45	1,434,480
168[b]	1/7/2009	32:05	3,133,531
	5/5/2009	00:45	21,774
	5/19/2009	00:15	4,601
169	11/7/2008	5:55	190,191
	1/7/2009	9:20	934,903
170	--	--	--

[a] *January 2009 overflow at NPDES099 estimated by SPU from level data in storage tank.*
[b] *Overflows reported at NPDES168 come from a monitor in the overflow pipe downstream from the weir, which may be in error.*

Figure 3-5 shows the maximum water level recorded at each of the overflow structures in the Delridge/Longfellow Basin as a percentage of the weir height. Two overflows were reported by ADS at the NPDES168 Basin in May 2009 as shown in Table 3-4. However, Figure 3-3 shows that the level in the control chamber did not exceed the overflow weir height. Detailed examination of this issue indicates that flow in the adjacent storm sewer affected the velocity probe in the overflow pipe. Stormwater runs up the

overflow pipe over the velocity probe when depth is high in the storm sewer. As the depth in the storm sewer recedes, the outflow of stormwater stored in the overflow pipe generates a positive velocity that gives a false indication of overflow. Thus, the two overflows reported at the NPDES168 Basin in May 2009 may be false.

3.3.6 Facility Operations

The CSO facilities in the Delridge/Longfellow Basin consist of four overflow weirs, four HydroBrakes, and four storage tanks. The Delridge/Longfellow Basin has no pump stations. The NPDES170 Basin has a storage tank downstream from the overflow weir with a horizontal HydroBrake in the tank.

HydroBrake 069-144

This HydroBrake was not monitored in the Phase 1 monitoring period. Monitors were installed in the storage tank to provide characterization of the HydroBrake in the Phases 2–3 monitoring period.

HydroBrake 055-478

Figure 3-6 shows the HydroBrake curves based upon monitoring data at an upstream meter and a downstream meter with respect to the HydroBrake location. The level data at the upstream meter 055-478 at MH 055-478 were used for the HydroBrake analysis. The level and flow data at the downstream meter 055-165 were also used for the analysis. The gathered data were then compared to the HydroBrake manufacturer's curve. Figure 3-6 shows the manufacturer's curve, "previous data" (October through April), and the "current data" (April through May). Data from the second year of flow monitoring will be used to determine the appropriate curve to be used for model calibration.

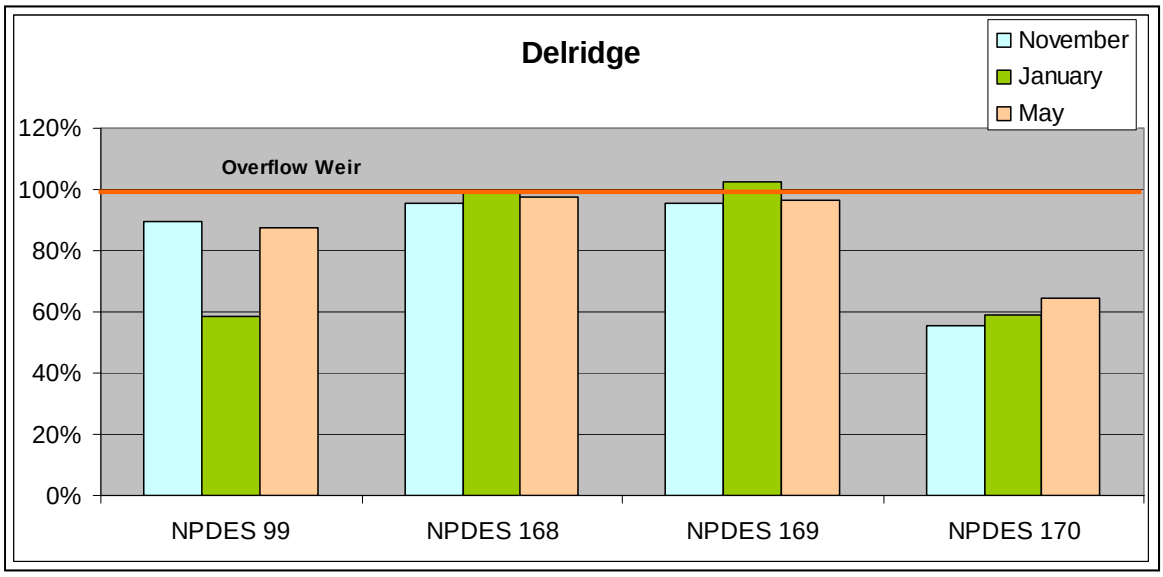

Figure 3-5. Maximum water level recorded in Delridge/Longfellow Basin by NPDES site for major events
(the recorded levels at the NPDES168 Basin are from depth recorded upstream from the weir)

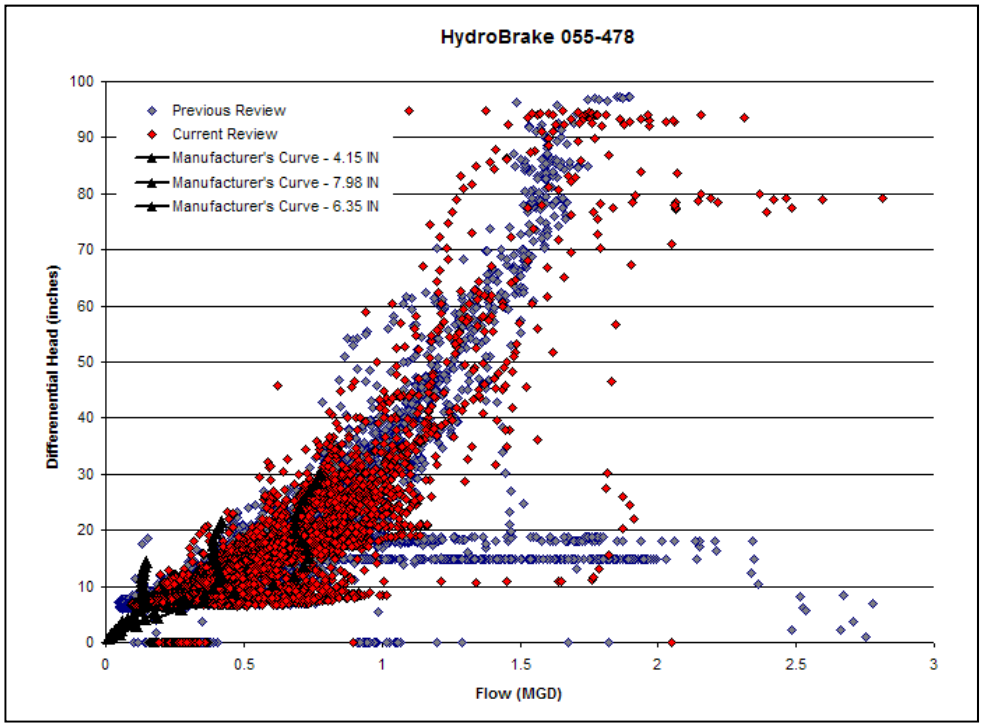

Figure 3-6. NPDES099 Basin HydroBrake characterization

HydroBrake 069-428

Figure 3-7 below shows the HydroBrake curve based upon monitoring data at an upstream meter and a downstream meter with respect to the HydroBrake location. The level data at upstream meter 069-428 were used for the HydroBrake analysis. The level and flow data at downstream meter 069-406 were also used for the analysis. The HydroBrake manufacturer's curve was not available for this HydroBrake analysis. Figure 3-7 shows "previous data" (October 2008 through April 2009) and the "current data" (April 2009 through May 2009). Data from the second year of flow monitoring will be used to determine the appropriate curve to be used for model calibration.

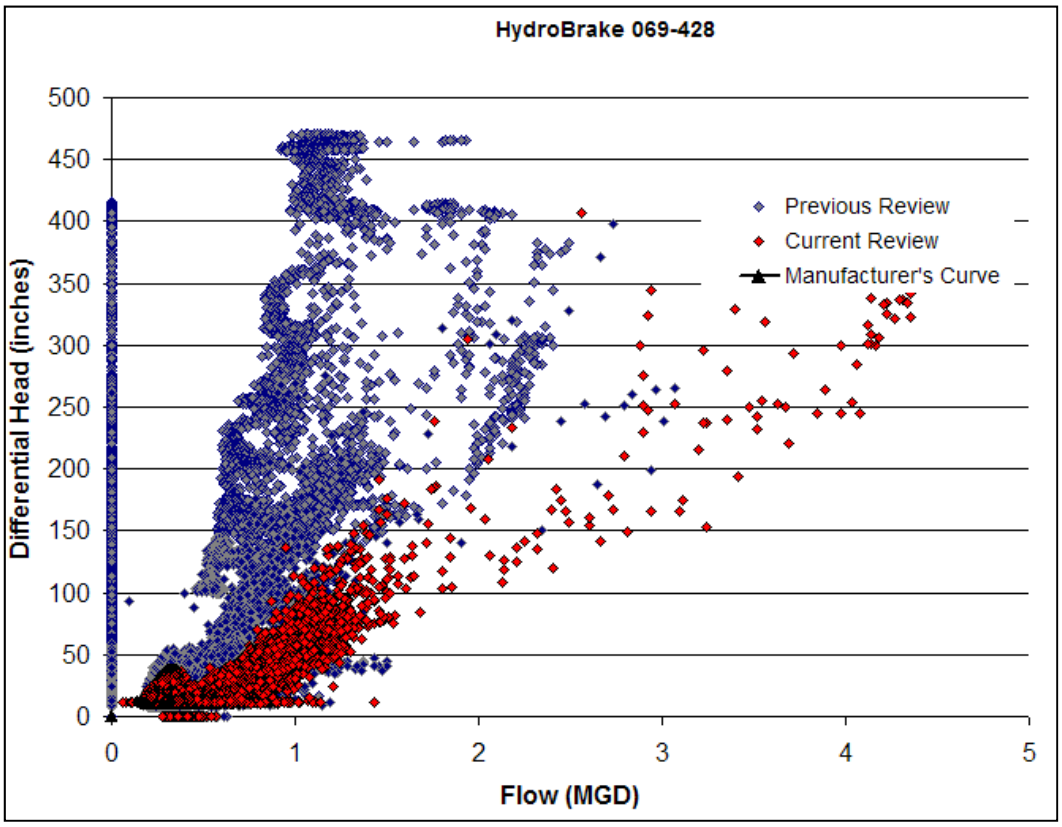

Figure 3-7. NPDES168 Basin HydroBrake characterization

HydroBrake 076-367

Figure 3-8 shows the HydroBrake curve based upon monitoring data at an upstream meter and a downstream meter with respect to the HydroBrake location. The level data at upstream meter 076-367 were used for the HydroBrake 076-367 analysis. The level and flow data at downstream meter 076-362 were also used for the analysis. The HydroBrake manufacturer's curve was not available for this HydroBrake. Figure 3-8shows "previous data" (October 2008 through April 2009) and the "current data" (April 2009 through May 2009). The flat line of data at approximately 374 inches indicates the overflow height of the weir in the control chamber. The horizontal series of points close to 350 inches indicates flow into the storage tank from the control chamber. Data from the second year of flow monitoring will be used to finalize the curve to be used for model calibration.

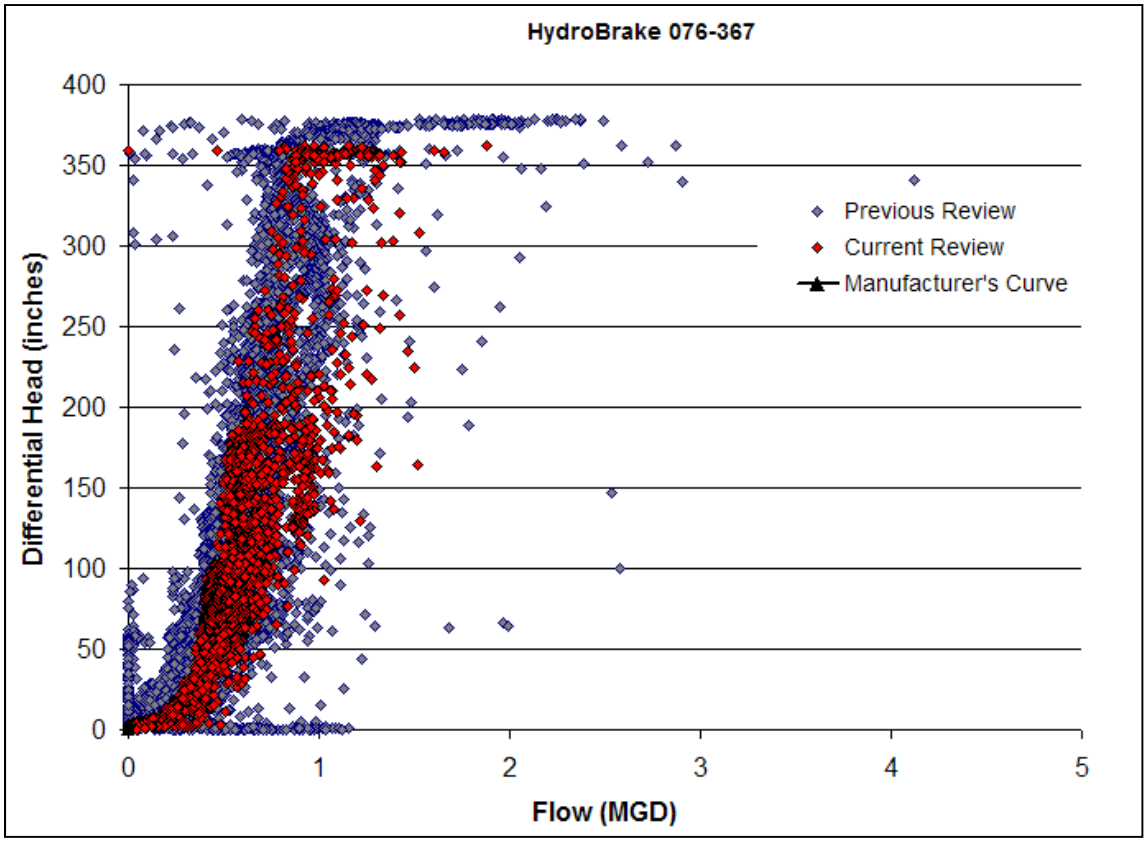

Figure 3-8. NPDES169 Basin HydroBrake characterization

3.3.6.1 Storage Tank Operations

Four storage tanks are located in the Delridge area as well as temporary meters at each site to measure level.

Storage Tank 055-478

The storage tank located at 055-478 is an offline storage tank that works in conjunction with HydroBrake 055-478. When the HydroBrake triggers during storm events, the tank fills. Temporary monitor DEL99_055-473A measures the level in the storage tank during wet weather events. During large wet weather events the flow begins to fill the 84-inch-diameter, 550-foot-long storage tank. The total volume of the storage tank is 160,000 gallons. During the January 2009 storm event, the entire storage was utilized, and no overflow was reported at the permanent meter. The level sensor at the permanent meter failed in the peak of the January event, which resulted in an incorrect depth measurement. Based on depth measurements at surrounding meters and elevations from the GIS data, SPU determined that an overflow occurred on 1/7/2009 and issued a corrected CSO report.

Storage Tank 069-428

The storage tank located at 069-428 is an offline storage tank that works in conjunction with HydroBrake 069-428. When the HydroBrake triggers during storm events, the tank fills. Temporary monitor DEL168_069-408A measures the level in the storage tank during wet weather events. During large wet

weather events, the flow begins to fill the 100-foot-diameter, 27-foot-deep storage tank. The total volume of the storage tank is 1.6 million gallons. During the January 2009 storm event, the storage capacity was entirely utilized and an overflow occurred.

Storage Tank 076-367

The storage tank at 076-367 is an offline storage tank that works in conjunction with HydroBrake 076-367. When the HydroBrake triggers during storm events, the tank fills. Temporary monitor DEL169_076-366A measures the level in the storage tank during wet weather events. During large wet weather events, the flow begins to fill the 100-foot-diameter, 27-foot-deep storage tank. The total volume of the storage tank is 1.6 million gallons. During the January 2009 storm event, the storage capacity was entirely utilized and an overflow occurred.

Storage Tank NPDES170

The NPDES170 Basin storage tank is an offline storage tank located at the intersection of 24th Avenue SW and SW Webster Street. The storage tank works in conjunction with a HydroBrake located in MH 069-146 downstream from the overflow weir. When the HydroBrake is activated during storm events, the flow is stored in the 8-foot-diameter, 521-foot-long storage tank at MH 069-146. A temporary monitor at DEL170_069-146 was installed for the Phases 2–3 monitoring period to measure the level in the HydroBrake chamber to develop the HydroBrake curve to be used in the model. An intermediate weir is located in the storage tank. If the tank capacity is exceeded during large wet weather events, a CSO will occur. Meter DEL170_DWF-069144 is a permanent monitoring site located at the CSO overflow weir, one MH upstream from the storage facility and HydroBrake. This meter measures the total flow from the NPDES170 Basin and was used to quantify CSOs at NPDES Outfall 170. The meter was also used to perform a total flow quantity calculation (flow balance) into the HydroBrake structure.

3.3.7 Recommendations for Additional Data Collection

All flow monitoring sites that were not removed during the Phase 1 monitoring period are recommended to remain in place throughout Phases 2 –3 of the wet season monitoring period. DEL169_076-351A and DEL169_076-351B were removed during the Phase 1 monitoring period. Only the depth monitor in the NPDES170 Basin storage tank has been identified for addition in Phases 2–3 of the wet weather season.

3.4 Duwamish Basin

The Duwamish Basin, which consists of the NPDES107 and NPDES111 Basins, covers an area of approximately 585 acres.

The combined sewer flows in the NPDES111 Basin were monitored with temporary and permanent meters, and the combined sewage flows from east to west were monitored with temporary meters at seven locations. The Duwamish Basin has a total of eight overflow locations, and overflows from the NPDES111 Basin flow into the eastern shore of the Duwamish River. One permanent meter monitors NPDES107 Basin, which has no suitable location to measure flows. Overflows in the NPDES107 Basin flow into the East Waterway at the mouth of the Duwamish River. Rainfall in the Duwamish Basin is monitored by RG 15, located at the Puget Sound Clean Air Monitor Station, and ADS monitors nine overflow points within the Duwamish Basin.

Overflows were monitored at 10 permanent monitoring points, and 7 temporary meters were installed during the review period. Appendix E contains detailed information on each meter, and a basin schematic is contained in Appendix B.

3.4.1 NPDES107 Basin

The Duwamish NPDES107 Basin, located due north of the NPDES111 Basin along the eastern shore of the Duwamish River, is approximately 51 acres in area. One permanent meter monitors the basin to verify overflows. It was found to be impossible to install a meter to collect reliable velocity data in this basin. Thus, there are no flow data with which to calibrate a model.

NPDES107_MH056097

This permanent monitor was installed to measure depth at the NPDES107 Basin overflow weir. The site is not expected to provide repeatable and reliable dry weather flow data and is classified as a wet weather site. The site captured suitable data for all wet weather events. The data is typically noisy. Four overflow events occurred at this location during the Phase 1 monitoring period. Depth data quality was classified as "Good" for the Phase 1 monitoring period. The monitor should continue to be screened for the Phases 2–3 monitoring period.

3.4.2 NPDES111 Basin

The Duwamish NPDES111 Basin, located on the eastern shore of the Duwamish River, is approximately 534 acres in area. CSO Facility 35 is a CSS control facility located in the NPDES111(H) Basin. The facility contains three control structures: a 0.16 MG in-line storage pipe, a HydroBrake, and an overflow weir. Eight permanent meters monitor the basin to verify overflows. The NPDES111 Basin has seven temporary monitoring locations.

DUW111_056-166A

DUW111_056-166A is a temporary monitoring installation that records both level and velocity. The meter was installed to measure the combined flows from the western part of the NPDES111 Basin. The meter is located downstream from the basin's 111H CSS control facility and 111D, 111E, 111F, and 111G CSO weirs, but upstream from the basin's 111A, 111B, and 111C CSO weirs and the King County Duwamish pump station. Data at the site captured a consistent diurnal dry weather flow pattern. Also, the data correlated well with the theoretical Manning's curve during storm flows. Depths exceeding 70 inches were recorded in the 35-inch-diameter pipe. Because of backwater effects, the usefulness of the data is somewhat limited. The backwater effects were caused either by high tides inflowing through the 111A and 111B CSO weir flap gates

or possibly by the King County pump station. Debris from 1 to 2 inches was also observed several times at this site. The site captured suitable data for the Phase 1 monitoring period.

Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. The tidal and backwater effects from the King County pump station will need to be accounted for. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DUW111_057-039A

DUW111_057-039A is a temporary monitoring installation that records both level and velocity. The meter was installed to measure the combined flows from the eastern portion of the basin. The site was chosen after review of inspections at MHs 057-037, 057-038, 057-040, 057-041, 057-043, 057-045, and 057-046.

The data at this location had a consistent diurnal dry weather flow pattern and correlated well with the theoretical Manning's curve during storm flows. The site captured suitable data for all wet weather events. Data quality was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DUW111_057-229A

DUW111_057-229A is a temporary monitoring installation that records both level and velocity. The meter was installed to measure the combined flows leaving the HydroBrake of the basin's 111H CSO facility (CSO Facility 35). Data from this site will be used to characterize the HydroBrake. The data at this site had a consistent diurnal dry weather flow pattern. The data correlate well with the theoretical Manning's curve during storm flows. The site captured suitable data for the Phase 1 monitoring period. Data quality was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DUW111_057-241A

DUW111_057-241A is a temporary monitoring installation that records level and velocity. The meter was installed to measure the combined flows from west part of the residential area in the NPDES111 Basin upstream from that basin's 111H CSO weir and HydroBrake. The site was chosen after review of inspections at MH 057-240. The data at this site captured a consistent diurnal dry weather flow pattern. The data correlated well with the theoretical Manning's curve during storm flows. The site captured suitable data for all wet weather events. Data quality was classified as "Excellent" for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DUW111_057-241B

DUW111_057-241B is a temporary monitoring installation that records both level and velocity. The meter was installed to measure the combined flows from one single mainline in the residential area of the NPDES111 Basin upstream from that basin's 111H CSO weir and HydroBrake. The site was chosen after review of inspections at MHs 057-165 and 057-240. The data at this site captured a consistent diurnal dry weather flow pattern, which is different than the pattern generated from meter DUW111_057-241A. Dry weather flow was typically 1 inch in depth, which affected dry weather data accuracy. Velocity and depth data correlated well with the theoretical Manning's curve during storm flows. The site captured suitable data for all wet weather events. Data quality was classified as "Good" for dry weather flow and "Excellent" for wet weather flow for the Phase 1 monitoring period. It is recommended that the meter remain in place for the Phases 2–3 monitoring period.

DUW111_057-247A

DUW111_057-247A was a temporary monitoring installation that records both level and velocity. The meter was installed to measure the combined flows diverting from the NPDES111H Basin into the King County Michigan Street area during wet weather flow. The meter was located upstream from the NPDES111 Basin's 111H CSO weir and HydroBrake (CSO Facility 35). Diversions occur frequently under modest rainfall. Wet weather flow from this site is conveyed south away from the NPDES111H Basin CSO Facility 35. The site captured suitable data for the November 2008 and January 2009 storms, in addition to smaller storms before the end of March 2009. It was observed that only small amounts of flow were diverted out of the NPDES111H Basins from this location for short periods of time during storm events (peak diversion flows were generally less than 0.15 million gallons per day [mgd]). Data quality was classified as "Good" for wet weather flow. The pipe is dry except during overflow events. The meter was removed on 3/30/2009 as it was determined that sufficient data had been collected. The diversion was temporarily plugged in August 2009 for the Phases 2–3 monitoring period.

DUW111_057-350A

DUW111_057-350A is a temporary monitoring installation that records level only. The monitor was installed to measure the water depth within the HydroBrake chamber at the NPDES111H Basin CSO weir. The site was chosen after review of inspections at MH 057-348. The pressure depth probe is mounted on the wall of the chamber 13 inches above the invert of the structure, which is just above the water surface during normal dry weather flow. The data were used for HydroBrake characterization. The monitor was installed on 1/26/2009 and captured suitable data for the May 2009 storms, in addition to smaller storm events in March and April 2009.

Data quality was classified as "Excellent" for the Phase 1 monitoring period. The mounting of the pressure probe above the invert was necessitated by the configuration of the structure. The lower range of the HydroBrake curve will be approximated. It is recommended that the monitor remain in place for the Phases 2–3 monitoring period.

NPDES111A_MH056195

NPDES111A_MH056195 is a permanent monitoring installation that records both level and velocity. The meter was installed to measure depth at the NPDES111A Basin CSO weir. Meters were installed in both the upstream and downstream pipes. The site is not expected to provide repeatable and reliable dry weather flow data and is classified as a wet weather site. The site captured suitable data for all wet weather events. No overflows occurred during the review period. The data at this site show backwater effects from either high tides through a leaking flap gate or from the King County pump station located just downstream. Data quality was classified as "Excellent" for the Phase 1 monitoring period. The meter should continue to be screened for the Phases 2–3 monitoring period.

DUW111_DWF-056270

DUW111_DWF-056270 is a permanent monitoring installation that records both level and velocity. The meter was installed in the upstream pipe on the dry weather flow side of the NPDES111B CSO weir to measure the overflow volumes, and to provide dry weather flow data for basin characterization. The meter generally captured a consistent diurnal dry weather flow pattern. The data were consistent with expected backup conditions during storm flows. The data indicated backwatering from high tides. Negative velocities (and thus negative flow) were recorded in the November 2008 and January 2009 events. The site captured suitable data for all wet weather events. Data quality was classified as "Excellent" for the Phase 1 monitoring period. Two overflow events were reported in May 2009. The meter should continue to be screened for the Phases 2–3 monitoring period.

NPDES111C_MH056365

NPDES111C_MH056365 is a permanent monitoring installation that records both level and velocity. The meter was installed to measure depth at the NPDES111C Basin CSO weir. The site is not expected to provide repeatable and reliable dry weather flow data and is classified as a wet weather site. The site captured suitable depth data for all wet weather events. The data indicated backwatering and perhaps tidal flow into the structure during high tides. One overflow was recorded at this site on 5/5/2009. Data quality was classified as "Good" for the Phase 1 monitoring period. The meter should continue to be screened for the Phases 2–3 monitoring period.

NPDES111D_MH057253

NPDES111D_MH057253 is a permanent monitoring installation that records both level and velocity. This permanent meter was installed to measure the overflow volumes at the NPDES111D Basin CSO weir. The site is not expected to provide repeatable and reliable velocity data and is classified as a wet weather site. The site captured suitable data for all wet weather events. No overflow events occurred at this site during the Phase 1 monitoring period. The data indicated backwatering from high tides. Depth data quality was classified as "Excellent" for the Phase 1 monitoring period. The meter should continue to be screened for the Phases 2–3 monitoring period.

NPDES111E_MH057065

NPDES111E_MH057065 is a permanent monitoring installation that records both level and velocity. The permanent meter was installed to measure the overflow volumes at the NPDES111E Basin CSO weir. The sensors at this site were installed in the elevated overflow pipe, and therefore no dry weather flow data were to be collected at this site. The site is classified as a wet weather site so that velocity data are not considered reliable for basin characterization. No overflow events occurred at this location during the Phase 1 monitoring period. Depth data quality was classified as "Excellent" for the Phase 1 monitoring period. The meter should continue to be screened for the Phases 2–3 monitoring period.

NPDES111F_MH057079

NPDES111F_MH057079 is a permanent monitoring installation that records both level and velocity. The meter was installed to measure the overflow volumes at the NPDES111F Basin CSO weir and to measure dry weather flows for basin characterization. The site captured consistent dry weather flow patterns. The data correlated well with the theoretical Manning's curve during storm flows, and the site captured suitable data for all wet weather events. The data reflected groundwater inflow into the combined system at this location. No overflow events occurred at this location during the Phase 1 monitoring period. Data quality was classified as "Excellent" for the Phase 1 monitoring period. The meter should continue to be screened for the Phases 2–3 monitoring period.

NPDES111G_MH057513

NPDES111G_MH057513 is a permanent monitoring installation that records both level and velocity. Three sets of sensors are installed at this location. The first sensor set measures the upstream flow, the second set measures the stormwater flow diverted by the low flow diversion structure into the CSS, and the third set measures the overflow volumes at the NPDES111G Basin CSO weir. The site is not expected to provide repeatable and reliable dry weather flow data and is classified as a wet weather site. The site captured suitable data for all wet weather events. No overflow events occurred at this site during the Phase 1 monitoring period. Depth data quality was classified as "Excellent" for the Phase 1 monitoring period. The meter should continue to be screened for the Phases 2–3 monitoring period.

NPDES111H_MH057347

NPDES111H_MH057347 is a permanent monitoring installation that records both level and velocity. The meter was installed to measure the depth at the NPDES111H Basin CSO weir and HydroBrake (CSO Facility 35) to calculate overflow volumes. Depth data from this site were also used to characterize the HydroBrake. The site is not expected to provide repeatable and reliable dry weather flow data and is classified as a wet weather site. The site captured suitable depth data throughout Phase 1 monitoring. One overflow event occurred at this location during the January 2009 storm in the Phase 1 monitoring period. Depth data quality was classified as "Good" for the Phase 1 monitoring period. The meter should continue to be screened for the Phases 2–3 monitoring period.

3.4.3 Combined Sewer Overflows

ADS reported that seven CSOs occurred in the Duwamish Basin during the Phase 1 monitoring period; Table 3-6 lists the CSOs that occurred during the Phase 1 monitoring period.

Table 3-6. 2008–2009 Combined Sewer Overflows in Duwamish Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
111A	--	--	--
111B	5/5/2009	0:40	45,195
	5/19/2009	0:10	3,774
111C	5/5/2009	0:30	38,110
111D	--	--	--
111E	--	--	--
111F	--	--	--
111G	--	--	--
111H	1/7/2009	3:40	1,231,772
107	11/7/2008	11:40	625,537
	1/7/2009	5:45	165,998
	4/2/2009	1:50	244,327
	5/5/2009	2:30	402,134

Figure 3-9 shows the maximum water level recorded at each of the overflow structures in the NPDES95 Basin as a percentage of the weir height. May 2009 data include the 5/19/2009 storm event.

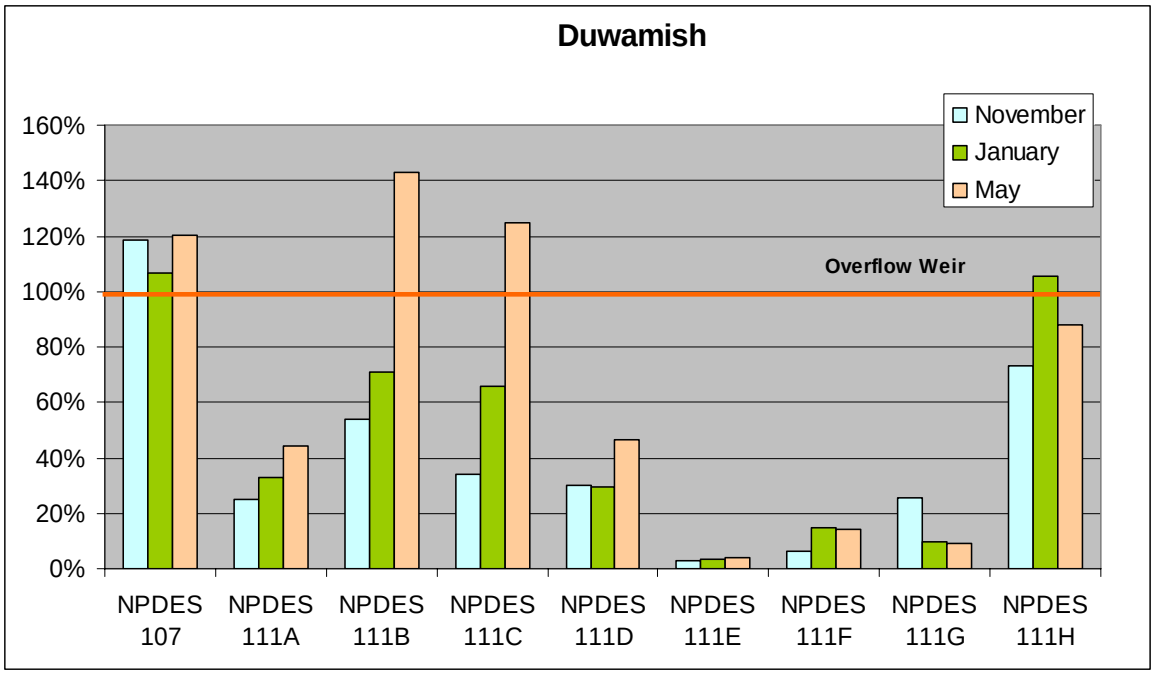

Figure 3-9. Maximum water level recorded in Duwamish Basin for major events

3.4.4 Facility Operations

The CSO facilities in the Duwamish Basin consist of nine overflow weirs as described in the sections above. One HydroBrake and one storage tank are located in the Duwamish Basin. One pump station is located in the Duwamish Basin. However, it is a King County pump station, and it was not monitored during this review period.

HydroBrake 057-350

Figure 3-10 below shows the HydroBrake curve based upon monitoring data at an upstream meter and a downstream meter with respect to the HydroBrake location. The level data at upstream meter 057-350 were used to calculate the head at the HydroBrake. The level and flow data at downstream meter 057-229 were used to calculate the flow going through the HydroBrake and the differential head. The HydroBrake manufacturer's curve was not available for this HydroBrake. Figure 3-10 shows "previous data" (February through April) and the "current data" (April through May). Data from the Phases 2–3 monitoring period will be used to determine the appropriate curve to be used for model calibration.

Storage Tank 057-350

The storage tank located at 057-350 is an in-line storage tank that works in conjunction with HydroBrake 057-350. When the HydroBrake triggers during storm events, the tank fills. Temporary monitor DUW111_057-350A measures the level in the storage tank during wet weather events.

During large wet weather events, the flow begins to fill the 84-inch-diameter, 550-foot-long storage tank. During the May 2009 storm event, 60 percent of the entire storage was utilized. During the January 2009 storm event, the storage was fully utilized when the site was overflowing.

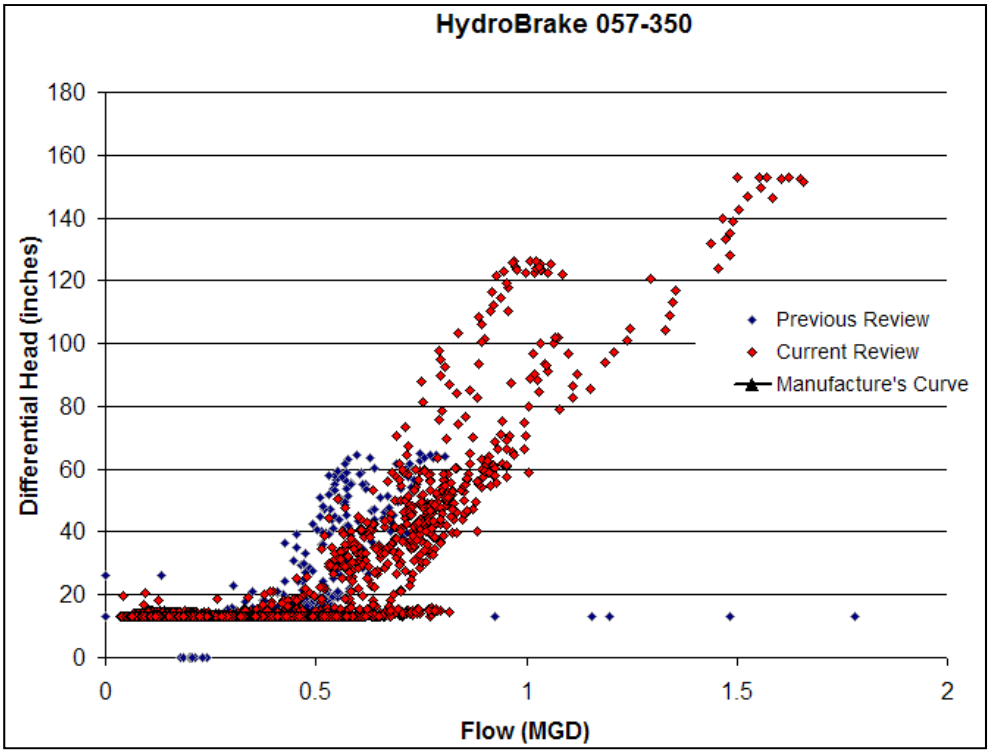

Figure 3-10. NPDES111H Basin HydroBrake characterization "previous data" (February through April) and "current data" (April through May)

3.4.5 Recommendations for Additional Data Collection

All sites that were not removed during the Phase 1 monitoring period should remain in place throughout Phases 2–3 of the wet season monitoring period. Meter DUW111_057-247A was removed on 3/3/2009. No additional sites within the Duwamish Basin have been identified for Phases 2–3 of the wet weather season.

3.5 Fremont/Wallingford Basin

The Fremont/Wallingford Basin, which consists of the NPDES147, NPDES148, and NPDES174 Basins, is approximately 624 acres in area. The combined sewer flows from the NPDES147 Basin are broken up into two subcatchments: NPDES147(A) and NPDES147(B). Each subcatchment has its own overflow structure but the two share a common outfall. The NPDES147(A) Subcatchment is on the eastern side of the NPDES147 Basin, while the NPDES147(B) Subcatchment is on the western side. Flows from each subcatchment proceed from north to south by gravity to their respective overflow structures, then into the King County system. The NPDES148 Basin is a small 33-acre basin that flows into the NPDES174 Basin through PS 54. All monitoring sites in the NPDES148 Basin are discussed in Section 3.5.2 with sites from the NPDES174 Basin. The flows from the western and eastern parts of the NPDES174 Basin combine just north of the NPDES174 Overflow Structure, and flow into the King County system.

RG 09, located in the Woodland Park Zoo in the northern part of the NPDES174 Basin, monitors rainfall in the entire Fremont/Wallingford Basin.

Combined sewage flow was monitored by 3 permanent stations and 15 temporary meters installed during the review period. Detailed information on the Fremont/Wallingford Basin can be found in Appendix F; a basin schematic is in Appendix B.

3.5.1 NPDES147 Basin

NPDES147 Basin is the eastern basin in Fremont/Wallingford. The basin is located on the northern shore of the Lake Washington Ship Canal west of Lake Union. In general, NPDES147 Basin, with an area of approximately 292 acres, is bounded to the north by N 50th Street, to the west by Fremont Avenue N, and to the east by Woodlawn Avenue N. Woodland Park Zoo is at the northern boundary. It is monitored by two permanent meters to verify overflows from the NPDES147(A) Subcatchment (eastern basin) and NPDES147(B) Subcatchment (western basin). Seven temporary monitoring locations are located in the NPDES147 Basin.

FRE147_022-118A

FRE147_022-118A is a temporary monitoring location that records both level and velocity. The meter measures flow from the western part of the NPDES147(B) Subcatchment. The meter is located in the west pipe in a dual FlowShark configuration with site FRE147_022-118B. This meter receives flow from part of the basin along State Route 99. No alternative monitoring locations were considered for FRE147B_022-118A.

Data quality was classified as "Good" for the Phase 1 monitoring period because the early morning low dry weather flows are overestimated due to water pooling in front of the velocity sensor. All other data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE147_022-118B

FRE147_022-118B is a temporary monitoring location recording both level and velocity. The meter estimates flow from the western part of the NPDES 147(B) Subcatchment. The meter is located in the east pipe in a dual FlowShark configuration with site FRE147_022-118A. The site was chosen after review of an alternative location at 022-119.

Data quality was classified as "Good" for the Phase 1 monitoring period because the early morning low dry weather flows are overestimated due to water pooling in front of the velocity sensor. All other data are

suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE147_022-152A

FRE147_022-152A is a temporary monitoring location that records both level and velocity. The meter estimates flow from the north part of the NPDES147(B) Subcatchment. The site was chosen after review of alternative locations at 022-150, 022-151, and 022-159.

Data between 10/23/2008 and 11/1/2008 were suspect and will not be used in calibration. Examination of spikes in the flow data by Stantec in data finalization indicated that the highest peak flows may be overestimated. Data quality was therefore classified as "Good" for the Phase 1 monitoring period. The modelers should be aware that the spikes in the data may not be representative. All data, excluding data from 10/23/2008 to 11/1/2008 and the flow spikes, are suitable for use in model calibration. At the end of October 2009, debris appeared to have accumulated on the sensor or immediately downstream, creating an unrepresentatively high flow depth and very low velocity. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE147_022-174A

FRE147_022-174A is a temporary monitoring location that records both level and velocity. The meter estimates flow entering the King County interceptor from the west (NPDES147 [B] Subcatchment) and southwest parts of the NPDES147 Basin. No alternative monitoring locations were considered for FRE147_022-174A.

The meter is located in a large pipe with a mild slope (0.22 percent) and is, therefore, susceptible to siltation. It quickly became clear that the site was not conducive to collection of reliable velocity data. The velocity data were intermittent throughout the data period, and the velocity meter was rotated out of the silt multiple times. The quality of the depth data was classified as "Good" for the Phase 1 monitoring period because some data were missing in minor wet weather periods. The level data provide a boundary condition for the model, reflecting the influence of the King County north interceptor, and are more important than velocity at this location. All level data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE147_022-306A

FRE147_022-306A is a temporary monitoring installation that records both level and velocity. The meter was installed to estimate flow from the western part of the NPDES147(A) Subcatchment. The site was chosen after review of alternative locations at 022-310, 022-309, and 022-305.

Data quality was classified as "Good" for the Phase 1 monitoring period because there are some data gaps during dry and wet weather. All data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE147_022-318A

FRE147_022-318A is a temporary monitoring installation that records both level and velocity. The meter was installed to estimate flow from the eastern part of the NPDES147(A) Subcatchment. The site was chosen after review of alternative locations at 022-317 and 022-420.

Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps. All data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE147_DWF-022187

FRE147_DWF-022187 is a permanent monitoring installation that records both level and velocity. The site has two monitors: one located in the incoming 30-inch pipe (dry weather site), and one located in the overflow line (wet weather site). The level data are used to alarm for CSO events from the NPDES147(A) Subcatchment and calculate the volume of CSOs using a weir equation.

Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during wet and dry weather and lack of data gaps. At the dry weather site, the velocity data are finalized. At the wet weather site, the velocity data are not finalized and are not intended to be used for model calibration. All other data are suitable for use in model calibration.

FRE147_DWF-022160

FRE147_DWF-022160 is a permanent monitoring location that records both level and velocity. The site has two monitors: one located in the incoming 21-inch pipe (dry weather site), and one located in the overflow line (wet weather site). The level data are used to alarm for CSO events from the NPDES147(B) Subcatchment and calculate the volume of CSOs using a weir equation.

Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during wet and dry weather and lack of data gaps. At the dry weather site, the velocity data are finalized. At the wet weather site, the velocity data are not finalized and are not intended to be used for model calibration. All other data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

SPU_022-188A

SPU_022-188A is a temporary monitoring installation that records level only. The meter was installed to measure level downstream from the non-return valve that prevents backflow from the King County interceptor near the NPDES147(A) Subcatchment overflow. No alternative monitoring locations were considered for SPU_022-188A.

The meter was installed 1/27/2009. Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during wet weather and lack of data gaps. All data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

3.5.2 NPDES174 Basin

The NPDES174 Basin is the western basin in Fremont/Wallingford. Located on the northern shore of the Lake Washington Ship Canal and west of Lake Union, the basin is approximately 329 acres in area. The NPDES148 Basin, which is approximately 33 acres in area, flows into the NPDES174 Basin via PS 54. The CSS control facilities in the NPDES174 Basin do not contain any storage or HydroBrakes. Overflows in the NPDES148 Basin are monitored by the SCADA system recording of wet well level at PS 54. The NPDES148 Basin is considered to be controlled.

Eight temporary meters and one permanent meter to verify overflows monitor the basin.

FRE174_013-115A

FRE174_013-115A is a temporary monitoring location that records both level and velocity. The meter estimates flow from the Woodland Park Zoo in the northern part of the NPDES174 Basin. No alternative monitoring locations were considered for FRE174_013-115A.

The flow from the Woodland Park Zoo adds twice-daily nontraditional discharges (cleaning or tank water from the zoo is suspected). The timing and magnitude of the discharges are variable. These discharges exceed the wet weather response of the tributary area except in the most intense rainfall events. The flows from the zoo will require special handling in modeling the wet and dry weather flow. Data quality was classified as "Good" for the Phase 1 monitoring period because the data had a clear, consistent site signature with no data gaps. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE174_022-039A

FRE174_022-039A is a temporary monitoring location that records both level and velocity. The meter estimates flow from the northeastern part of the NPDES174 Basin. The meter was installed on 11/11/2008. The site was chosen after review of alternative locations at 022-035, 022-036, 022-037, 022-038, and 021-074.

The meter is downstream from site FRE174_013-115A; therefore, the meter measures flows farther downstream from Woodland Park Zoo. The data exhibit the same nontraditional flows from the zoo as the upstream meter. Data quality was classified as "Good" for the Phase 1 monitoring period because of relatively wide scatter at peak flows. The upstream meter data will need to be used as an upstream boundary condition for model calibration. All data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE174_022-043A

FRE174_022-043A is a temporary monitoring location that records both level and velocity. The meter estimates flow from the middle-eastern part of the NPDES174 Basin. No alternative monitoring locations were considered for FRE174_022-043A.

Data quality was classified as "Good" for the Phase 1 monitoring period because dry weather data have a variable diurnal pattern (inconsistent signature). All wet weather data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE174_021-044A

FRE174_021-044A is a temporary monitoring location recording both level and velocity. The meter estimates flow from the northwestern part of the NPDES174 Basin and is downstream from PS 54 (NPDES148 Basin). The site was chosen after review of alternative locations at 021-045 and 021-046.

During the review period, the meter band was damaged; therefore, there is a data gap from 10/1/2008 to 10/19/2008. However, the data gap did not occur during a wet weather event. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during wet and dry weather. All data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE174_021-045B

FRE174_021-045B is a temporary monitoring location recording both level and velocity. The meter estimates flow from the northwestern part of the NPDES174 Basin. The site was chosen after review of alternative locations at 021-083 and 021-046.

The meter is located in the northeast pipe that enters the maintenance hole. Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during wet and dry weather. During low flows the data presented lower resolution. All data at peak flows during storm events are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE174_021-050A

FRE174_021-050A is a temporary monitoring location that records both level and velocity. The meter estimates flow from the western part of the NPDES174 Basin and is downstream from PS 54 (NPDES148 Basin). No alternative monitoring locations were considered for FRE174_021-050A.

Data quality was classified as "Good" for the Phase 1 monitoring period as there are multiple dry weather regimes from the pump station at low flow, and there is a change in site signature in mid-October 2009. All wet weather data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE174_021-066A

FRE174_021-066A is a temporary monitoring location that records both level and velocity in a brick sewer. The meter estimates flow from the northeast part of the NPDES174 Basin. No alternative monitoring locations were considered for FRE174_021-066A.

The meter is downstream from sites FRE174_013-115A and FRE174_022-039A; therefore, it measures flows farther downstream from Woodland Park Zoo. The data exhibit the same nontraditional flows from the zoo. There is a data gap 11/27/2008 to 12/3/2008 because the meter was damaged and needed to be replaced. However, this data gap did not occur during a significant wet weather event. Data quality was classified as "Good" for the Phase 1 monitoring period are due to the wide scatter at low flows and a change in site signature in the latter part of January 2009. The upstream zoo flow data will need to be used as an upstream boundary condition for calibration. All data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

FRE174_DWF-021052

FRE174_DWF-021052 is a permanent monitoring location that records both level and velocity. The site has two monitors: one located in the incoming 48-inch pipe (dry weather site), and one located in the overflow line (wet weather site). The level data are used to alarm for CSO events from the NPDES174 and NPDES148 Basins and calculate the volume of CSOs using a weir equation.

The data exhibit the influence of flows from the Woodland Park Zoo as well as PS 54. Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent and repeatable data response during wet and dry weather and lack of data gaps. At the dry weather site, the velocity data are finalized. At the wet weather site used to confirm overflow, the velocity data are not finalized and are not intended to be used for model calibration. All dry weather side data are suitable for use in model calibration.

KC_021-056B

KC_021-056B is a temporary monitoring location recording level only in the King County north interceptor immediately downstream from the connection from the NPDES174 Basin. The meter was installed to determine the impact of the King County interceptor levels on NPDES174 Basin overflows. No alternative monitoring locations were considered for KC_021-056B.

The meter was installed 3/6/2009. Data quality was classified as "Good" for the Phase 1 monitoring period because of their consistent and repeatable response during wet and dry weather with a few data gaps. All data are suitable for use in model calibration. It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

3.5.3 Fremont/Wallingford Combined Sewer Overflows

Table 3-7 shows overflows reported by ADS at each of the Fremont/Wallingford overflow points. All three overflow points are affected by the flow levels in the King County north interceptor. In particular, NPDES174 Basin was observed to overflow only when the interceptor level was above the weir level, closing the check valve to prevent backflow from the interceptor to the weir. The NPDES147(A) Subcatchment overflowed 40 times in the monitoring period while NPDES147(B) Subcatchment and NPDES 174 Basin overflowed five and six times, respectively. Examination of the hydraulic conditions at the NPDES147(A) Subcatchment has shown that a hydraulic jump occurs upstream from the check valve, which prevents backflow from the interceptor. The hydraulic jump induced by the hydraulic restriction of the check valve, results in overflows at this location during most rain events.

Table 3-7. 2008–2009 Combined Sewer Overflows in Fremont/Wallingford Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
147(A)	10/3/2008	3:10	39,997
	10/6/2008	1:55	247,663
	10/13/2008	5:55	151,785
	10/15/2008	0:10	229
	10/31/2008	1:05	72,500
	11/1/2008	72:10	1,234,642
	11/6/2008	49:15	1,696,538
	11/11/2008	8:00	44,333
	11/20/2008	0:20	6,611
	11/21/2008	1:00	96,990
	12/2/2008	0:15	3,851
	12/7/2008	22:55	62,045
	12/12/2008	19:00	180,826
	12/28/2008	2:00	98,799
	12/29/2008	0:45	103,785
	12/31/2008	0:50	20,076
	1/1/2009	1:20	257,889
	1/42009	14:55	445,462
	1/6/2009	42:00	3,844,142
	1/10/2009	0:10	20,927
	2/9/2009	18:55	16
	2/23/2009	19:10	268,844
	2/25/2009	2:10	228,840
	3/1/2009	31:40	460,281
	3/5/2009	4:10	315,792
	3/7/2009	0:15	56,236
	3/14/2009	14:25	388,267
	3/17/2009	1:15	126,253

Table 3-7. 2008–2009 Combined Sewer Overflows in Fremont/Wallingford Basin 10/1/2008–5/31/2009			
NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
147(A)	3/20/2009	12:55	168,465
	3/25/2009	4:00	386,101
	3/28/2009	0:45	2,920
	4/1/2009	45:15	1,614,708
	4/12/2009	34:05	207,319
	4/28/2009	0:35	110,090
	5/2/2009	2:00	213,306
	5/4/2009	15:15	1,413,243
	5/6/2009	1:00	18,552
	5/7/2009	0:50	19,368
	5/13/2009	13:55	61,358
	5/18/2009	26:00	673,920
147(B)	1/7/2009	4:45	269,366
	4/2/2009	0:40	133,399
174	11/4/2009	2:10	206,611
	11/7/2009	0:50	3,094
	1/7/2009	10:00	1,480,816
	4/2/2009	11:40	542,063
	5/5/2009	4:10	403,878
	5/19/2009	2:55	168,632

Figure 3-11 shows the maximum water level recorded at each of the overflow structures in the NPDES147 and NPDES174 Basins as a percentage of the weir height.

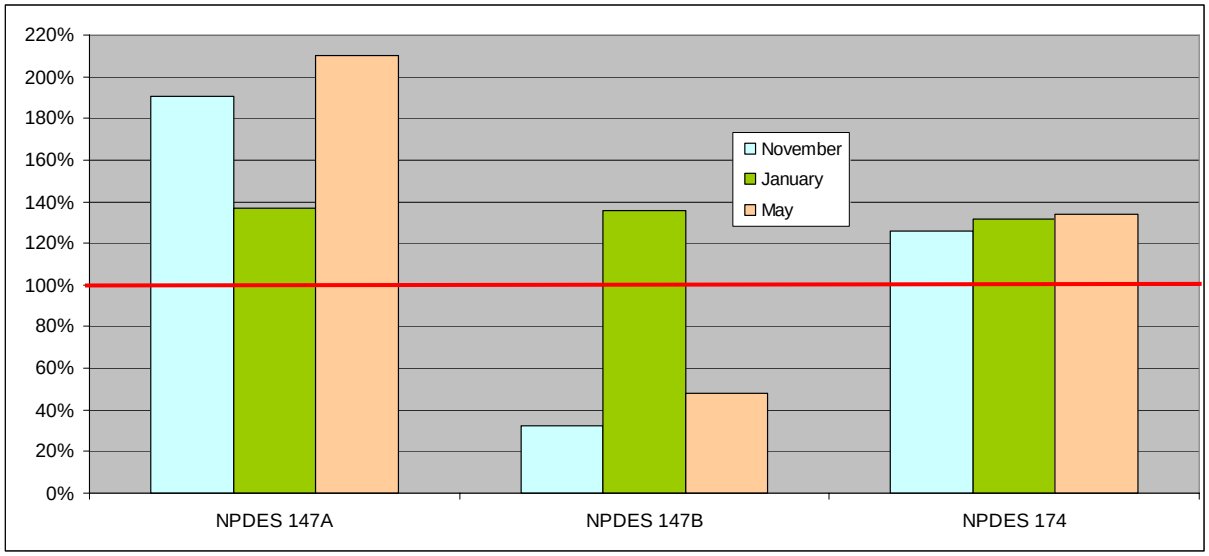

Figure 3-11. Maximum recorded levels compared to weir heights for major events

3.5.4 Facility Operations

The CSO facilities in the Fremont/Wallingford Basin consist of the three overflow weirs described above; it has no HydroBrakes or storage structures. One pump station (PS 54) is located in the NPDES174 Basin.

Pump Station 54

SPU monitors PS 54 via its SCADA system. The SCADA system records wet well level and pump run times. The SCADA data will be used in model calibration to determine pump switch on-off levels, and in conjunction with drawdown test results to calculate the pump station flow rate.

Data collected during Phase 1 monitoring include the pump on-off states and the wet well depth. These data were plotted versus time and rainfall for review. Review consisted of observing the normal rise and fall of wet well elevations with time during wet and dry weather. In general, no anomalies in operation were noted that could not be explained by response to rainfall.

3.5.5 Recommendations for Additional Data Collection

All sites that were not removed during the Phase 1 monitoring period should remain in place throughout the 2009–2010 wet season monitoring period. No additional sites within the Fremont/Wallingford Basin have been identified for the 2009–2010 wet weather season.

3.6 Interbay Basin

The Interbay Basin, located between Magnolia and Queen Anne, is approximately 287 acres in area. It consists of the NPDES068 Basin, which is divided into two subcatchments, NPDES068(A) in the north and NPDES068(B) in the south. These two subcatchments have separate overflow structures, but both overflow into the drainage system and share a common outfall, numbered NPDES068.

It is important to note that between the publishing of the 2001 CSO Reduction Plan and the LTCP Flow Monitoring Data Reports, documents regarding the Interbay Basin switched the (A) and (B) designation of the NPDES068(A) and NPDES068(B) Subcatchments, including the FO&M Blue Book. Uncontrolled CSO Basin Modeling Plans were written within this period. For consistency, the designation in this report will be as specified in the 2001 CSO Reduction Plan and as illustrated in the Interbay Basin schematic found in Appendix B. SPU will be making revisions to the next edition of the CSO Map Book.

The combined sewage in the NPDES068(A) Subcatchment flows from the north and a portion of the northeast part of the basin into the NPDES068(A) Overflow Facility 33A. The combined sewage from the NPDES068(B) Subcatchment flows from the southeastern and a portion of the northeastern part of the basin into the NPDES068(B) Overflow Facility 33B. The low flows from each overflow structure combine and proceed north, joining the King County north interceptor. Overflows from NPDES068(A) and NPDES068(B) are collected in the drainage system and discharge through a 96-inch-diameter pipe south into Elliot Bay.

RG 11, located in Myrtle Edwards Park, and RG 12, located at the Catherine Blaine K–8 School campus, monitor rainfall in the Interbay Basin. It was determined that the flow data in Interbay is better represented by RG 12.

Combined sewage was monitored at two permanent stations, located at each of the overflow facilities, and at 10 temporary monitoring locations. Only one temporary monitoring location was located in the NPDES068 Basin during Phase 1 monitoring. Most of the meters in the Interbay Basin remained installed at the end of Phase 3 but no additional information was required for model calibration, GSI or retrofit purposes and all meters were recommended for removal.

More detailed information can be found in Appendix N; a basin schematic is contained within Appendix B.

3.6.1 NPDES068 Basin

NPDES068 Basin is located east of Magnolia and west of Queen Anne. If an overflow occurs, the flow is directed to Puget Sound via the drainage pipe network. Two permanent meters to verify overflows monitor Interbay NPDES068 Basin, with an area of approximately 312 acres. One temporary monitoring location was located in the NPDES068 Basin during the 2008–2009 monitoring period.

INT068_028-422A

INT68_028-422A is a temporary monitoring installation located just downstream from the overflow point and HydroBrake in the NPDES068(A) Subcatchment. Level is monitored at this location to monitor storage utilization of the offline storage pipe to the north in the NPDES068(A) Subcatchment and to provide depth upstream from the HydroBrake. No alternative locations were considered. The monitor was installed on 1/13/2009.

Data quality was classified as "Excellent" for the Phase 1 monitoring period as the level was recorded during all storm events with no data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period and that velocity data starts to be collected.

NPDES68A_028425 (WW)

NPDES68A_028425 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Flow is calculated from the level and velocity data.

Although the quality of the level data collected at the location was classified as "Good" (that is, no data gaps, and ultrasonic and pressure measurement of depths align well) and are suitable for model calibration, the quality of the velocity data was classified as "Some Limitations" based on the site hydraulics. The pipe has a slope of over 9 percent entering the structure and 7.7 percent leaving the structure. There is some possibility of a hydraulic jump near the meter and a possibility of overestimation of the flow. Therefore, velocity data are not considered suitable for model calibration until verified by other data.

It is recommended that data from this monitoring installation continue to be reviewed for the Phases 2–3 monitoring period. It is also recommended that additional temporary meters be installed upstream to better characterize hydrology in the NPDES068(A) Subcatchment for the Phases 2–3 monitoring period.

NPDES68B_028431 (WW)

NPDES68B-028431 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Flow is calculated from the level and velocity data. Level data are used to characterize the HydroBrake just downstream.

Data quality was classified Phase 1 monitoring are classified as "Good" for the Phase 1 monitoring period as the level and velocity data have a consistent and repeatable response and lack data gaps; the data are suitable for use in model calibration.

It is recommended that data from this monitoring installation continue to be reviewed for the Phases 2–3 monitoring period.

3.6.2 Combined Sewer Overflows

ADS reported that one CSO occurred in the Interbay Basin during the Phase 1 monitoring period; Table 3-8 lists the CSO reported during the Phase 1 monitoring period.

Table 3-8. 2008–2009 Combined Sewer Overflows in Interbay Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
68A	--	--	--
68B	1/7/2009	1:15	120,387

The maximum recorded levels at each overflow structure in the Interbay Basin are shown in Figure 3-12. Levels were calculated as a percentage of weir height.

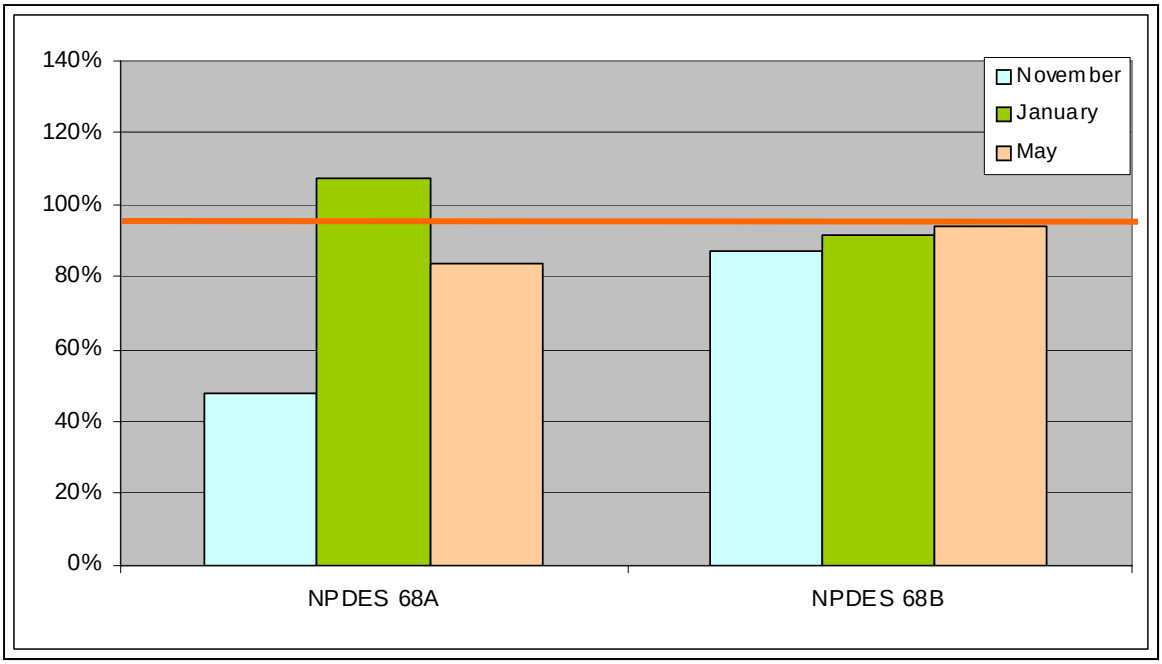

Figure 3-12. Maximum recorded levels compared to weir heights in Interbay for major events

3.6.3 Facility Operations

The CSO facilities in the Interbay Basin consist of the two overflow weirs described above. The NPDES068(A) Basin has CSO Facility 33(A) and the NPDES068(B) Basin has CSO Facility 33(B). Two HydroBrakes and one offline and one in-line storage tank are located in the NPDES068 Basin. The offline storage tank and one of the HydroBrakes are located near temporary meter INT068_028-422A. The other HydroBrake and in-line storage tank are located at permanent meter NPDES68B_028431. No pump stations are located in the NPDES068 Basin.

HydroBrake 028-422

This HydroBrake is located in CSO Facility 33(A). Meters will be installed to monitor upstream from this HydroBrake during the 2009–2010 wet season to better characterize the HydroBrake performance. No suitable location has been found to monitor flow leaving the HydroBrake. Therefore, characterization will be done using estimated inflow to the HydroBrake and a mass balance with the volume stored in the adjacent offline storage tank.

HydroBrake 028-431

This HydroBrake is located in CSO Facility 33(B). Meters will be installed to monitor downstream from this HydroBrake during the 2009–2010 wet season to characterize the HydroBrake performance.

Offline Storage 028-422

The storage tank is located offline near MH 026-422 in CSO Facility 33(A). The tank works in conjunction with HydroBrake 028-422. When the HydroBrake triggers during storm events, the tank fills once the level is above the tank weir level. Temporary monitor INT068_028-422 measures the level in the storage tank during dry and wet weather events. During large wet weather events, the flow begins to fill the offline 144-inch-

diameter, 365-foot-long storage tank. The total volume of the storage tank is 308,708 gallons, and the entire storage was utilized during the May 2009 storm event.

In-Line Storage 028-431

The 48-inch and 72-inch pipes upstream from the overflow in CSO Facility 33(B) serve as in-line storage. The 48-inch pipe is 379 feet long, and the 72-inch pipe is 368 feet long. The 72-inch pipe includes a cunette.

3.6.4 Recommendations for Additional Data Collection

All current monitoring sites should remain in place throughout the 2009–2010 monitoring period. Additional sites should be added to the Interbay Basin to characterize the hydrology and the HydroBrake in the NPDES068(B) Subcatchment.

3.7 Leschi Basin

The Leschi Basin, located on the western shore of Lake Washington along Lake Washington Boulevard, extends from approximately S. McClellan Street to E. John Street. The Leschi Basin, which consists of the NPDES026–NDPES036 Basins, is approximately 425 acres in area. The total acreage includes 47 acres that divert flow only into the Leschi Basin, specifically the NPDES030 and NPDES036 Basins, during significant storm events. During development of the CSO LTCP project, the points of diversion were monitored to ascertain under what conditions flow is diverted to the NPDES basin. In the NPDES036 Basin it was determined that diversion of flow into the basin occurs only during very intense storm events, and only in very small volumes. In the NPDES030 Basin, flows were not diverted for the entire duration of the monitoring period.

Combined sewage flows south from the NPDES026 Basin and north from the NPDES036 Basin and collects at the East Pine Street pump station in the NPDES027 Basin. The flow is then pumped into the King County interceptor and flows toward the Montlake regulator. Flow is conveyed through the basins in a line that starts in the south as a 16-inch-diamater pipe and ends in the NPDES027 Basin as a 24-inch-diameter pipe. This line runs along the shoreline of Lake Washington and is referred to herein as the Leschi trunk sewer.

Twelve permanent stations and 38 temporary meters monitor combined sewage flow. All related site information, photographs, and data representation are included in Appendix H; a basin schematic is contained within Appendix B.

3.7.1 NPDES026 Basin

NPDES026 Basin is a small 10-acre basin, located in the northernmost part of the Leschi Basin. Overflows from this partially separated basin are directed to Lake Washington when flow depths exceed the side-cast weir elevation located just east of Denny-Blaine Place in MH 038-081. The NPDES026 Basin has no storage.

One temporary site and one permanent site that verify overflows only monitor the basin. The basin did not overflow during the Phase 1 monitoring period.

LES26_042-270A

LES26_042-270A is a temporary monitoring installation that records level and velocity in the NPDES026 Basin downstream from the overflow site. The site was installed to characterize hydrology in the NPDES026 Basin. The site was chosen after review of an alternate site at MH 042-266.

Although the quality of the level data collected at the location was classified as "Good" for the Phase 1 monitoring period (that is, no data gaps and ultrasonic and pressure measurement of depths align well), the quality of the velocity data was classified as "Poor" due to a bump in the channel immediately downstream from the meter that caused dropouts in the velocity data at low flows. Consequently, the monitoring data do not provide reliable dry weather flow. Dry weather flow at the site will be estimated from upstream water use records and adjusted for seasonal infiltration using the available data.

The meter was removed in July 2009 as it was determined that the hydraulics of the site prevented the collection of suitable calibration data.

NPDES26_MH038081

NPDES26_MH038081 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The velocity data are not expected to be reliable at this site.

The quality of the level data was classified as "Good" for the Phase 1 monitoring period because of the consistent and repeatable response of the data and no data gaps. The data are suitable for model calibration. The velocity data are not suitable for model calibration. The pipe downstream from the overflow location was cleaned in the summer of 2009.

It is recommended that this monitoring installation continue to be screened in the Phases 2–3 monitoring period.

3.7.2 NPDES027 Basin

The NPDES027 Basin, which extends along the east side of the Leschi Basin along Lake Washington, is approximately 39 acres in area. The partially separated basin drains to the King County East Pine Street pump station, which is located along the shore of Lake Washington. All of the flows from the Leschi Basin that do not overflow at the upstream overflow structures pass through the NPDES027 Basin.

The basin is monitored by one temporary meter and one permanent meter that measures dry and wet weather data. The basin did not overflow during the Phase 1 monitoring period.

LES27_042-273A

LES27_042-273A is a temporary monitoring installation that records level and velocity in the Leschi trunk sewer in the NPDES027 Basin. The site was installed to characterize flow and level in the Leschi trunk sewer just downstream from the overflow point in the NPDES028 Basin. The site was chosen after review of an alternate location at MH 042-226. The depth at this site did not exceed 15.5 inches in the 24-inch pipe throughout the monitoring period.

Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. The depth data are suitable for model calibration with only a data gap in March 2009 due to Leschi trunk sewer cleaning. The quality of the velocity data was also classified as "Some Limitations," but due to significant sediment depth at the site, the quality of the data changed over time; a correction to the data is not considered feasible. Therefore, the flow data calculated from the velocity will not be used for model calibration. The depth data may help in understanding conditions that cause NPDES28 to overflow however.

The meter was removed in 9/17/2009 as it was determined that the permanent meter (LES27_DWF-042269) downstream provides flow data suitable for model calibration.

LES27_DWF-042269

LES27_DWF-042269 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The level and velocity data are used to calculate flow.

Data quality was classified as "Excellent" for the Phase 1 monitoring period; a clear relationship is evident between level and velocity.

Flow balancing results from upstream temporary monitors at LES27_042-273A indicate that the calculated flows from this permanent monitoring were within the correct range.

It is recommended that this monitoring installation continue to be screened in the Phases 2–3 monitoring period.

3.7.3 NPDES028 Basin

The NPDES028 Basin, located in the northern part of the Leschi Basin, is approximately 20 acres in area. A side-cast overflow weir in MH 042-275 conveys the excess flows from this basin to Lake Washington through a 15-inch-diameter outfall pipe.

Two temporary meters monitor the basin. One permanent meter verifies overflows and is used to compute overflow volume, but does not collect dry weather data. The basin overflowed during the major storm events, and once during April 2009.

LES28_042-276A

LES28_042-276A is a temporary monitoring installation that records level and velocity in a small subcatchment of the NPDES028 Basin. The site was installed to characterize hydrology in the NPDES028 Basin. No alternatives were considered for this location.

Data quality was classified as "Good" for the Phase 1 monitoring period; storm data were captured with no data gaps. Below a level of 0.8 inch, a thick scatter of velocity data indicates that the velocity probe is detecting multiple velocities. The low nighttime dry weather flow may be overestimated. Wet weather flow is suitable for model calibration.

The meter was removed in September 2009 as it was determined that sufficient suitable data had been collected for the purposes of model calibration from this small area.

LES28_042-282A

LES28_042-282A is a temporary monitoring installation that records level and velocity from the south part of the NPDES028 Basin. The site was installed to characterize hydrology in the Leschi trunk sewer near the overflow point in the NPDES028 Basin. No alternatives were considered for this location.

Data quality was classified as "Good" for the Phase 1 monitoring period; storm data were captured with no data gaps. Below a level of 1.5 inches, a thick scatter of velocity data indicates that the velocity probe detected multiple velocities. The low nighttime dry weather flow may be overestimated.

Due to line cleaning in the Leschi trunk sewer, it is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain additional storm data to determine if site signatures have changed as a result of Leschi trunk sewer cleaning.

NPDES028_MH042275

NPDES028_MH042275 is a permanent monitoring installation that records both level and velocity, using two monitoring locations for level. The velocity and pressure sensor is mounted inside pipe (MP2); the ultrasonic sensor is mounted above pipe to measure overflows (MP1). The ultrasonic level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation.

The quality of the level data was classified as "Good" for the Phase 1 monitoring period. The quality of the velocity data was classified as "Poor" because of poor site hydraulics. Velocity data are not expected to be of high quality at this site and will not be used for model calibration. The principal use of this site is to provide depth data.

It is recommended that this monitoring installation continue to be screened during the 2009–2010 monitoring period.

3.7.4 NPDES029 Basin

The NPDES029 Basin, located near the center of the Leschi Basin, is approximately 21 acres in area. One CSO control facility is located within the NPDES029 Basin. CSO Facility 18 includes 300 feet of an in-line, 18-inch-diameter storage pipe, one HydroBrake, and two overflow structures. In addition to the 18-inch in-line storage, another 12-inch pipe is located to the north that provides additional storage. The basin is monitored by five temporary meters and one permanent meter that collects both dry and wet weather data. The basin overflowed four times during the Phase 1 monitoring period, once during each of the major storm events and also in April 2009. The water surface elevation in the Leschi trunk sewer was observed to be above the NPDES029 weir in the January and May 2009 events.

LES29_042-300A

LES29_042-300A is a temporary monitoring installation that records level and velocity upstream from the HydroBrake in the NPDES029 Basin. This site was installed to characterize hydrology in the NPDES029 Basin. No alternatives were considered for this location. Data quality was classified as "Good" for the Phase 1 monitoring period; all storm events were captured. The meter data recording drops out when storage backs up with flow. Data from smaller storms will be used to characterize hydrology.

Flow balancing was undertaken using the data from this temporary monitoring installation, the temporary monitoring installation at LES29_042-306A, and the permanent monitoring installation downstream at LES29_DWF-042303. The flow balance determined that the calculated flows from this temporary monitoring were within the correct range.

Due to line cleaning in the Leschi trunk sewer upstream and downstream from the NPDES029 Basin, it is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain additional storm data to determine if any changes in site signatures result from the Leschi trunk sewer cleaning.

LES29_042-302A

LES29_042-302A is a temporary monitoring installation that records level just upstream from the HydroBrake in the NPDES029 Basin. The site was installed to characterize the HydroBrake in the NPDES029 Basin. No alternatives were considered for this location. Data quality was classified as "Excellent" for the Phase 1 monitoring period; sufficient data were captured to characterize the HydroBrake performance.

Due to line cleaning in the Leschi trunk sewer upstream and downstream from the NPDES029 Basin, it is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain additional level data. The data should be analyzed to determine if the HydroBrake performance has changed as a result of the Leschi trunk sewer cleaning.

LES29_042-305A

LES29_042-305A is a temporary monitoring installation that records level and velocity downstream from the permanent meter in the NPDES029 Basin. The site was installed to monitor flow leaving NPDES029 Basin and entering the Leschi trunk sewer. In addition, the site provides level data in the Leschi trunk sewer. No alternatives were considered for this location.

Flow balancing was undertaken using the data from this temporary monitoring installation and the permanent monitoring installation upstream at NPDES29_042303. The flow balance determined that the calculated flows from this temporary monitoring were within the correct range. It was observed that flow was being relieved from the Leschi trunk sewer over the NPDES029 overflow weir. The scatter plot indicates the

restriction of flow entering the Leschi trunk sewer (velocity is nearly uniform around 2 fps up to 14 inches of depth) and shows the backflow from the Leschi trunk sewer (negative velocities at depths over about 15 inches). This behavior will assist in model validation. However, during the first storm events the data was affected by the line cleaning. Therefore, data quality was classified as "Some Limitations" for the Phase 1 monitoring period; storm data were captured with no data gaps.

Due to line cleaning in the Leschi trunk sewer upstream and downstream from the NPDES029 Basin, it is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain additional level and velocity data.

LES29_042-305B

LES29_042-305B is a temporary monitoring installation that records level and velocity in the Leschi trunk sewer near the NPDES029 Basin. The site was installed to characterize flow and level in the Leschi trunk sewer at the confluence with the discharge from the NPDES029 Basin. The site was chosen after review of an alternate location at MH 042-308.

Data quality was classified as "Good" for the Phase 1 monitoring period; storm data were captured with no data gaps. The scatter plot reflects the rise and fall in level caused by the flow from PS 2 as well as the flow restrictions from debris and roots in the Leschi trunk sewer. The site exhibited a significantly different flow signature following Leschi trunk sewer cleaning. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period; storm data were captured with no data gaps. Data following cleaning will be used for calibration.

Due to line cleaning upstream and downstream from this monitoring installation, it is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain additional level and velocity data.

LES29_042-306A

LES29_042-306A is a temporary monitoring installation that records level and velocity upstream from the HydroBrake in the NPDES029 Basin. The site was installed to characterize hydrology in the NPDES029 Basin. No alternatives were considered for this location. Data quality was classified as "Good" for the Phase 1 monitoring period; all storm events were captured. The meter data recording drops out when the storage backs up. Data from smaller storms will be used to characterize hydrology.

Flow balancing was undertaken using the data from this temporary monitoring installation, the temporary monitoring installation at LES29_042-300A, and the permanent monitoring installation downstream at LES29_DWF-042303. The flow balance determined that the calculated flows from this temporary monitoring were within the correct range.

Due to line cleaning in the Leschi trunk sewer upstream and downstream from the NPDES029 Basin, it is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain additional storm data to see if any changes in site signatures result from the Leschi trunk sewer cleaning.

LES29_DWF-042303

LES29_DWF-042303 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The level and velocity data are used to calculate flow.

Data quality was classified as "Excellent" for the Phase 1 monitoring period; the data show a clear relationship between level and velocity.

Flow balancing using data from the upstream temporary meters at LES29_042-300A and LES29_042-306A and the downstream meter at LES29_042-305A indicate that the calculated flows from the permanent monitoring were within the correct range.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period.

3.7.5 NPDES030 Basin

The NPDES030 Basin is approximately 60 acres in area. CSO Facility 17 is a control facility located in the NPDES030 Basin. The facility contains four control structures: an 18,000-gallon in-line storage tank with an overflow weir, a sluice gate, and two overflow weirs. In the western part of the basin, at MH 042-008, an overflow weir could allow flows from an additional 47 acres to flow into the NPDES030 Basin during periods of extremely high flow or downstream blockages..

Six temporary meters and one permanent meter monitor the basin. The permanent meter captures both dry and wet weather data.

LES30_041-385A

LES30_041-385A is a temporary monitoring installation that records level and velocity in the western part of the NPDES030 Basin. The site was installed to characterize the hydrology in the western part of the NPDES030 Basin that may contribute flow if the level downstream at LES030_041-008 overtops the weir at this location. No alternatives were considered for this location. During dry weather conditions, the flow at this site does not pass through the overflow point at LES30_DWF-042322. The quality of the level and velocity data collected during all storm events was classified as "Good" for the Phase 1 monitoring period.

The meter was removed in April 2009 as it was determined that sufficient suitable data had been collected for the purposes of model calibration. Any flow that overtops the weir will be recorded at LES30_042-202A.

LES30_041-386A

LES30_041-386A is a temporary monitoring installation that records level and velocity in the western part of the NPDES030 Basin. The site was installed to characterize the hydrology in this part of the NPDES030 Basin. The site has a weir immediately downstream with a height of nearly 8 feet. If the level exceeds the weir height, flow will proceed down to the next weir at LES30_042-008A. Under normal conditions, flow from this site proceeds northward away from the Leschi Basin. No alternatives were considered for this location. The quality of the level and velocity data during all storm events was classified as "Excellent" for the Phase 1 monitoring period; the level and velocity data never reached a level above 2 inches.

The meter was removed in April 2009 as it was determined that sufficient suitable data had been collected for the purposes of model calibration. Any flow that overtops the weir will be recorded at LES030_042-202A.

LES30_042-008A

LES30_042-008A is a temporary monitoring installation that records level in the western part of the NPDES030 Basin. The site was installed to characterize the level in the pipe compared to the weir height to determine if the flow overtops the weir (any overflow would contribute to the overflow point at LES30_DWF-042322). The site has a weir height of approximately 14 inches. Under normal conditions, the flow at this site proceeds northward away from the Leschi Basin. No alternatives were considered for this location. The quality of the level data collected during all storm events was classified as "Good" for the Phase 1 monitoring period; the level data never reached a level above 2.25 inches. The dry weather pattern at this site shows a school flow contribution signature with higher flows during the weekdays and very small flows over the weekend.

The monitor was removed in September 2009 as it was determined that sufficient suitable data had been collected for the purposes of model calibration. Any flow that overtops the weir will be recorded at LES30_042-202A.

LES30_042-202A

LES30_042-202A is a temporary monitoring installation that records level and velocity upstream from the permanent meter in the NPDES030 Basin. The site was installed to characterize hydrology in the NPDES030 Basin upstream from the permanent meter. The site was chosen after review of an alternate location at MH 046-173. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period due to an overestimation of velocity data that was identified from flow balancing results.

Flow balancing was undertaken using the data from this temporary monitoring installation, the temporary monitoring installation at LES30_046-015A, and the permanent monitoring installation downstream at LES30_DWF-042322. The flow balance determined that the calculated flows from this temporary monitoring location were overestimated. Further investigation indicated that the velocity was overestimated due to site hydraulics. The meter was moved upstream one pipe segment in August 2009, and the new data appears to be in the correct range. The older data will be corrected if possible, but the new data are suitable for model calibration

It is recommended that this revised monitoring installation remain in place during the Phases 2–3 monitoring period to obtain improved velocity data.

LES30_042-205A

LES30_042-205A is a temporary monitoring installation that records level upstream from the sluice gate in the NPDES030 Basin. This site was installed to characterize the storage utilization of the in-line storage pipe upstream from this meter. No alternatives were considered for this location. Data quality was classified as "Excellent" for the Phase 1 monitoring period, and the data are suitable for model calibration.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period as sluice gate operations will likely be modified.

LES30_042-206B

LES30_042-206B is a temporary monitoring installation that records level and velocity in the outlet pipe from the NPDES030 Basin to the Leschi trunk sewer. The site was installed to characterize the sluice gate in the NPDES030 Basin and to provide level data in the Leschi trunk sewer. No alternatives were considered for this location. During storm events, this site experiences backwater conditions from the Leschi trunk sewer. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period; data was captured from all storm events with no data gaps. Flow balancing was undertaken using the data from this temporary monitoring installation and the permanent monitoring installation upstream at LES30_DWF-042322. The flow balance determined that the calculated flows from this temporary monitoring were within the correct range. It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period.

LES30_046-015A

LES30_046-015A is a temporary monitoring installation that records level and velocity upstream from the in-line storage pipe in the NPDES030 Basin. The site was installed to characterize hydrology in the NPDES030 Basin. The site was chosen after review of alternate locations at MHs 046-155, 046-154, 046-153, and 046-161. Data quality was classified as "Excellent" above about 0.6 inch of level for the Phase 1 monitoring period. Under a level of about 0.6 inch, the site shows signs of ramping over the meter.

Flow balancing was undertaken using the data from this temporary monitoring installation, the temporary monitoring installation at LES30_042-202A, and the permanent monitoring installation downstream at LES30_DWF-042322. The flow balance determined that the calculated flows from this temporary monitoring were within the correct range.

The meter was removed in September 2009 as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES30_DWF-042322

LES30_DWF-042322 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The level and velocity data are used to calculate flow. Data quality was classified as "Good" for the Phase 1 monitoring period; a clear relationship is shown between level and velocity.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period.

3.7.6 NPDES031 Basin

The NPDES031 Basin is approximately 6 acres in area; overflows from this partially separated basin are directed to Lake Washington. The NPDES031 Basin contains one control structure: an overflow weir. There is no storage in the NPDES031 Basin.

One temporary site and one permanent site monitor the basin. The permanent site captures dry and wet weather data. The basin overflowed during November 2008, January 2009, and twice during May 2009.

LES31_046-042A

LES31_046-042A is a temporary monitoring installation that records level in the Leschi trunk sewer near the permanent meter in the NPDES031 Basin. This site was installed to compare the level in the Leschi trunk sewer to the elevation of the overflow weir at the permanent site. The site is not conducive to accurate velocity measurement due to siltation. No alternatives were considered for this location. The quality of the level data was classified as "Good" for the Phase 1 monitoring period, although some level data were missing.

Due to line cleaning in the Leschi trunk sewer in the vicinity of the meter, it is recommended that this monitoring installation continue monitoring during the Phases 2–3 monitoring period to collect additional level data in the Leschi trunk sewer now that the line has been cleaned.

LES31_DWF-046033

LES31_DWF-046033 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The level and velocity data are used to calculate flow. Data quality was classified as "Good" for the Phase 1 monitoring period. The data show a clear relationship between level and velocity; however, some data for the 1/7/2009 storm event are missing. It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period.

3.7.7 NPDES032 Basin

The NPDES032 Basin, which consists of two hydraulically separate subcatchments that share one outfall, is approximately 40 acres in area. The first subcatchment, NPDES032(A), comprises the majority of area and flow. The second subcatchment, NPDES032(B), has a contributing area of less than 1 acre and contains only three houses. CSO Facility 16 is a control facility located in the NPDES032 Basin. The facility contains four

control structures: a 6,000-gallon in-line storage tank, a HydroBrake, and two overflow weirs. Low flows in the NDPES032(B) Subcatchment are directed to the 18-inch-diameter Leschi trunk sewer and low flows in the NPDES032(A) Subcatchment are conveyed through a HydroBrake into the 18-inch Leschi trunk sewer. The Leschi trunk sewer then conveys flows to the East Pine Street pump station. Overflows from both NPDES032(A) and NPDES032(B) are directed to the 12-inch-diameter outfall pipe to Lake Washington. It was observed (before Leschi trunk sewer cleaning) that the water surface elevation in the Leschi trunk sewer exceeded the apparent elevation of the NPDES032(B) weir in the January 2009 event. Overflows at this location appear to be driven by high levels in the Leschi trunk sewer more than by high flows from the tributary area.

Three temporary sites and two permanent sites monitor NPDES032 Basin. The permanent site at NPDES032(A) collects dry and wet weather data. The permanent site at NPDES032(B) is used only to provide depth data to quantify overflows. The NPDES032(A) and NPDES032(B) Subcatchments overflowed in January 2009, and NPDES032(B) overflowed twice in May 2009.

LES32_046-084A

LES32_046-084A is a temporary monitoring installation that records level and velocity upstream from the permanent meter in the NPDES032(A) Subcatchment. The site was installed to characterize hydrology in the NPDES032(A) Subcatchment. No alternatives were considered for this location.

The velocity sensor was creating a rooster tail, which artificially changes the level readings. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period; the data show a clear relationship between level and velocity above a level of 0.8 inch. Below a level of 0.8 inch, a thick scatter of velocity data indicates that the velocity probe is picking up multiple velocities. The low nighttime dry weather flow may be overestimated.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain more hydrology data in the NPDES032(A) Subcatchment.

LES32_046-156A

LES32_046-156A is a temporary monitoring installation that records level upstream from the HydroBrake in the NPDES032(A) Subcatchment. The site was installed to characterize the HydroBrake. No alternatives were considered for this location. The quality of the level data was classified as "Excellent" for the Phase 1 monitoring period; all storm data were captured during the Phase 1 monitoring period.

Due to line cleaning in the Leschi trunk sewer downstream from this meter, it is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to collect additional storm data to characterize the HydroBrake curve with the clean Leschi trunk sewer.

LES32_046-163A

LES32_046-163A is a temporary monitoring installation that records level and velocity downstream from the HydroBrake in the NPDES032(A) Subcatchment. The site was installed to characterize the HydroBrake. No alternatives were considered for this location. Although the quality of the level data was classified as "Excellent" (all storm events were captured with no data gaps), the quality of the velocity data was classified as "Poor." The site experiences reverse flow from the Leschi trunk sewer into the basin storage on a daily basis. This reverse flow is associated with pump operations at PS 2. During high flows, the level in the Leschi trunk sewer exceeds the invert elevation of the in-line storage pipe, consuming a substantial part of the storage volume. The scatter plot shows three apparent lines of data: one in the range of 8 to 15 fps, likely associated with unloading of the storage after backflow from the Leschi trunk sewer; one at near zero velocity associated with normal flow and the backup caused by high levels in the Leschi trunk sewer; and one near

negative 10 fps associated with backflow into storage from the Leschi trunk sewer. Consequently, the quality of the velocity and calculated flow data was classified as "Some Limitations" for the Phase 1 monitoring period. Although periods of data are suitable for model calibration, these data must be selected carefully.

Due to line cleaning in the Leschi trunk sewer in the vicinity of the meter, it is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to collect additional storm data to characterize the HydroBrake curve with the clean Leschi trunk sewer.

LES32A_DWF-046157

LES32A_DWF-046157 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The level and velocity data are used to calculate flow. The quality of the level data was classified as "Excellent" for the Phase 1 monitoring period, whereas the quality of the velocity data was classified as "Some Limitations." The limitations are based on flow balancing with the upstream temporary meter at LES032_046-084A, which suggests that the velocity data are overestimated. It is recommended that an additional temporary meter be identified upstream from the permanent meter to determine if the permanent meter is overestimating flows. It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period.

NPDES032B_MH046078

NPDES032B_MH046078 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The quality of the level data was classified as "Excellent" for the Phase 1 monitoring period; all storm events were captured. However, due to the poor site hydraulics, the quality of the velocity data was classified as "Poor." Consequently, only level data will be used for calibration purposes. No reliable flow data are available for this small basin. Examination of the level data at LES032_046-163A indicates that overflows occur due to the water surface elevation in the Leschi trunk sewer exceeding the elevation of the overflow weir. Model construction will use hydrologic parameters from the adjacent NPDES032(A) Subcatchment.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period.

3.7.8 NPDES033 and NPDES034 Basins

The NPDES033 and NPDES034 Basins have a combined area of 76 acres. During periods of high flow, both basins act as one CSS control facility. CSO Facility 15 stores combined flow from both basins. This CSS control facility includes 122 feet of 84-inch-diameter offline storage pipe, two HydroBrakes, two overflow weirs, and one pump station (PS 2). A weir located in MH 046-172A directs excess flow in the NPDES033 Basin to a large HydroBrake also located in MH 046-172A, and then into the offline 84-inch-diameter storage pipe associated with SPU PS 2. When the level behind the other HydroBrake in the overflow control structure at MH 046-171A for the NPDES033 Basin reaches the level of the overflow weir, overflow is conveyed to Lake Washington through the 20-inch-diameter outfall pipe. The NPDES034 Basin contributes partially separated flow from the north and south of CSO Facility 15, which is conveyed to PS 2. During high-flow periods, when the capacity of PS 2 is exceeded, flow overtops a weir in MH 046-176 and is sent to the offline, 84-inch-diameter storage pipe. When the storage pipe is full, water continues to rise above the weir until it reaches the invert of the NPDES034 Overflow Structure, which is approximately 1.4 feet above the MH 046-176 weir. Overflow from the NPDES034 Basin is conveyed to Lake Washington through a 15-inch-diameter outfall pipe.

Four temporary meters and two permanent meters monitor NPDES033 and NPDES034 Basins. The permanent meters collect dry and wet weather data. Neither NPDES033 nor NPDES034 have overflowed during the Phase 1 monitoring period.

LES33_046-050A

LES33_046-050A is a temporary monitoring installation that records level and velocity downstream from the HydroBrake in the NPDES033 Basin. The site was installed to calculate flow data downstream from the HydroBrake in the NPDES033 Basin to characterize the HydroBrake performance. Although the quality of the depth data collected at the location for the Phase 1 monitoring period was classified as "Good" (that is, no data gaps and ultrasonic and pressure measurement of depths align well), the quality of the velocity data was classified as "Some Limitations" due to the influence of PS 2 discharge downstream. When the pump station discharged downstream from the monitoring installation, the level data spiked and then returned back to the original level. Once the level spikes are removed, the relationship between level and velocity is clearer.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The flow from the meter was compared to the flow recorded at the upstream permanent meter at LES33_DWF-046171 and the upstream temporary meter at LES33_046-120A. The flow balances indicated that both the permanent meter and LES33_046-050A may be overestimating flows.

The meter was removed on 4/2/2009 as it was determined that sufficient suitable data had been collected for the purposes of HydroBrake characterization.

LES33_046-120A

LES33_046-120A is a temporary monitoring installation that records level and velocity in the NPDES034 Basin. The site was installed to characterize hydrology in the NPDES033 Basin. Data quality was classified as "Good" for the Phase 1 monitoring period because of relatively wide scatter at low flows that may reflect pulsing flow on the steep slope. This site was chosen after review of alternate locations at MHs 046E-172, 046-118, and 046-119.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The flow from this meter was compared to the flow from the downstream permanent meter at LES33_DWF-046171. The flow balance suggested that the permanent meter was overestimating flows.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain more hydrology data within the NPDES033 Basin. In addition, it is recommended that additional sites be added within the NPDES033 Basin to determine if the permanent meter is correctly measuring or overestimating flows.

LES33_046-174A

LES33_046-174A is a temporary monitoring installation that records level in the in-line storage pipe in the NPDES034 Basin. The site was installed to capture data on storage utilization of the upstream storage pipe. The site was chosen after review of alternate locations at MH 046-173. The quality of the level data was classified as "Excellent" for the Phase 1 monitoring period.

The meter was removed in 4/2/2009 as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

LES34_046-061A

LES34_046-061A is a temporary monitoring installation that records level and velocity in the NPDES034 Basin upstream from PS 2. The site was installed to characterize hydrology in the sanitary line adjacent to the lakefront north of the overflow site. This site was chosen after review of inspections at MH 046-059. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

The meter was removed on 4/2/2009 as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

Flow balancing was undertaken using the data from this permanent monitoring installation and the temporary monitoring installations upstream at LES35_046E-026A. The flow balance determined that the calculated flows from this permanent monitoring location were within the correct range.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period.

LES33_DWF-046171

LES33_DWF-046171 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The quality of the level data was classified as "Excellent" for the Phase 1 monitoring period. However, the quality of the velocity data was classified as "Some Limitations" because flow balancing with upstream temporary meter at LES33_046-120A indicates that the velocity may be overestimated. The level data are suitable for model calibration, but the velocity data should not be used until verified by additional data.

The scatter plot reflects the backup of flow behind the HydroBrake (velocities between 0.5 and 1.0 fps at depths greater than about 10 inches). Velocities also show a second series around 2.0 fps over the range from 10 to 40 inches. It is believed that this behavior reflects the rise and fall of level on the downstream side of the HydroBrake associated with PS 2 operations. When the pump station ceases pumping, the flow can exit the HydroBrake at a greater rate, which results in the higher velocities.

It is recommended that an additional temporary meter be installed just upstream to validate the accuracy of the velocity data at the permanent monitoring installation.

LES34_DWF-046054

LES34_DWF-046054 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The quality of the level and velocity data was classified as "Good," showing a distinct relationship above about 2.5 inches of water. Below a level of 2.5 inches in the pipe, the scatter is wide, which indicates that the meter is picking up multiple velocities at a given depth. The data are considered suitable for model calibration.

3.7.9 NPDES035 Basin

The NPDES035 Basin is a 60-acre basin with one CSS control facility. CSO Facility 14 includes 65 feet of an offline, 72-inch-diameter storage pipe, one sluice gate, one flap valve, three weirs, and one HydroBrake. The HydroBrake and an overflow structure are located in MH 046E-138 at the intersection of Lakeside Avenue South and South Massachusetts Street. A sluice gate controls the flows and during high flow closes partially to fill the storage pipe in CSO Facility 14. Once the storage pipe is filled, flows overflow the bypass weir over the sluice gate and proceed to the overflow structure where the HydroBrake controls flow. Once the HydroBrake backs up the upstream line to the level of the overflow weir, flows are discharged into Lake Washington at the NPDES035 Outfall.

Six temporary meters and one permanent meter monitors NPDES035 Basin to determine and quantify overflows. The permanent meter collects dry and wet weather data. The basin overflowed three times in May 2009.

LES35_046-139A

LES35_046-139A is a temporary monitoring installation that records level and velocity. The site was installed to characterize the sluice gate in the NPDES035 Basin. The quality of the level and velocity data was classified as "Good" for the Phase 1 monitoring period.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period because the sluice gate operations have changed over time. More data are required to understand how the sluice gate operations affect the storage utilization.

LES35_046-188A

LES35_046-188A is a temporary monitoring installation that records level and velocity. The site was installed to measure depth upstream from the sluice gate, which was installed to replace a HydroBrake as part of a retrofit program. The monitoring site was installed as a dual meter with LES35_046-188B that records depth in the adjacent storage pipe. The quality of the level and velocity data was classified as "Excellent" for the Phase 1 monitoring period. Velocity data should be used for validation of the upstream and downstream monitors.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period because the sluice gate operations have changed over time. More data are required to understand the effects of the new operations.

LES35_046-188B

LES35_046-188B is a temporary monitoring installation that records level in the offline storage pipe in the NPDES035 Basin. Typically dry, the pipe is only used during storm events to collect storage utilization data. The quality of the level data was classified as "Good" for the Phase 1 monitoring period.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period because the sluice gate operations have changed over time. More data are required to understand how the sluice gate operations affect storage utilization.

LES35_046E-017A

LES35_046E-017A is a temporary monitoring installation that records level and velocity. The site was installed to characterize NPDES035 Basin hydrology. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps. The site was chosen after review of alternate locations at MHs 046E-016 and 046E-015.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The flow from the downstream temporary monitoring location at LES035_046E-188A was compared to the flow at this meter. The flow balance determined that the calculated flows from this temporary monitoring location were within the correct range.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain more hydrology data within the NPDES035 Basin to better understand the sluice gate performance downstream.

LES35_046E-026A

LES35_046E-026A is a temporary monitoring installation that records level and velocity downstream from the HydroBrake in the NPDES035 Basin. The site was installed to characterize the HydroBrake at the

NPDES035 Basin. The site was chosen after review of alternate locations at MHs 046E-027, 046E-139, and 046E-025.

Flow balancing was undertaken using the data from this temporary monitoring installation and the permanent monitoring installations at LES34_DWF-046054 during Phase 1 monitoring. The flow balance determined that the calculated flows from this temporary monitoring location were within the correct range. The silt and debris in the line caused a greater depth; however, the velocity probe recorded the velocity of the flow over the sediment which is not representative of the entire cross-section. Therefore, the quality of the level and velocity data was classified as "Poor" for the Phase 1 monitoring period.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to collect more storm data to characterize the HydroBrake curve and collect additional hydrology data.

LES35_046E-138A

LES35_046E-138A is a temporary monitoring installation that records level above the HydroBrake at the overflow site in the NPDES035 Basin. Because the permanent monitor at this site is not at the same elevation as the HydroBrake, this site was installed to better characterize the level just upstream from the HydroBrake. The quality of the level data was classified as "Excellent" for the Phase 1 monitoring period as the monitor responds well to storm events and shows the level increase above the HydroBrake during storm events.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to collect more storm data to characterize the HydroBrake curve.

LES35_DWF-046E138

LES35_DWF-046E138 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The quality of the level data was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data and lack of data gaps. The level data are suitable for use in model calibration. However, the quality of the velocity data was classified as "Poor." The data are not suitable for use in model calibration due to poor site hydraulics.

Flow balancing was undertaken using the data from this permanent monitoring installation and the temporary monitoring installations downstream at LES36_046E-141A and LES35_046E-026A. The sum of LES35_DWF-046E138 and LES36_046E-141A was compared to downstream flows at LES35_046E-026A. The flow balance determined that the calculated flows at the permanent monitoring installation were overestimated, likely due to the poor site hydraulics.

It is recommended that an additional temporary meter be installed just upstream to collect level and velocity data to calculate more accurate flow data.

3.7.10 NPDES036 Basin

The NPDES036 Basin, located in the southern part of the Leschi Basin, is approximately 45 acres in area. This basin has one CSS control facility. CSO Facility 13 includes 1,200 feet of an in-line, 16-inch-diameter storage pipe (the original drainage for the Basin), one HydroBrake, and an overflow structure.

Four temporary meters and one permanent meter monitor the basin to verify overflows monitored the NPDES036 Basin during Phase 1 monitoring. The permanent meter is used only to verify overflows and does not collect dry weather data. The basin overflowed twice in January 2009, once in April 2009, and once in May 2009.

LES36_046E-044A

LES36_046E-044A is a temporary monitoring installation that records level and velocity in an 8-inch pipe having just over 900 feet of upstream pipe length. A small weir about 2.5 inches high connects this small system to NPDES036 Basin. The site was installed to characterize flows that overtop the weir and enter NPDES036 Basin. No alternative sites were considered.

The quality of the level and velocity data was classified as "Good" for the Phase 1 monitoring period because the data follow a clear, consistent relationship that can be used to develop dry and wet weather flows. During the Phase 1 monitoring period, the level in the pipe reached the weir elevation only in the 1/7/2009 storm event; but no overflow occurred. The meter should remain in place for the 2009–2010 monitoring period.

LES36_046E-113A

LES36_046E-113A is a temporary monitoring installation that records level and velocity. The site was installed along with LES36_046E-113B to characterize NPDES036 Basin hydrology. The site was chosen after review of alternate locations at MH 046E-120.

The meter is located on a steep slope of just over 11 percent grade. Although the level data collected at the location was good (that is, no data gaps, and ultrasonic and pressure measurement of depths align well), the velocity data were poor due to the steep slope. Consequently, the quality of the flow data calculated using the level and velocity measurements was classified as "Poor" for the Phase 1 monitoring period.

The site was removed on 1/8/2009 and relocated downstream at MH 046E-149.

LES36_046E-113B

LES36_046E-113B is a temporary monitoring installation that records level and velocity. The site was installed along with LES36_046E-113A to characterize NPDES036 Basin hydrology. The site was chosen after review of alternate locations at MHs 046E-114 and 046E-115.

The meter is located on a steep slope of just over 11 percent grade. Although the level data collected at the location was good (that is, no data gaps, and ultrasonic and pressure measurement of depths align well), the velocity data were poor due to the steep slope. Consequently, the quality of the flow data calculated using the level and velocity measurements was classified as "Poor" for the Phase 1 monitoring period.

The site was removed on 1/8/2009. Data for this area will be captured at MH LES36_046E-149B.

LES36_046E-141A

LES36_046E-141A is a temporary monitoring installation that records level and velocity downstream from the HydroBrake in the NPDES036 Basin. The site was installed to characterize the HydroBrake performance in the NPDES036 Basin. Because of failure to locate a monitoring site upstream from the HydroBrake conducive to collection of accurate data, this meter will also be used together with depth recorded at the upstream meters to characterize the basin hydrology. The quality of the level and velocity data was classified as "Good" for the Phase 1 monitoring period. The data are used to calculate the flows downstream from the HydroBrake. The level data from LES36_046E-142A and the flow data from this site are used to characterize the HydroBrake in the NPDES036 Basin.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain more data to characterize the HydroBrake curve.

LES36_046E-142A

LES36_046E-142A is a temporary monitoring installation that records level and velocity upstream from the HydroBrake in the NPDES036 Basin. The site was installed to characterize the HydroBrake performance in the NPDES036 Basin, providing depth upstream in the storage pipe. The velocity data at this site were inconsistent, and three different types of meters were installed in an attempt to capture better quality velocity data. The ADS FlowShark meter was replaced with an ADS Pulse meter on 12/4/2008, and then replaced with ISCO 2150 AV monitor on 1/13/2009. Since replacing with ISCO, the velocity data quality has improved. The depth data at this location serve as the critical parameter for HydroBrake characterization. The quality of the depth data was classified as "Good" for the Phase 1 monitoring period. Velocity data and computed flows should be used with caution and only for verification of the downstream monitoring site.

It is recommended that this monitoring installation continue monitoring during the Phases 2–3 monitoring period in order to obtain more data to characterize the HydroBrake curve.

LES36_046E-149B

LES36_046E-149B is a temporary monitoring installation that records level and velocity. The site was installed to replace sites at LES36_046E-113A and LES36_046E-113B to characterize NPDES036 Basin hydrology. The site was chosen after review of alternate locations at MH 046E-108.

The meter is located on a steep slope of 30 percent grade. The level and velocity measurements were poor due to the steep slope. Consequently, the quality of the flow data calculated using the level and velocity measurements was classified as "Poor" for the Phase 1 monitoring period.

The site was removed on 4/2/2009. No acceptable monitoring site was found for the southern part of the NPDES036 Basin. As a result, the model calibration will rely on the depth measurements at the permanent site (NPDES036_046E150), depth measurements at LES36_046E-142A, and computed flows at LES36_046E-141A.

NPDES036_046E150

NPDES036_046E150 is a permanent monitoring installation that records level. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. During storm events, the downstream HydroBrake at MH 046E-142 restricts and controls flows from the NPDES036 Basin to the downstream system. When NPDES036 Basin storage is exceeded, flow is diverted over the weir to the NPDES036 Basin outfall. The quality of the level data was classified as "Good" for the Phase 1 monitoring period. The level data have a consistent repeatable pattern and lack of data gaps, and are suitable for use in model calibration. The site signature changed in April 2009. The velocity data are not suitable for use in model calibration due to site hydraulics.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period.

3.7.11 Meters outside Leschi Basin

Two meters were placed outside the Leschi Basin to determine additional flows that enter into the King County system downstream from the Leschi Basin connection. Measurements of the flows at these sites help to better understand the flows conveyed to the Montlake regulator. The data will assist in calibration of the system-wide model.

SPU_038-353A

SPU_038-353A is a temporary monitoring installation that records level and velocity from an area outside of the Leschi Basin. The site was installed to characterize hydrology in an area with flows that join flows from the Leschi Basin downstream from the King County East Pine Street pump station. These flows enter the King County system flowing to the Montlake regulator. No alternatives were considered for this location.

Data quality was classified as "Good" for the Phase 1 monitoring period because the data follow a consistent and repeatable pattern. The level and velocity data can be used for flow calculation and model calibration. The meter was removed on 4/1/2009 after it was determined that sufficient suitable data had been collected for the purposes of model calibration.

SPU_042-231A

SPU_042-231A is a temporary monitoring installation that records level and velocity from an area outside of the Leschi Basin. The site was installed to characterize hydrology in an area that joins flows with flows from the Leschi Basin and flows from SPU_038-353A. These flows enter the King County system, which flows to the Montlake regulator. No alternatives were considered for this location.

Data quality was classified as "Good" for the Phase 1 monitoring period. Level and velocity data follow a consistent and repeatable response and can be used for flow calculation and model calibration.

The meter was removed in 4/2/2009 as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

3.7.12 Combined Sewer Overflows

Table 3-9 summarizes estimates for Leschi CSOs occurring during the Phase 1 monitoring period. ADS provided the estimates. The overflow at NPDES036 on 1/11/2009 is believed to be due to debris clogging the HydroBrake.

Table 3-9. 2008–2009 Combined Sewer Overflows in Leschi Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
26	--		--
27	--		--
28	11/6/2008	4:45	2,862
	1/7/2009	22:05	35,696
	4/2/2009	0:10	4.38
	5/5/2009	1:15	4,982
29	11/6/2009	14:50	131,014
	1/7/2009	25:50	540,961
	4/2/2009	2:00	22,658
	5/5/2009	2:15	51,066
30	1/7/2009	3:45	89,479
31	11/6/2008	2:40	24,056
	1/8/2009	23:00	234,639
	4/3/2009	11:40	559

Table 3-9. 2008–2009 Combined Sewer Overflows in Leschi Basin 10/1/2008–5/31/2009			
NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
	5/5/2009	2:05	24,278
	5/19/2009	0:35	6,892
32A	1/7/2009	1:50	1937
32B	1/8/2009	6:25	57,352
	5/5/2009	1:50	12,201
	5/19/2009	0:25	2,894
33	--		--
34	--		--
35	5/5/2009	0:15	1,181
	5/13/2009	0:05	2,307
	5/19/2009	21:20	7,569
36	1/8/2009	10:10	31,962
	1/11/2009	27:55	44,743
	4/3/2009	0:40	476
	5/5/2009	0:10	194

Figure 3-13 below shows the maximum recorded level on the weirs in the Leschi Basin during each major storm event during the Phase 1 monitoring period.

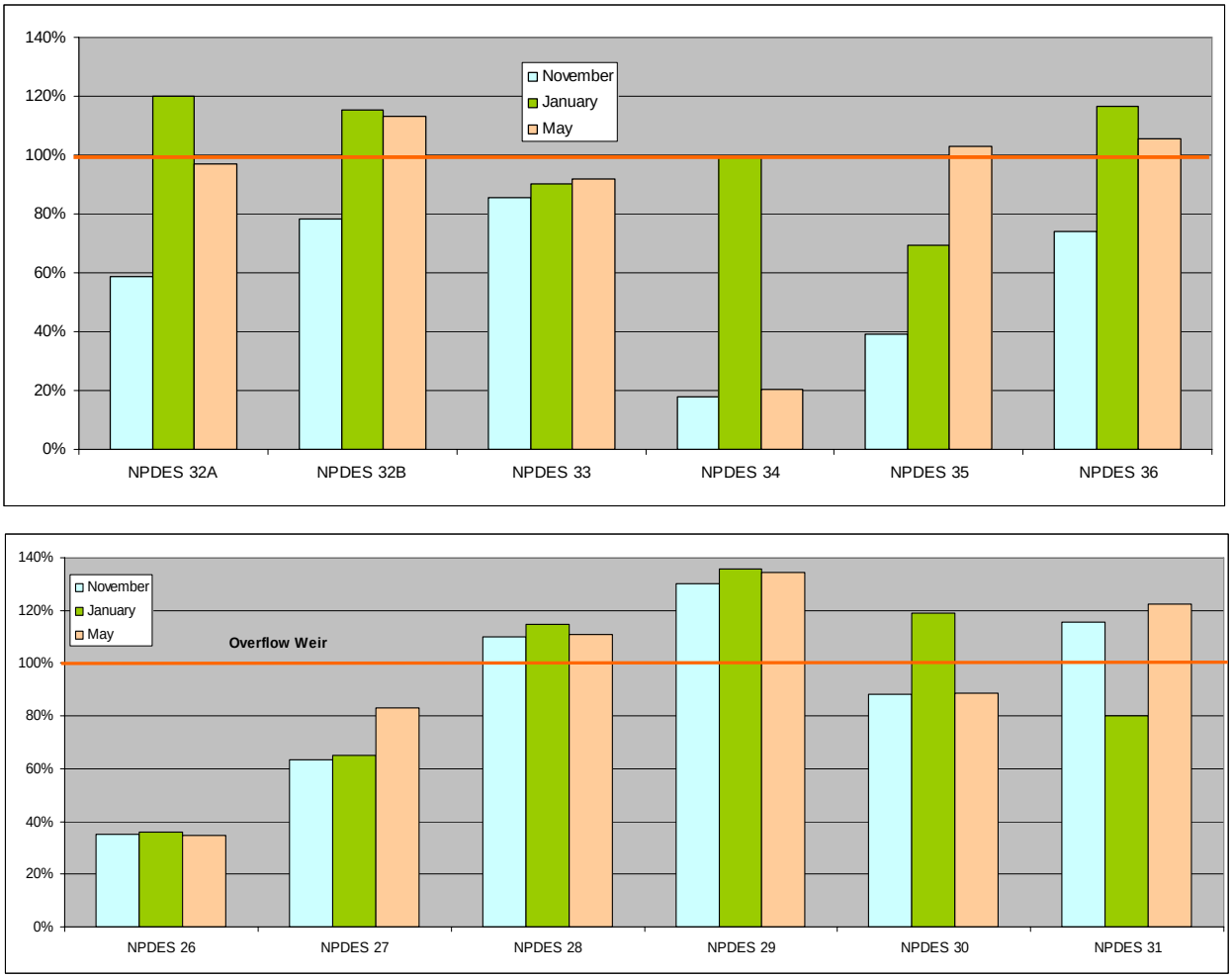

Figure 3-13. Maximum recorded levels over weir heights in Leschi Basin for major events

3.7.13 Facility Operations

Eleven permitted outfalls are located in Leschi Basin; all divert excess combined sewer flows to Lake Washington. Five HydroBrakes and two sluice gates within the Leschi Basin control flow upstream or downstream from overflow points or divert flow into storage facilities. The two sluice gates are retrofit projects that were once HydroBrakes. The basin has four locations for in-line storage and two offline detention systems. These facilities are further described below, by NPDES basin.

NPDES026 Basin

NPDES026 Basin does not include a CSO facility. Overflows from this partially separated basin are directed to Lake Washington when flow depths exceed the side-cast weir elevation located just east of Denny-Blaine Place in MH 038-081. The highest recorded level at the 12.38-inch-high weir was 4.46 inches during the January 2009 storm event (less than 40 percent of the weir height). No overflows were recorded in the monitoring period. The NPDES026 Basin has no storage.

NPDES027 Basin

NPDES027 Basin does not include a CSO facility. An overflow weir designed to protect the King County East Pine Street pump station from flooding is located in MH 042-269 just east of the pump station. If the capacity of the pump station is exceeded, the weir allows overflows to discharge into a 24-inch-diameter outfall pipe (NPDES27 outfall). No overflows were observed during the Phase 1 monitoring period. The NPDES027 Basin has no storage. Both SPU and King County have permits for this outfall.

NPDES028 Basin

NPDES028 Basin includes a side-cast overflow weir in MH 042-275 that conveys overflows from the basin to Lake Washington through a 15-inch-diameter outfall pipe. The highest recorded level over the 13.63-inch-long weir was 15.66 inches. Level in the Leschi trunk sewer may affect overflows.

NPDES029 Basin

CSO Facility 18 utilizes 300 feet of the original sewer system as an in-line, 18-inch-diameter storage pipe that was fully utilized during each of the major storm events. A HydroBrake in MH 042-302 at the intersection of Lake Washington Boulevard and Fullerton Avenue is at the downstream end of the storage pipe. Level data collected at MH 042-302 and flow data collected at the downstream permanent meter characterize the HydroBrake. Figure 3-14 shows the HydroBrake characterization. Two curves that represent behavior with and without vortex collapse are exhibited.

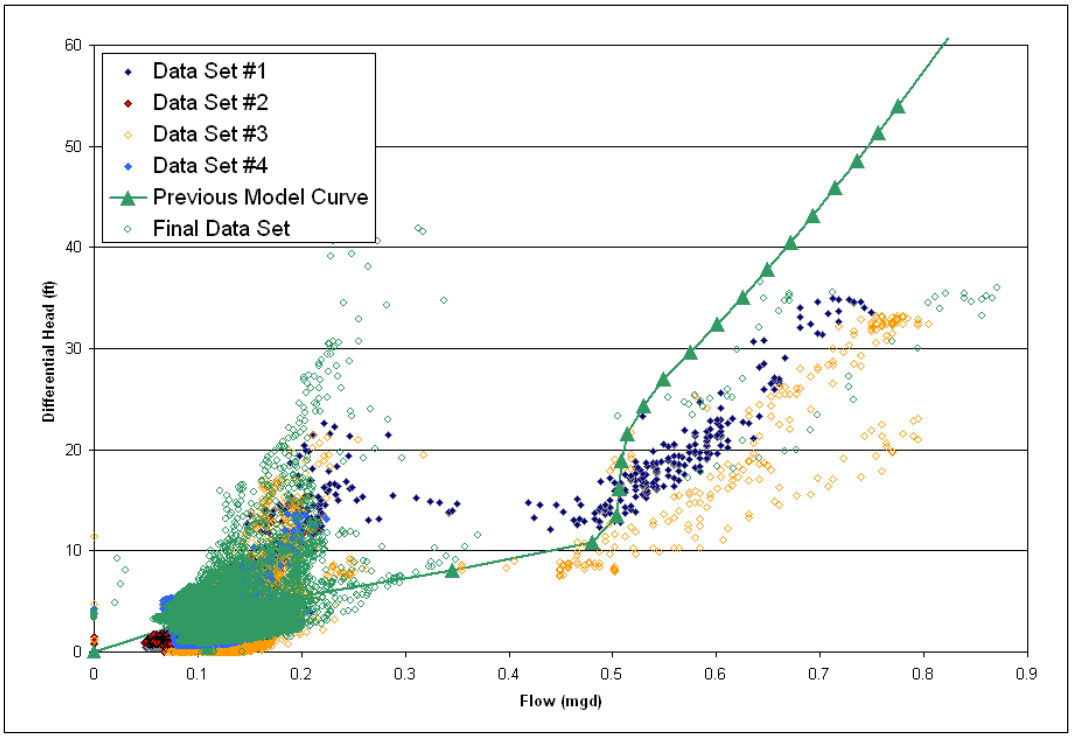

Figure 3-14. NPDES029 Basin HydroBrake characterization

Flows pass through the HydroBrake, then through the overflow maintenance hole (MH 042-303) to an 8-inch-diameter pipe, and eventually to the East Pine Street pump station through the 21-inch-diameter Leschi trunk sewer that runs along Lake Washington. The highest recorded level on the 8.5-inch-high weir was 11.54

inches during the January 2009 rainfall event. When the capacity of the HydroBrake is exceeded, flows are stored in the in-line storage pipes. The in-line storage pipes upstream from the HydroBrake were fully utilized during all three major storm events. A weir in MH 042-325 diverts flow around the HydroBrake when storage is filled to the overflow weir located in MH 042-303. The level in the Leschi trunk sewer was observed to be above the overflow weir during overflow conditions. Data from Phases 2–3 of the flow monitoring program will be used to complete characterization of the curve of the HydroBrake.

NPDES030 Basin

Under normal operating conditions, low flows in the western part of the NPDES030 Basin are directed to the north and away from the NPDES outfall. During periods of extremely high flow, wastewater might discharge over weirs located in MHs 041-386 and 42-008 to the east into NPDES030 Basin.

CSO Facility 17 at the NPDES030 Basin includes 250 feet of an in-line, 42-inch-diameter storage pipe. The storage facility was fully utilized during the May 2009 storm event. A meter was not installed for prior storm events to determine storage utilization.

A sluice gate in MH 042-205 at the intersection of Lake Washington Boulevard and East Alder Street is located at the downstream end of the storage pipe and upstream from the overflow weir. Flows passes under the sluice gate, through the overflow MH 042-322 to a 10-inch-diameter pipe, and eventually to the East Pine Street pump station through the 21-inch-diameter Leschi trunk sewer that runs along Lake Washington.

When a downstream control is activated, the sluice gate shuts and stores flow in the in-line storage pipe. A weir in MH 042-324 diverts flow around the sluice gate when storage is filled to the weir located in MH 042-322. The level in the Leschi trunk sewer was observed to be higher than the NPDES030 Basin overflow weir during overflow conditions. During the Phase 1 monitoring period, the highest level recorded on the 13-inch-high weir was 15.5 inches during the January 2009 storm event.

NPDES031 Basin

Overflows from this partially separated basin are directed to Lake Washington when flow depths exceed the side-cast weir elevation located just north of South Leschi Place in MH 046-033. The level in the Leschi trunk sewer was observed to be higher than the NPDES031 Basin overflow weir during overflow conditions. The NPDES031 Basin has no storage, pump stations, or HydroBrakes. The highest recorded level on the 7.9-inch-high weir was 9.68 inches during the May 2009 storm event.

NPDES032 Basin

NPDES032 Basin consists of two hydraulically separate basins that share one outfall. NPDES032 Basin CSO Facility 16 includes 165 feet of an in-line, 30-inch-diameter storage pipe. A HydroBrake in MH 046-156, located at the intersection of Lakeside Avenue South and South Lane Street, is at the downstream end of the storage pipe. Flows pass through the HydroBrake to the 18-inch-diameter Leschi trunk sewer that conveys flow to the East Pine Street pump station. When the capacity of the HydroBrake is exceeded, flows are stored in the storage pipe. The storage facility was fully utilized in the January and May 2009 events. A weir in MH 046-157 at the upstream end of the storage discharges to the 12-inch-diameter outfall pipe that is shared with NPDES032(B) Subcatchment. The highest recorded level on the 32.75-inch-high weir was 39.29 inches during the Phase 1 monitoring period.

Meters in MHs 046-156 and 046-163 characterize the HydroBrake in the NPDES032(A) Subcatchment. Figure 3-15 shows the curve developed from 2008–2009 data. Due to reverse flow from the Leschi trunk sewer, the HydroBrake curve falls on both sides of the y-axis. The HydroBrake may be submerged under all wet weather flow conditions. The reverse flow from the Leschi trunk sewer impacts the overflow performance at CSO 32A.

Overflow Structure 32B has a contributing area of less than 1 acre. Low flows are directed to the 18-inch-diameter sanitary line that conveys flows to the East Pine Street pump station. Overflows are directed to the 12-inch-diameter outfall pipe that is shared with NPDES032(A) Subcatchment. Measured CSOs at the site are likely caused by surcharging of the downstream Leschi trunk sewer, which submerges the weir. During overflows, it has been observed that the water surface elevation in the Leschi trunk sewer was above the weir elevation. The highest recorded level over the weir was 14.7 inches on the 12.75-inch-high weir.

Data from Phases 2–3 of the flow monitoring program will be used to complete characterization of the HydroBrake.

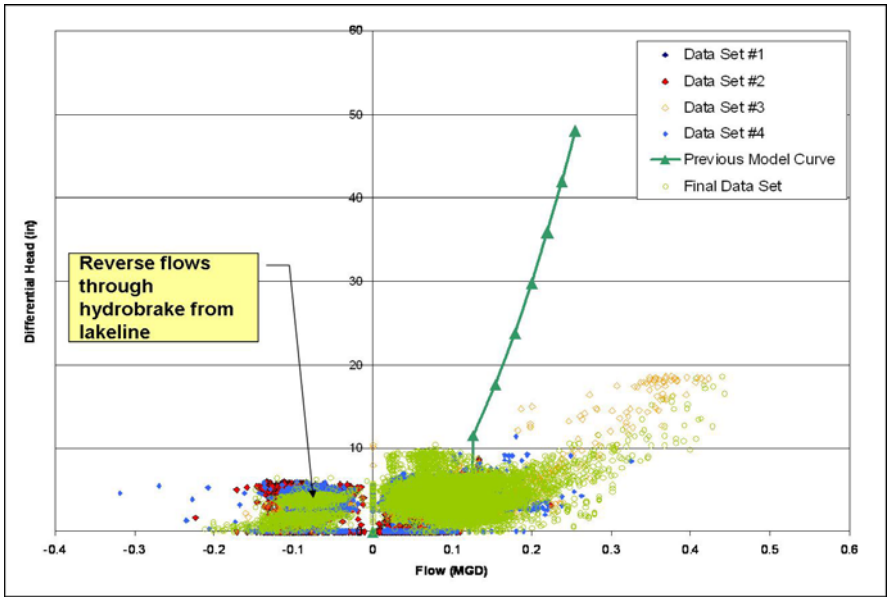

Figure 3-15. NPDES032 Basin HydroBrake characterization

NPDES033 and NPDES034 Basins

During periods of high flow, NPDES033 and NPDES034 Basins may act as one CSO facility. CSO Facility 15 could store excess flow from both basins. CSO Facility 15 includes 122 feet of 84-inch-diameter storage pipe. During dry periods, wastewater flows from the NPDES033 Basin (conveyed along Parkland Place) enter a HydroBrake in MH 046-171 and continue through it. Just downstream in MH 046-050, flow combines with PS 2 discharge. These combined flows are then conveyed through an 18-inch-diameter sanitary mainline to the north and eventually to the East Pine Street pump station.

A weir located in MH 046-172 directs excess flow in the NPDES033 Basin to a large HydroBrake (also located in MH 046-172) and then into the offline, 84-inch-diameter storage pipe associated with SPU PS 2. Eventually PS 2 pumps out the stored flow. When the level behind the downstream HydroBrake (MH 046-171) reaches the level of the NPDES033 Basin overflow weir (also located in MH 046-171 and approximately 0.3 foot higher than the weir elevation in MH 046-172), overflow is conveyed to Lake Washington through the 20-inch-diameter outfall pipe.

The highest recorded level upstream from the overflow weir at the NPDES033 Basin was 40.3 inches on the 43.63-inch-high weir (92.4 percent of weir height). The permanent meter (MH 046-171) and temporary meter at MH 046-050 characterize the HydroBrake at MH 046-171. Figure 3-16 shows the HydroBrake

characterization based on flow monitoring data. There is no indication of a two-curve condition (with or without clogging or vortex collapse) in the collected data.

NPDES034 Basin contributes partially separated flow from the north and south of CSO Facility 15, which is conveyed to PS 2. The 8-inch-diameter pump station force main discharges to an 18-inch-diameter sanitary mainline (at the same location as NPDES033 Basin low flows, MH 046-050). During high flow periods, when the capacity of PS 2 is exceeded, flow overtops a weir in MH 046-176 and is sent to the offline, 84-inch-diameter storage pipe. During the January storm event, 100 percent of the storage was utilized. When the storage pipe is full, water continues to rise above the weir until it reaches the invert of the NPDES034 Basin outfall pipe, which is approximately 0.4 foot above the MH 046-176 weir. Overflow from the NPDES034 Basin is conveyed to Lake Washington through a 15-inch-diameter outfall pipe. The highest recorded level upstream from the overflow weir at MH 046-054 in the NPDES034 Basin was 99 percent of the weir height in the January 2009 event.

Data from Phases 2–3 of the flow monitoring program will be used to complete characterization of the HydroBrake.

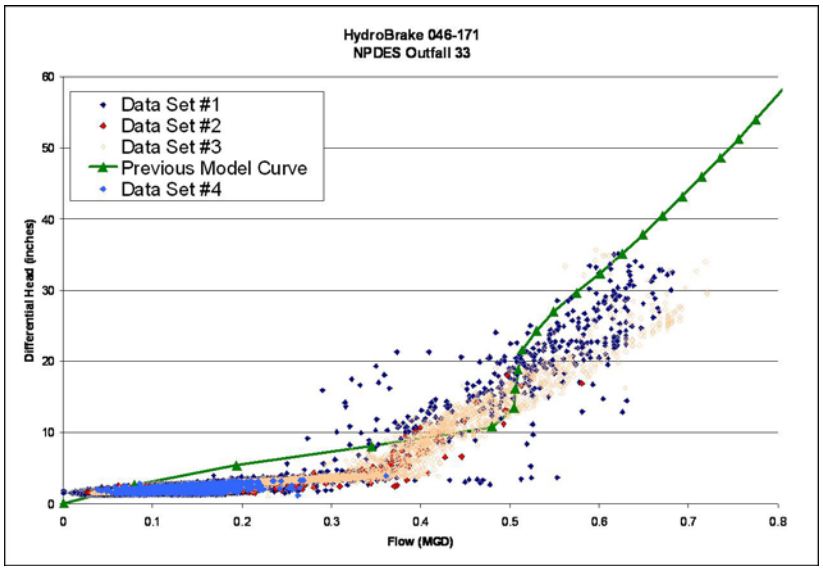

Figure 3-16. NPDES033 Basin HydroBrake characterization

NPDES035 Basin

The upper part of CSO Facility 14 (located in the NPDES035 Basin) includes a sluice gate and storage facility. Under normal dry weather operating conditions, flow passes through the sluice gate (located in MH 046-188) and proceeds down to Lakeside Avenue South, then to the south toward the lower part of CSO 14 located at South Massachusetts Street. During periods of extreme wet weather flow when the sluice gate in MH 046-188 is shut, excess flow is diverted over a weir to storage. If the storage tank fills completely, backwater behind the sluice gate continues to rise until it reaches a second weir approximately 2 feet higher than the first. Flow over this bypass weir is routed over the sluice gate and conveyed to the lower part of CSO Facility 14 and subsequently to the NPDES035 Basin Overflow Structure.

The offline, 72-inch-diameter storage pipe also includes a sluice gate and a flap gate. The sluice gate always remains closed and is used for maintenance and emergencies (for example, if the flap gate gets stuck in the closed position). The flap gate allows for the release of flow out of the storage pipe when conditions

downstream allow (that is, there is a positive head out of the storage pipe). During the Phase 1 monitoring period, the highest level recorded in the storage was 66 inches.

The lower part of CSO Facility 14 consists of a HydroBrake and overflow weir located in MH 046E-138 at the intersection of Lakeside Avenue South and South Massachusetts Street. When flow exceeds the capacity of the HydroBrake, flow backs up and discharges over the weir to the 15-inch-diameter outfall pipe. Initially, the permanent meter at 046E-138 characterized the HydroBrake by subtracting the flow at 046E-141 from the flows downstream at 046E-026. However, there is an elevation difference between the invert of the HydroBrake and the permanent meter; thus, a level-only site was installed in MH 046E-138 to better characterize the HydroBrake. Data from Phases 2–3 of the flow monitoring program will be used to complete characterization of the HydroBrake.

NPDES036 Basin

CSO Facility 13 (located in the NPDES036 Basin) includes 1,200 feet of an in-line, 16-inch-diameter storage pipe. A HydroBrake in MH 046E-142 is located at the downstream end of the storage pipe. Dry weather flows pass through the HydroBrake and continue north through the 16-inch-diameter pipe along Lakeside Avenue South. The HydroBrake causes flow to be stored in the storage pipe during larger events. During all three major storm events, 100 percent of the storage was utilized. A weir in MH 046E-150 diverts flow to the 21-inch-diameter outfall pipe to Lake Washington. The highest level recorded over the 7.13-inch weir was 8.32 inches during the January 2009 storm event.

Meters in MHs 046E-142 and 046E-141 characterize the HydroBrake. Figure 3-17 depicts the HydroBrake characterization based on data collected during the following five time periods during the Phase 1 monitoring period:

- Data set 1: install date–11/9/2008
- Data set 2: 11/10/2008–12/6/2008
- Data set 3: 12/7/2008–1/13/2009
- Data set 4: 1/14/2009–2/28/2009
- Final data set: 2/29/2009–5/31/2009.

These time periods are relevant for all HydroBrake curves in the Leschi Basin section.

Data set 2 shown in Figure 3-17 was collected with a FlowShark Pulse meter. In this period, debris hindered the operations of the upward-looking ultrasonic, which limited the usefulness of the data. The HydroBrake also appeared to be clogged with debris during the 1/7/2009 storm event. The final data set provides the most accurate data from the monitoring period. The data show two distinct curves. The curve to the left generally follows the manufacturer's curve and may represent a clogged condition or behavior of the HydroBrake prior to the collapse of vortex motion. The second curve to the right may represent behavior after debris clears, or behavior after the vortex motion collapses. Data from Phases 2–3 of the flow monitoring program will be used to finalize characterization of the curve for the HydroBrake.

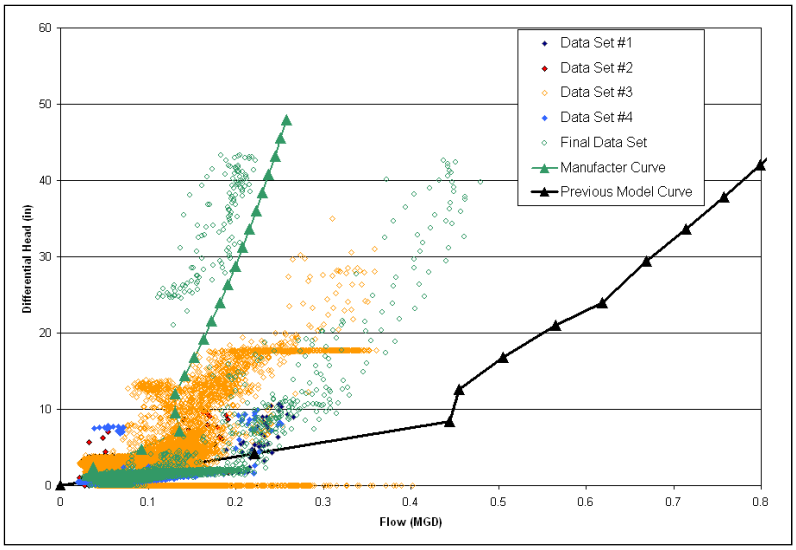

Figure 3-17. NPDES036 Basin HydroBrake characterization

King County East Pine Street Pump Station

The King County East Pine Street pump station is located along the shore of Lake Washington near the terminus of East Pine Street. The station pumps into a 12-inch-diameter force main that discharges into a 24- by 36-inch elliptical sanitary mainline located at the intersection of East Pine Street and 40th Avenue. The pump station contains two firm and one standby identical pump, each with a pump capacity of 1,737 gallons per minute (gpm) at 112 feet of total dynamic head. Operating parameters will be deduced from the SCADA data. Data will be assessed in the 2009–2010 monitoring period data report.

SCADA Data: SPU Pump Station 2

PS 2 is located at 901 Lakeside Drive South in the NPDES034 Basin. The pump station collects flows from the NPDES036, NPDES035, NPDES034 Basins, and storm flows from the NPDES033 Basin (dry weather flows from the NPDES033 bypass the pump station). The station pumps flows to NPDES032 Basin to the north via a force main (approximately 66 feet long x 8 inches diameter). The station includes two pumps.

SPU monitors PS 2 via its SCADA system. The SCADA system records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on-off levels, and in conjunction with drawdown test results to calculate the pump station flow rate. Data quality was classified as "Good" for the Phase 1 monitoring period as operations were consistent throughout the monitoring period.

3.7.14 Recommendations for Additional Data Collection

Meters that have been removed due to poor performance, or that can be removed having collected sufficient data, include the following:

- LES26_042-270A
- LES27_042-273A
- LES28_042-275A
- LES30_041-385A
- LES30_041-386A
- LES30_042-008A
- LES30_046-051A
- LES33_046-050A
- LES36_046E-113A and B
- LES36_046E-149B
- SPU_036-353A
- SPU_042-231A.

Monitoring locations that should be added for the 2009–2010 monitoring period are listed below:

- Meter upstream from permanent meter at the NPDES035 Basin to confirm inflow to the overflow structure and HydroBrake.
- Obtain more hydrology data in the NPDES033 Basin upstream from permanent meter.

3.8 Madison Park/Union Bay Basin

The Madison Park/Union Bay Basin, located on the western shore of Lake Washington, consists of the NPDES022, NPDES024, and NPDES025 Basins and is approximately 240 acres in area. Flows from the NPDES022 Basin in the north are pumped to the NPDES025 Basin via PS 50. Flows from the NPDES024 and NPDES025 Basins combine at PS 7, and then are pumped to the King County system.

RG 03 monitors rainfall in the Madison Park/Union Bay Basin. ADS monitors three overflow points within the basin.

Three permanent stations and a total of 11 temporary meters installed during the review period monitored combined sewage flow. All related site information, photographs, and data representation are included in Appendix I; a basin schematic is contained within Appendix B.

3.8.1 NPDES022 Basin

NPDES022 Basin is the farthest basin to the north in Madison Park. With an area of approximately 9 acres, the basin is located on the southern shore of Madison Park/Union Bay. One permanent meter to verify overflows monitors the basin. No temporary monitoring locations are in the NPDES022 Basin as it has no suitable site for flow measurement.

NPDES022_MH032014

NPDES022_MH032014 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to compute the volume of CSOs using a weir equation. The site is adjacent to an air lift pump station (PS 50). The site has two sensor locations: one located in the maintenance hole and one in the overflow pipe.

The quality of the depth data are classified as "Good" for the Phase 1 monitoring period. The level data have a consistent and repeatable response and lack of data gaps; the level data are suitable for use in model calibration. The velocity data are not suitable for use in model calibration due to the site hydraulics and pump station influence. Flows in this basin will be estimated from PS 50 operations and data from the monitoring location downstream at UB25_032-044A.

3.8.2 NPDES024 Basin

NPDES024 Basin is on the western shore of Lake Washington immediately north of the Leschi Basin. Three temporary meters and one permanent meter to verify overflows monitor the approximately 183-acre basin area. One of the temporary meters, installed to confirm the data from the permanent meter, is located on the downstream side of the overflow weir.

UB24_032-097A

UB24_032-097A is a temporary monitoring installation that records both level and velocity in the northern section of the NPDES024 Basin. The site was chosen after review of an alternative location at MH 038-142. The level and velocity data are used to calculate the flows from the northern part of the NPDES024 Basin in order to characterize hydrology for basin modeling.

Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps. The storm response at this location is relatively minor.

The meter was removed in April 2009 as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

UB24_038-141A

UB24_038-141A is a temporary monitoring installation that records both level and velocity in the southern part of the NPDES024 Basin just upstream from SPU PS 7. The site was chosen after review of an alternative location MH 038-142.

The level and velocity data are used to calculate the flows from the southern part of the NPDES024 Basin in order to characterize hydrology for basin modeling. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. The data generally have a consistent and repeatable response. However, velocity dropouts occurred at the site during large storm events due to backwater from PS 7. Data from the January and May storms do not provide peak flow rates for model calibration. Velocity data in smaller storms and the November 2008 storm are suitable for model calibration. The depth data also provided confirmation of the level in the PS 7 wet well. The storm response at this location is relatively minor.

It is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

UB24_038-283A

UB24_038-283A is a temporary monitoring installation that records level only. The site was chosen after review of an alternative location at MH 038-146. The level data are used to verify the data from the permanent monitoring installation in NPDES024_PS7 and to provide a boundary condition for overflow calculations. The meter is located in MH 038-283, which is downstream from the NPDES024 Basin overflow weir at PS 7. The quality of the data collected for the Phase 1 monitoring period has not yet been classified as there have been no overflows in the NPDES024 Basin since the meter was installed in November 2008.

The meter is located in the NPDES024 Basin outfall, and the maintenance hole has some standing water. The variation in the water level in Lake Washington caused the variation in level observed at the site, which gradually increased from February to May 2009.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain level data during overflow events at the NPDES024 Basin.

NPDES024_PS7

NPDES024_PS7 is a permanent monitoring installation that records level only on the inlet to SPU PS 7. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The site was installed on 3/13/2009. Previously, the PS 7 level data from the SCADA system were used to alarm for CSO events.

Data quality was classified as "Excellent" for the Phase 1 monitoring period. The level data have a consistent and repeatable response. No CSO events were reported at the site during the Phase 1 monitoring period.

3.8.3 NPDES025 Basin

NPDES025 Basin is located between NPDES022 and NPDES024 Basins on the western shore of Lake Washington. Nine temporary meters and one permanent meter to verify overflows monitor the basin, which is approximately 49 acres in area. One of the temporary meters is located on the downstream side of the overflow weir to confirm the data from the permanent meter. Four of the temporary meters were removed during the review period.

UB25_032-044A

UB25_032-044A is a temporary monitoring installation that records both level and velocity just downstream from SPU PS 50. No alternative locations were inspected.

The level and velocity data are used to calculate the flows from the NPDES022 Basin and the northern part of the NPDES025 Basin in order to characterize hydrology for basin modeling. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to capture additional data for hydrology characterization.

UB25_032-078A

UB25_032-078A is a temporary monitoring installation that records both level and velocity. Alternative monitoring locations considered were MHs 032-079 and 032-197.

The level and velocity data are used to calculate the flows from the NPDES022 Basin and the western part of the NPDES025 Basin in order to characterize hydrology for basin modeling. The quality of the finalized data was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps. A significant amount of editing was applied in the data finalization process. Flow balancing with upstream and downstream meters indicated that the finalized data are in the expected range.

It is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

UB25_032-187A

UB25_032-187A is a temporary monitoring installation that records both level and velocity. The site was installed to characterize NPDES025 Basin hydrology. The site was chosen after review of alternative locations at MHs 032-188 and 038-285.

The meter is located at the upstream end of a cunette that is part of the online storage pipe in the NPDES025 Basin. Although the level data collected at the location were good (that is, no data gaps and ultrasonic and pressure measurement of depths align well), the relationship between level and velocity data was not clear or consistent due to the unusual hydraulics at the monitoring location. Consequently, the quality of the flow data calculated using the level and velocity measurements was classified as "Poor" for the Phase 1 monitoring period. The site was not conducive to collecting data suitable for model calibration due to the site hydraulics. Therefore, the meter was removed on 4/15/2009 and relocated to UB25_032-188A.

UB25_032-188A

UB25_032-188A is a temporary monitoring installation that records both level and velocity. The site was installed to characterize NPDES025 Basin hydrology. The site was chosen as a replacement site to UB25_032-187A as the site hydraulics were not conducive to collecting data suitable for model calibration at that location.

The site was located one maintenance hole farther upstream than the previous site UB25_032-187A. The level and velocity data are used to calculate flows from part of the NPDES025 Basin and to characterize basin hydrology. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period, as site surcharged during storm events.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring and comparing the data to data from the upstream site at UB25_032-078A. The flow balance indicated that the calculated flows from this temporary monitoring location were within the expected range based on the contributing length of pipe to each of the locations.

It is recommended that this monitoring installation remain in place during the Phases 2–3 monitoring period to obtain additional data for hydrology characterization.

UB25_032-193A

UB25_032-193A is a temporary monitoring installation installed in the sewer in Madison Street. Both level and velocity are monitored at this location. An alternative monitoring location considered was MH 032-108.

The level and velocity data are used to calculate flows from part of the NPDES025 Basin in order to characterize basin hydrology. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period as the velocity data are inconsistent below a depth of about 2.5 inches. The data at peak flows during storm events are suitable for use in model calibration. The meter was removed on 4/1/2009 as it was determined that sufficient data had been collected for model calibration.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The total flow from three upstream temporary monitoring locations (UB25_032-193A, UB25_032-078A, and UB25_032-202A) was compared to the downstream flow at UB25_032-187A. The flow balance determined that the peak calculated flows from this temporary monitoring location were within the expected range.

UB25_032-202A

UB25_032-202A is a temporary monitoring installation. Both level and velocity are monitored at this location. No alternative monitoring locations were considered.

The level and velocity data are used to calculate flows from part of the NPDES025 Basin in order to characterize basin hydrology. Data quality was classified as "Good" for the Phase 1 monitoring period because the data have a consistent and repeatable response during both dry and wet weather. Data are missing for the latter half of the January 2009 storm because the meter had to be replaced; thus, model calibration will rely on the November 2008 storm and other smaller storms. The meter was removed on 4/1/2009 as it was determined that sufficient data had been collected for model calibration.

UB25_038-149A

UB25_038-149A is a temporary monitoring installation on the downstream side of the NPDES025 Basin overflow weir. At this location, only level is monitored. No alternative monitoring locations were considered. The site was previously incorrectly named UB25_038-280A.

The level data are used to verify the occurrence of overflow indicated by the permanent monitoring installation in the NPDES025 Basin and to provide a boundary condition for overflow calculations.

The meter was installed in January 2009. The first overflow at the NPDES025 Basin occurred in May 2009. Review of data from the CSO event during the 7/14/2009–7/15/2009 data review workshop indicated that the meter had been incorrectly installed on the upstream side from the weir.

Data quality was classified as "Some Limitations" for the Phase 1 monitoring period; the data are only usable for confirmation of the depth reading of the permanent meter in the same maintenance hole.

It is recommended that the meter be relocated to the downstream side of the overflow weir in the same maintenance hole for the Phases 2–3 monitoring period.

UB25_038-153A

UB25_038-153A is a temporary monitoring installation. Both level and velocity are monitored at this location. No alternative monitoring locations were considered.

The level and velocity data are used to calculate flows from a small part of the NPDES025 Basin in order to characterize basin hydrology. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. Data collected during storm events, when the level is above a depth of 1.5 inches, are suitable for use in model calibration. Data collected during dry weather are not suitable for use in model calibration because the velocity data are inconsistent when the level is below a depth of 1.5 inches. The meter was replaced on 1/28/2009 in an attempt to obtain better velocity data, but the meter was eventually removed on 4/1/2009 due to the inability to obtain good velocity data at low flows. No suitable alternate locations were identified for meter relocation.

UB25_038-285A

UB25_038-285A is a temporary monitoring installation. Both level and velocity are monitored at this location. No alternative monitoring locations were considered.

The level and velocity data are used to calculate flows from the western part of the NPDES025 Basin to characterize basin hydrology. Data quality was classified as "Good" for the Phase 1 monitoring period due to the consistent and repeatable response of the data during both dry and wet weather. PS 7 influenced the velocity data during peak storm events; therefore, the November 2009 storm and other smaller storms should be used for model calibration in preference to the larger storm events.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to capture additional data for hydrology characterization.

NPDES 25_MH038149

NPDES 25_MH038149 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The monitoring location was on the dry weather list, but was changed to the wet weather site list, as only level is suitable for model calibration.

Data quality was classified as "Excellent" for the Phase 1 monitoring period. The level data have a consistent and repeatable response and lack of data gaps; the data are suitable for use in model calibration. A temporary meter was installed on the downstream side of the weir at MH 038-280 during Phase 1 monitoring in order to verify the occurrence of overflows indicated by the permanent meter and to provide a boundary condition for the model calculations.

A flow balance was undertaken for the final workshop using data from this location and comparing them to data from the upstream locations at UB25_032-188A and UB25_038-285A. The flow balance indicated that the calculated flows from the permanent monitoring location appeared to be overestimating flow.

3.8.4 Meters outside Madison Park/Union Bay Basin

KC_031-053A

KC_031-053A is a temporary monitoring installation. Both level and velocity are monitored at this location. An alternative monitoring location considered was MH 025-060.

The meter is located in the King County system near the end of the King County Southwest Lake Washington trunk. The level and velocity data are used to calculate flows from the Madison Park/Union Bay Basin, Leschi Basin, and an area outside the uncontrolled basins that contribute directly to the King County system.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to capture additional data for hydrology characterization.

3.8.5 Combined Sewer Overflows

ADS reported that two CSOs occurred in the Madison Park/Union Bay Basin during the Phase 1 monitoring period; Table 3-10 lists the CSOs that occurred during the Phase 1 monitoring period; both occurred during the January 2009 storm event.

Table 3-10. 2008–2009 Combined Sewer Overflows in Madison Park/Union Bay Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
22	1/7/2009	2:25	14,101
24	--		--
25	1/7/2009	1:20	27,830

The reported weir height at the NPDES025 Basin was revised during the Phase 1 monitoring period following survey work. Based on the revised weir height, the site also overflowed during the 5/5/2009 storm event.

Figure 3-18 shows the maximum water level recorded at each of the overflow structures in the basin as a percentage of the weir height. Data were not available at the NPDES024 Basin for the November 2008 and January 2009 events as the permanent meter was not installed until March 2009.

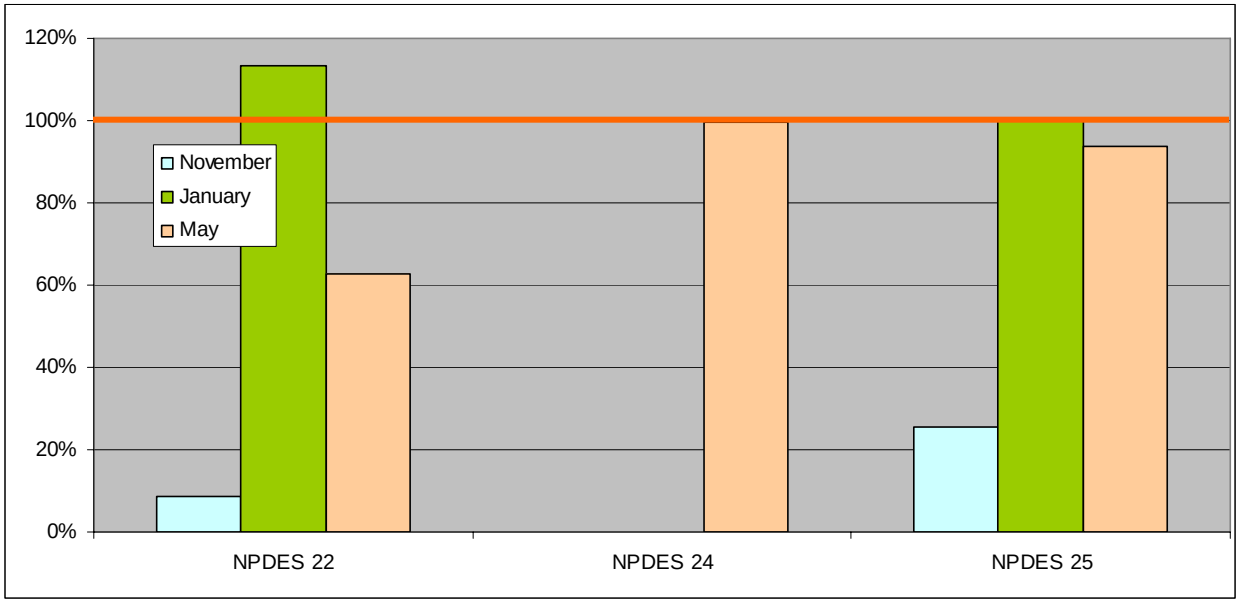

Figure 3-18. Maximum water level in the Madison Park/Union Bay Basin overflow structures in relation to weir height for major events

3.8.6 Facility Operations

The CSO facilities in the Madison Park/Union Bay Basin have overflow weirs. There are no HydroBrakes or storage structures with the exception of in-line storage in the NPDES025 Basin upstream from PS 7.

NPDES022 Basin

The CSO facility in the NPDES022 Basin consists of an overflow weir at MH 032-014 at the north end of 39th Avenue East, which is one maintenance hole upstream from PS 50. MH 032-014 is 162 inches deep, and the overflow line is elevated 123.38 inches from the invert of the maintenance hole. When the inflow to the pump station exceeds the pump station capacity, the flows back up in the gravity main system. Once the water level in MH 032-014 reaches a height of 123.38 inches above the invert, wastewater spills into Union Bay via an 8-inch-diameter overflow line and storm drain. SPU operations staff indicated that the air lift pump station has two 50-gallon cans that can be cycled on a 60-second cycle yielding a maximum pumping rate of 50 gpm.

NPDES024 Basin

The CSO facility in the NPDES024 Basin consists of an overflow weir at PS 7 located in East Lee Street between Knox Place East and 42nd Avenue East. Flows typically enter PS 7 via a 24-inch-diameter main that runs through a chamber (previously the grit chamber) separated from the wet well by a concrete wall. Once the water level in the chamber increases, flows can also enter the wet well through a cut-out in the wall. An overflow weir in the chamber is located approximately 46 inches above the base of the chamber. When the water level increases in the wet well, flow enters the chamber. If the flow continues to increase above the height of the weir wall, excess flows are diverted to Lake Washington via a 21-inch overflow line.

NPDES025 Basin

The CSO facility in the NPDES025 Basin consists of an overflow weir at MH 038-149 located upstream from PS 7 in East Lee Street. When the inflows to PS 7 exceed the pumping capacity, the flows back up in the gravity main system. MH 038-149 is 156 inches deep, and the overflow line is elevated 72 inches from the invert of the maintenance hole. The elevation at this overflow weir is lower than the elevation of the weir at the pump station itself, so there will be an overflow before NPDES024 overflows. Once the water level in MH 038-149 reaches a height of 72 inches above the invert, wastewater spills into Lake Washington via a 24-inch-diameter overflow line.

SCADA Data: Pump Station 7

SPU monitors PS 7 via its SCADA system. The SCADA system records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on-off levels, and in conjunction with drawdown test results to calculate the pump station flow rate.

Data quality was classified as "Good" for the Phase 1 monitoring period as operations were consistent throughout the monitoring period.

SCADA Data: Pump Station 50

SPU monitors PS 50 via its SCADA system. The SCADA system records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on-off levels, and in conjunction with drawdown test results to calculate the pump station flow rate.

Data quality was classified as "Good" for the Phase 1 monitoring period as operations were consistent throughout the monitoring period.

3.8.7 Recommendations for Additional Data Collection

No additional sites within the Madison Park/Union Bay Basin have been identified for the 2009–2010 wet weather season. In addition to the sites removed prior to the end of May 2009, a number of additional sites will be removed prior to the 2009–2010 wet season in order to place the meters at alternate locations in the system. The meters that will be removed are as follows:

- UB025_032-044A: Sufficient data collected
- UB025_032-078A: Sufficient data collected
- UB024_038-141: Sufficient data collected.

3.9 Magnolia Basin

The Magnolia Basin consists of the NPDES060, NPDES061, NPDES062, NPDES063, and NPDES064 Basins. The NPDES064 Basin is controlled and is not part of this monitoring effort. Overflow point and Outfall 63 was abandoned in 2003. The combined sewer flows from the NPDES060 Basin are pumped into the King County system via SPU PS 22. The low flows from the NPDES062 Basin flow to the overflow point for NPDES061 Basin. These two overflow points receive the identical flow and can be considered as one basin. Low flows proceed southwest to SPU PS 77 where they are pumped into the King County system. RG 12 monitors rainfall in the Magnolia Basin. Two overflow points are located within the NPDES061/062 Basin, and one in the NPDES060 Basin. ADS monitors each overflow point.

Combined sewage flow was monitored by two permanent stations and a total of seven temporary meters that were installed during the review period. No temporary meters are located in the NPDES060 Basin; therefore, there is no schematic for this basin. More detailed information can be found in Appendix J; a basin schematic is contained within Appendix B.

3.9.1 NPDES060 Basin

MAG60_DWF-010159 (WW)

MAG60_DWF-010159 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The site is classified as a wet weather site; thus, the velocity data are not finalized. The overflow is immediately upstream from SPU PS 22.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

3.9.2 NPDES061 Basin

MAG61_026-011A

MAG61_026-011A is a temporary monitoring installation that records level only. The level data are used to characterize the HydroBrake in the NPDES061 Basin. No alternative monitoring locations were considered for MAG61_026-011A. Due to the configuration of the site, it was necessary to mount the depth sensor 12.94 inches above the channel invert. As a result, the meter reads positive 12.94 inches until it is submerged and thus does not capture any data during dry weather periods.

Data quality was classified as "Good" for the Phase 1 monitoring period. Depth measurements were excellent when the HydroBrake backed up flow above the sensor, providing data for the upper part of the HydroBrake curve. The lower end of the HydroBrake curve can be estimated.

It is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

MAG61_DWF-026013 (DW)

MAG61_DWF-026013 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Level and velocity data are used to calculate flows from the NPDES061 Basin to characterize basin hydrology. The monitoring location is on the dry weather list, meaning that the velocity data are finalized in an attempt to

maximize data utility. No overflows have been reported at this location since ADS began monitoring in July 2007.

Data quality was classified as "Good" for the Phase 1 monitoring period. The scatter at depths below about 1.5 inches is wide, suggesting that the velocity probe is picking up multiple velocities in this range. The daily dry weather flow minimums in the early morning periods may be overestimated.

3.9.3 NPDES062 Basin

MAG63_019-271A

MAG63_019-271A is a temporary monitoring installation that records both level and velocity. The level and velocity data are used to calculate the flows in the upper eastern part of the NPDES062 Basin to characterize hydrology. The site was chosen after review of inspections at MHs 026-420 and 026-421.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

A flow balance was undertaken for the July workshop using data from this location and comparing them to the data from the downstream location at MAG63_026-423A. The flow balance indicated that the flows were within the expected range.

It is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

MAG63_026-003A

MAG63_026-003A is a temporary monitoring installation that records both level and velocity. The level and velocity data are used to calculate flow from the western part of the NPDES062 Basin to characterize hydrology. Alternative monitoring locations considered for MAG63_026-003A were MHs 026-002, 026-004, and 026-005.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

MAG63_026-045A

MAG63_026-045A is a temporary monitoring installation that records both level and velocity. The level and velocity data are used to calculate flow from the NPDES061 and NPDES062 Basins to characterize hydrology. The site is located upstream from PS 77. No alternative monitoring locations were considered for MAG63_026-045A.

Data quality was classified as "Excellent" due to the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

MAG63_026-422A

MAG63_026-422A is a temporary monitoring installation that records level only. The meter is installed in an in-line storage pipe upstream from the HydroBrake in the NPDES062 Basin, and the level data are used to determine storage utilization. No alternative monitoring locations were considered for MAG63_026-422A.

Data quality was classified as "Good" for the Phase 1 monitoring period. The level data show a consistent and repeatable response during both dry and wet weather; however, there is a data gap during the January storm due to meter damage.

It is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

MAG63_026-423A

MAG63_026-423A is a temporary monitoring installation that records both level and velocity. The installation is located downstream from the HydroBrake in the NPDES062 Basin. The level and velocity data are used to calculate flow from the NPDES062 Basin and to characterize the HydroBrake. No alternative monitoring locations were considered for MAG63_026-423A.

Data quality was classified as "Good" for the Phase 1 monitoring period. The scatter plots indicate that the velocity probe is picking up multiple velocities at low depths. A signature also suggests pooling of flow in front of the probe, which results in an overestimation of minimum flows in the early morning. The site signature at higher wet weather flows suggests a backup from the downstream HydroBrake.

A flow balance was undertaken for the final workshop using data from this location and comparing them to the data from the upstream location at MAG63_019-271A. The flow balance indicated that the flows were within the expected range. A second flow balance was also undertaken using data from this location and comparing them to the data from the downstream location at MAG63_026-465A. The flow balance indicated that the flows were within the expected range.

It is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

MAG63_026-465A

MAG63_026-465A is a temporary monitoring installation that records both level and velocity. The level and velocity data are used to calculate flow from the eastern part of the NPDES062 Basin to characterize hydrology. An alternative monitoring location considered for MAG63_026-465A was MH 026-009.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

A flow balance was undertaken for the final workshop using data from this location and comparing them to the data from the upstream location at MAG63_026-423A. The flow balance indicated that the flows were within the expected range.

It is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

MAG62_DWF-026010 (DW)

MAG62_DWF-026010 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Level and velocity data are used to calculate flows from the NPDES062 Basin to characterize basin hydrology. The

monitoring location is on the dry weather list, which means that the velocity data are finalized in an attempt to maximize data utility. Only one overflow (12/3/2007) has been reported at this location since ADS began monitoring in August 2007.

Data quality was classified Phase 1 monitoring are classified as "Excellent" due to their consistent and repeatable response during both dry and wet weather and lack of data gaps.

3.9.4 Combined Sewer Overflows

ADS reported that two CSOs occurred in the Magnolia Basin during the Phase 1 monitoring period; Table 3-11 lists reported CSOs during the Phase 1 monitoring period.

Table 3-11. 2008–2009 Combined Sewer Overflows in Magnolia Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
60	1/7/2009	2:25	173,216
	5/19/2009	0:35	18,245
61	--	--	--
62	--	--	--

Figure 3-19 shows the maximum water level recorded at each of the overflow structures in the NPDES060, NPDES061, and NPDES062 Basins as a percentage of the weir height.

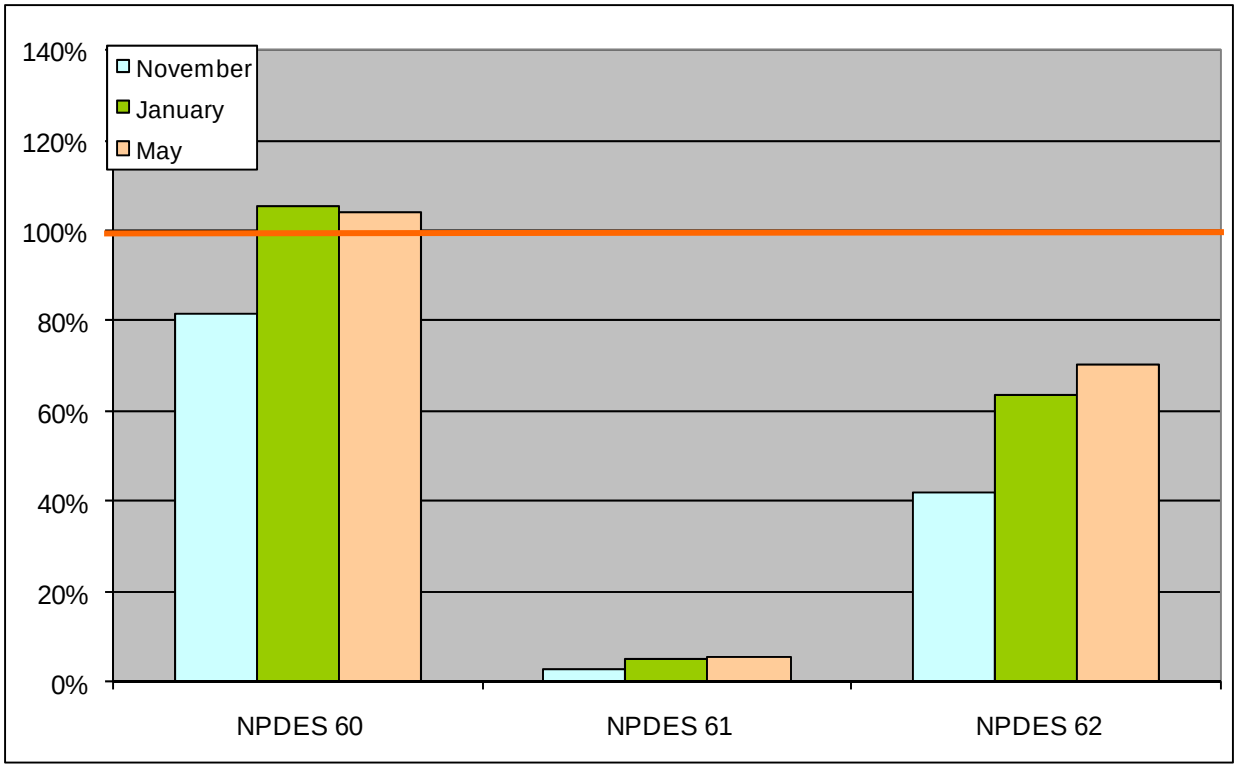

Figure 3-19. Maximum recorded levels compared to weir heights for major events

3.9.5 Facility Operations

The CSO facilities in the Magnolia Basin consist of the three overflow weirs described above. Two HydroBrakes and one storage tank are located in the NPDES061 and NPDES062 Basins. The storage tank and one of the HydroBrakes are located near temporary meter MAG63-026-422A. The other HydroBrake is located downstream from permanent meter MAG62_DWF-026010 and near temporary meter MAG61_026-011A. One pump station (PS 77) is located in the NPDES064 Basin.

HydroBrake 026-011

Figure 3-20 below shows the HydroBrake curve based upon monitoring data at an upstream and downstream meter with respect to the HydroBrake location. The upstream meter used for the HydroBrake 026-011 analysis was the level and flow data at meter MAG62_DWF-026010. The downstream meter used for the analysis was the level data at meter 026-011. The monitor data are then compared to the HydroBrake manufacturer's curve. Figure 3-21 shows the "manufacturer's curve," data from MAG62_DWF-026010, and data from 026-011.

HydroBrake 026-422

Figure 3-22 below shows the HydroBrake curve based upon monitoring data at an upstream and downstream meter with respect to the HydroBrake location. The upstream meter used for the HydroBrake 026-422 analysis was the level data at meter 026-422. The downstream meter used for the analysis was the level and flow data at meter 026-423. The monitor data are then compared to the HydroBrake manufacturer's curve. Figure 3-22 shows the "manufacturer's curve," "previous data" (October through April), and the "current

data" (April through May). The horizontal line near 155 inches of differential head indicates that storage has filled and flow is occurring over the bypass weir.

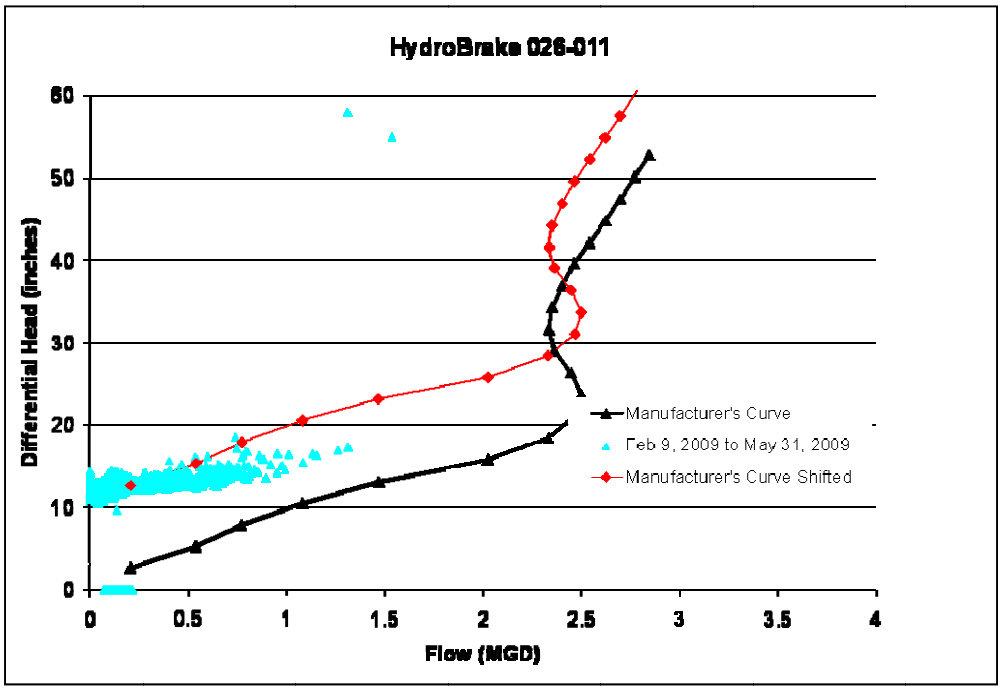

Figure 3-20. NPDES062 Basin HydroBrake characterization 026-011

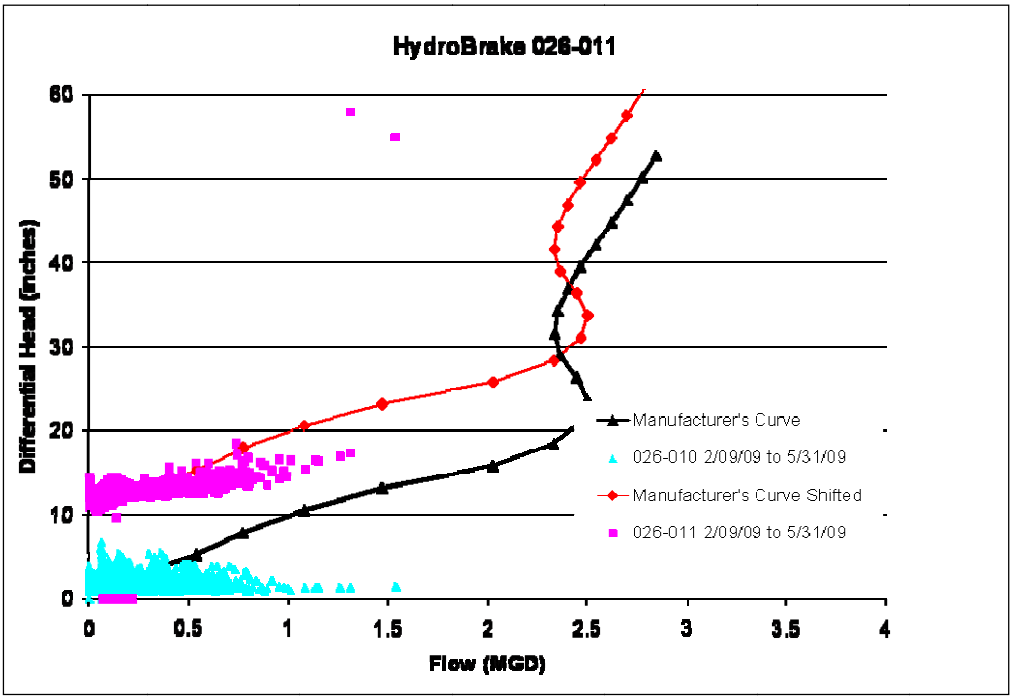

Figure 3-21. NPDES062 Basin HydroBrake characterization revised curve

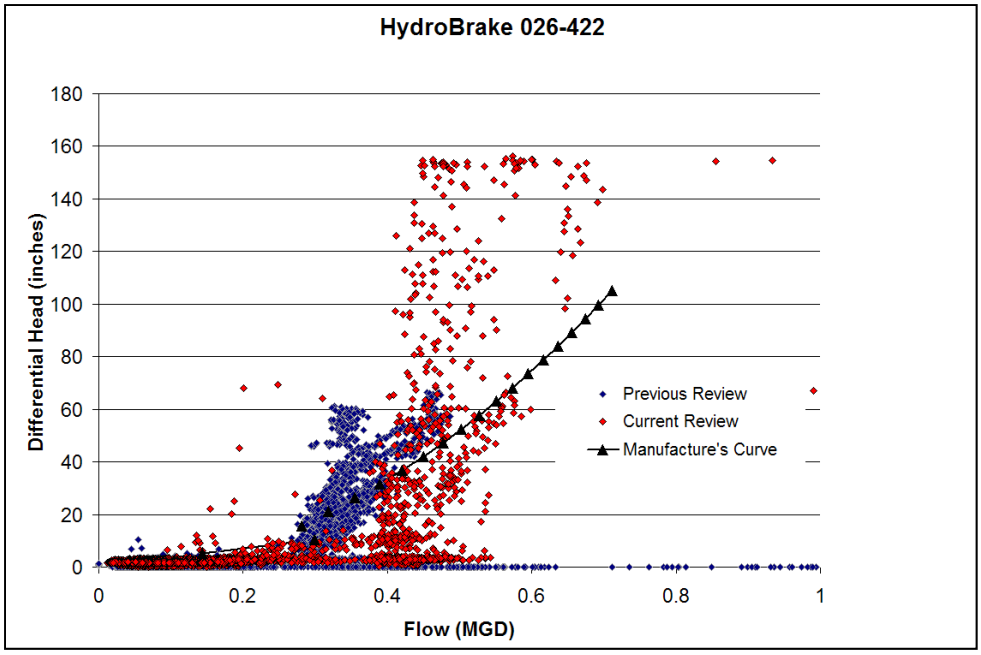

Figure 3-22. NPDES062 Basin HydroBrake characterization 026-422

Pump Stations 77 and 22

SPU monitors PSs 77 and 22 via its SCADA system. The SCADA system records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on-off levels, and in conjunction with drawdown test results to calculate the pump station flow rate.

Data collected during Phase 1 monitoring included the pump on-off states and the wet well depth. These were plotted versus time and rainfall for review. Review consisted of observing the normal rise and fall of wet well elevation with time during wet and dry weather. In general, no anomalies in operation were noted that could not be explained by response to rainfall.

Storage Tank 026-422

The in-line storage tank located at 026-422 works in conjunction with HydroBrake 026-422. When the HydroBrake activates during storm events, the tank fills. Temporary monitor MAG63_026-422A measures the level in the storage tank during dry and wet weather events. During dry weather events, the flow goes through the 12-inch cunette. During large wet weather events, the flow begins to fill the 72-inch-diameter, 235-foot-long storage tank. The total volume of the storage tank is 50,000 gallons, and during the January 2009 and May 2009 storm events, the entire storage was utilized.

3.9.6 Recommendations for Additional Data Collection

The Magnolia basin will not be monitored in the 2009–2010 monitoring period. All monitors will be removed.

3.10 Montlake Basin

The Montlake Basin, which consists of the NPDES020, NPDES139, and NPDES140 Basins, is approximately 120 acres in area. Flows from the NPDES020 Basin are pumped via PS 13 into the King County mainline upstream from the Montlake regulator. The flows from both the NPDES139 and NPDES140 Basins are collected in PS 25, which pumps them to the Montlake gravity basin.

RG 03 monitors rainfall in the Montlake Basin. ADS monitors three overflow points within the basin.

Three permanent stations and 10 temporary meters monitored combined sewage flow throughout the review period. Appendix K contains all related site information, photographs, and data representation; a basin schematic is contained within Appendix B.

3.10.1 NPDES020 Basin

NPDES020 Basin is located farthest to the east in Montlake, with the Lake Washington Ship Canal to the north. The basin is approximately 70 acres in area. Three temporary meters and one permanent meter to verify overflows monitor the basin. One of the temporary meters was removed during the review period.

MON20_031-027A

MAG62_DWF-026010 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Level and velocity data are used to calculate flows from the NPDES062 Basin to characterize basin hydrology. The monitoring location is on the dry weather list, which means that the velocity data are finalized in an attempt to maximize data utility. Only one overflow (12/3/2007) has been reported at this location since ADS began monitoring in August 2007.

Data quality was classified Phase 1 monitoring are classified as "Excellent" due to their consistent and repeatable response during both dry and wet weather and lack of data gaps.

MON20_031-037A

MON20_031-037A is a temporary monitoring installation that records both level and velocity. The level and velocity data are used to calculate flows from part of the NPDES020 Basin (south of Highway 520) and to characterize basin hydrology. The site was chosen after review of alternative locations at MHs 031-038, 031-039, and 031-369.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The flow from this location was compared to the flow at the downstream monitoring location MON20_031-381A. The flow balance indicated that the flows were not within the right range and that approximately three times the amount of flow per length of pipe were entering the CSS between the two meters as was entering upstream at MON20_031-037A. Data from the temporary location MON20_031-027A (downstream from PS 13) were also used to undertake a volume balance. It was determined during the workshops that MON20_031-381A was overestimating velocity and, therefore, flows. It was determined that data from MON20_031-037A should be used for model calibration and that MON020_031-381A should be removed.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period in order to capture additional data for hydrology characterization.

MON20_031-381A

MON20_031-381A is a temporary monitoring installation that records both level and velocity. The level and velocity data are used to calculate the flows in the NPDES020 Basin and to characterize hydrology. The site was chosen after review of an inspection at MH 031-384.

Data quality was classified as "Poor" for the Phase 1 monitoring period based on the flow balancing that was undertaken during the Phase 1 monitoring period. A flow and volume balance was undertaken using data from this location, in addition to data from MON20_031-037A and MON20_031-027A. It was determined that the velocity at this location was overestimated (refer to discussion in MON20_031-037A).

It is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period.

NPDES20_MH031382 (WW)

NPDES20_MH031382 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. The meter is located on the downstream side of the weir to the offline storage in the NPDES020 Basin. Therefore, only level and velocity are recorded when flow is diverted to offline storage facilities. The site is classified as a wet weather site; thus, the velocity data are not finalized.

The quality of the depth data was classified as "Excellent" for the Phase 1 monitoring period. The level data have a consistent and repeatable response and lack data gaps; the data are suitable for use in model calibration.

3.10.2 NPDES139 Basin

NPDES139 Basin is located farthest to the south and west in Montlake, on the southern shore of Portage Bay. The basin is approximately 54 acres in area. Two temporary meters and one permanent meter to verify overflows monitor the basin.

MON139_031-310A

MON139_031-310A is a temporary monitoring installation that records both level and velocity. The level and velocity data are used to calculate the flows in the NPDES139 Basin and to characterize hydrology. The site was chosen after review of inspections at MHs 031-311 and 031-303.

Data quality was classified as "Good" for the Phase 1 monitoring period. Data from storm peaks are suitable for model calibration once the level is above approximately 2 inches, below which level the meter is subject to ramping. The data have a consistent and repeatable pattern during wet weather.

Flow balancing was undertaken using data from this temporary monitoring location during the Phase 1 monitoring period (refer to the MON139_DWF-031313 site narrative for more details).

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to capture additional data for hydrology characterization.

MON139_031-313A

MON139_031-313A is a temporary monitoring installation that records level. The installation is located on the downstream side of the weir in the NPDES139 Basin, which overflows to a storm drain. No alternative monitoring locations were considered.

The level data will be used to provide a boundary condition of depth for the model to properly account for any submergence of the weir during a CSO event, and to provide an indication of whether reverse flow occurs over the weir from the storm drain system to the CSS.

Data quality was classified as "Excellent" for the Phase 1 monitoring period. There have not been any overflows in the NPDES139 Basin since the meter was installed, but the level data can be used to develop a boundary condition for the model. The level data gradually increased from March 2009 through May 2009 due to the influence of Lake Washington water levels.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period.

MON139_DWF-031313 (DW)

MON139_DWF-031313 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Level and velocity data are used to calculate flows from the NPDES139 Basin and characterize basin hydrology. The monitoring location is on the dry weather list, which means that the velocity data are finalized in an attempt to maximize data utility.

Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. The level data have a consistent and repeatable response and lack data gaps; the data are suitable for use in model calibration. However, during storm peaks PS 25 backs up to the site; also, there are velocity dropouts. The meter may also be reading the peak velocity from upstream where the depth is less than at the point where the depth is measured, which results in flow overestimation.

Flow balancing was undertaken using the data from this permanent monitoring location and data from the temporary monitoring location downstream at MON139_031-313A during Phase 1 monitoring. The flow balance indicated that the flows calculated from the downstream location were more than double the upstream flows. The downstream location had approximately 30 percent greater contributing pipe length than the upstream location. Based on the flow balance and the hydraulics at the permanent monitoring location, the flows calculated from MON139_031-313A data are considered more reliable and should preferentially be used for model calibration.

3.10.3 NPDES140 Basin

NPDES140 Basin is located north of the NPDES020 Basin on the southern side of the Lake Washington Ship Canal between Portage Bay and Union Bay. Two temporary meters and one permanent meter to verify overflows monitor the basin, which is approximately 16 acres in area. The permanent site is also used to characterize the HydroBrake although the velocity data are not finalized.

MON140_031-001A

MON140_031-001A is a temporary monitoring installation that records level. The installation is located on the downstream side of the weir in the NPDES140 Basin. No alternative monitoring locations were considered when the site was installed.

The level data will be used to confirm the data from the permanent meter and to develop a boundary condition for depth at the outfall.

Data quality was classified as "Good" for the Phase 1 monitoring period. There have been no overflows in the NPDES140 Basin since the meter was installed, but the level data can be used to develop a boundary condition for the model. The level data increased in April and May 2009 due to the influence of Lake Washington water levels.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain additional data for development of the boundary condition.

MON140_031-002A

MON140_031-002A is a temporary monitoring installation that records both level and velocity. An alternative monitoring location considered was MH 031-003.

The level and velocity data are used to calculate the flow through the HydroBrake and to provide an indication of the effect of PS 25 on the system.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain additional data for HydroBrake characterization and pump station influence.

MON140_DWF-031001 (WW)

MON140_DWF-031001 is a permanent monitoring installation that records both level and velocity. The level data are used to alarm for CSO events, calculate the volume of CSOs using a weir equation, and characterize the HydroBrake at MH 031-002. The site is classified as a wet weather site; thus, the velocity data are not finalized.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to the consistent and repeatable response of the data and lack of data gaps. While the site is not intended to collect reliable velocity data, the data during peak events appear to be useful and provide an estimate of peak flow and overflow volume when compared with the data from MON140_031-002A.

3.10.4 Meters outside Montlake Basin

SPU_031-143A

SPU_031-143A is a temporary monitoring installation that records both level and velocity. The level and velocity data are used to calculate the flows from the NPDES139 and NPDES140 Basins, and the Montlake gravity basin directly tributary to the King County system. The installation is located downstream from PS 25 and the temporary monitoring installations at SPU_031-231A and SPU_031-227A. No alternative monitoring locations were considered for SPU_031-143A.

Data quality was classified as "Good" for the Phase 1 monitoring period. In the influence of the King County siphon under Highway 520, the site experienced backup from the siphon during large storms.

It is recommended that the monitoring installation remain in place for the Phases 2–3 monitoring period.

SPU_031-227A

SPU_031-227A is a temporary monitoring installation that records both level and velocity. The level and velocity data are used to calculate the flows in the southern part of the Montlake gravity basin directly tributary to the King County system. The installation is located upstream from the temporary monitoring installation at SPU_031-143A. The site was chosen after review of inspections at MHs 031-221 and 031-220.

Data quality was classified as "Good" for the Phase 1 monitoring period due to their consistent and repeatable response during both dry and wet weather and lack of data gaps.

It is recommended that the monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

SPU_031-231A

SPU_031-231A is a temporary monitoring installation that records both level and velocity. The level and velocity data are used to calculate the flows in the northern part of the Montlake gravity basin directly tributary to the King County system. The installation is located upstream from the temporary monitoring installation at SPU_031-143A. The site was chosen after review of inspections at MHs 031-223 and 031-230.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to their consistent and repeatable response during dry and wet weather and lack of data gaps.

It is recommended that the monitoring installation be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

3.10.5 Combined Sewer Overflows

ADS reported that three CSOs occurred in the Montlake Basin during the Phase 1 monitoring period; Table 3-12 lists the CSOs that occurred: two during the January 2009 storm event and one during the 5/19/2009 event.

Table 3-12. 2008–2009 Combined Sewer Overflows in Montlake Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
20	1/7/2009	2:30	58,507
139	--		--
140	1/7/2009	1:05	29,916
	5/5/2009	0:05	549
	5/19/2009	0:30	4,084

Figure 3-23 shows the maximum water level recorded at each of the overflow structures in the basin as a percentage of the weir height.

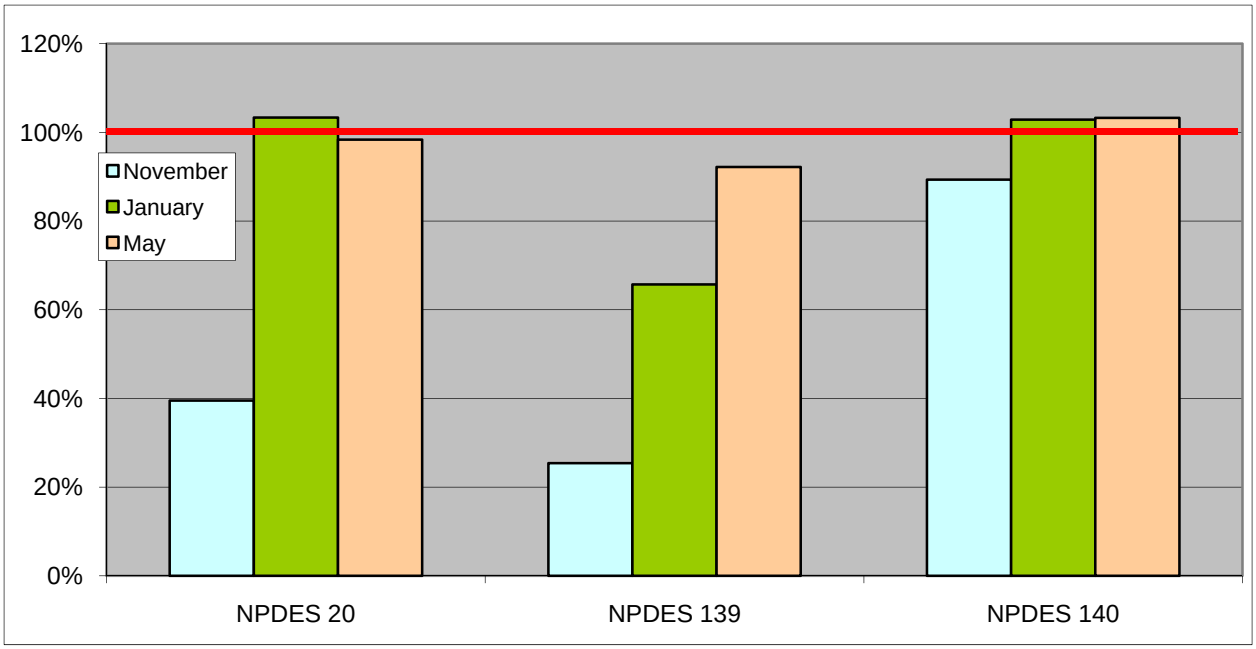

Figure 3-23. Maximum recorded levels compared with weir heights in Montlake Basin for major events

3.10.6 Facility Operations

Three overflow points are located within the Montlake Basin: NPDES020 overflows into Lake Washington and NPDES139 and NPDES140 discharge into the ship canal. One HydroBrake is in the NPDES140 Basin. The NPDES140 and NPDES020 Basins have offline storage. One pump station located centrally in Montlake Basin receives flow from the NPDES139 and NPDES140 Basins. PS 15 drains the offline storage in the NPDES140 Basin.

NPDES020 Basin Overflow Structure and Storage

The CSO facility in the NPDES020 Basin consists of overflow weirs at MHs 031-381 and 038-149, and parallel offline 72-inch detention pipes near the intersection of Shelby Street and 24th Avenue East. When the inflow to PS 13 exceeds the pumping capacity, the flows back up in the gravity main system. The overflow weir located at MH 031-381 diverts these excess flows into the offline detention pipes. The detention pipes continue to fill until the water level in the pipes exceeds the weir level at the second overflow location, MH 031-382, the location of the permanent meter. The weir height is 49 inches above the invert level of the maintenance hole. Flows overflow to Lake Washington via a 21-inch overflow line.

NPDES139 Basin Overflow Structure

The CSO facility in the NPDES139 Basin consists of an overflow weir at MH 031-313 located in the parking lot at the intersection of 16th Avenue E and E Calhoun Street. The overflow weir is a few pipe lengths upstream from PS 25. When the inflows to PS 25 exceed the pumping capacity, the flows back up in the gravity main system. MH 031-313 is approximately 163 inches deep; ADS reports that the meter reads 77.37 inches when the weir crest elevation is reached. The overflow line is a 24-inch-diameter pipe located on the dry side of the weir and the pipe, which then connects into a 42-inch storm drain. The NPDES139 Basin outfall overflows into Lake Washington.

NPDES140 Overflow Structure, Storage, and HydroBrake

The CSO facility in the NPDES140 Basin consists of two overflow weirs, a HydroBrake, an offline detention tank, and PS 15. The overflow weirs are located at MH 031-419, which is the overflow to the offline detention tank, and at MH 031-001, which is the overflow to Lake Washington.

The HydroBrake is located at MH 031-002 in an 8-inch-diameter pipe. The HydroBrake limits the flow entering the Montlake gravity basin from the NPDES140 Basin. When the water level increases on the upstream side of the HydroBrake and exceeds the level of the weir at MH 031-419, flows are diverted to the detention tank. The storage tank fills by gravity with flows pumped back to the system. Once the detention tank level exceeds the height at the overflow weir at MH 031-001, an overflow occurs and flows enter Lake Washington via a 15-inch-diameter overflow line. MH 031-001 is approximately 66 inches deep, and the weir wall height is 27 inches above the invert level of the maintenance hole.

The HydroBrake at MH 031-002 was characterized using depth data from the permanent meter at MON140_031001 and flow data from the temporary meter at MON140_031-002A. Figure 3-24 shows the head-discharge data pairs collected during the review period. The data exhibit two distinct regions that may be associated with clogging or vortex collapse. PS 25 influences the HydroBrake; levels at the pump station rise during wet weather, causing surcharge of the HydroBrake.

Storage Utilization

The estimated storage utilization in the Montlake Basin is shown in Figure 3-25. Storage utilization was estimated by using the maximum depth recorded at the permanent monitors and assuming that the same depth was reached in the storage facility. The water depth was compared to the invert level and crown level of the storage structure in order to estimate the percentage of the volume that was used.

An overflow was recorded at the NPDES020 Basin during the January 2009 event. However, Figure 3-25 indicates that the full capacity of the detention pipes was not utilized. There may be opportunities for retrofit in this basin. The detention tanks in the NPDES140 Basin were completely full when the CSOs occurred in that basin.

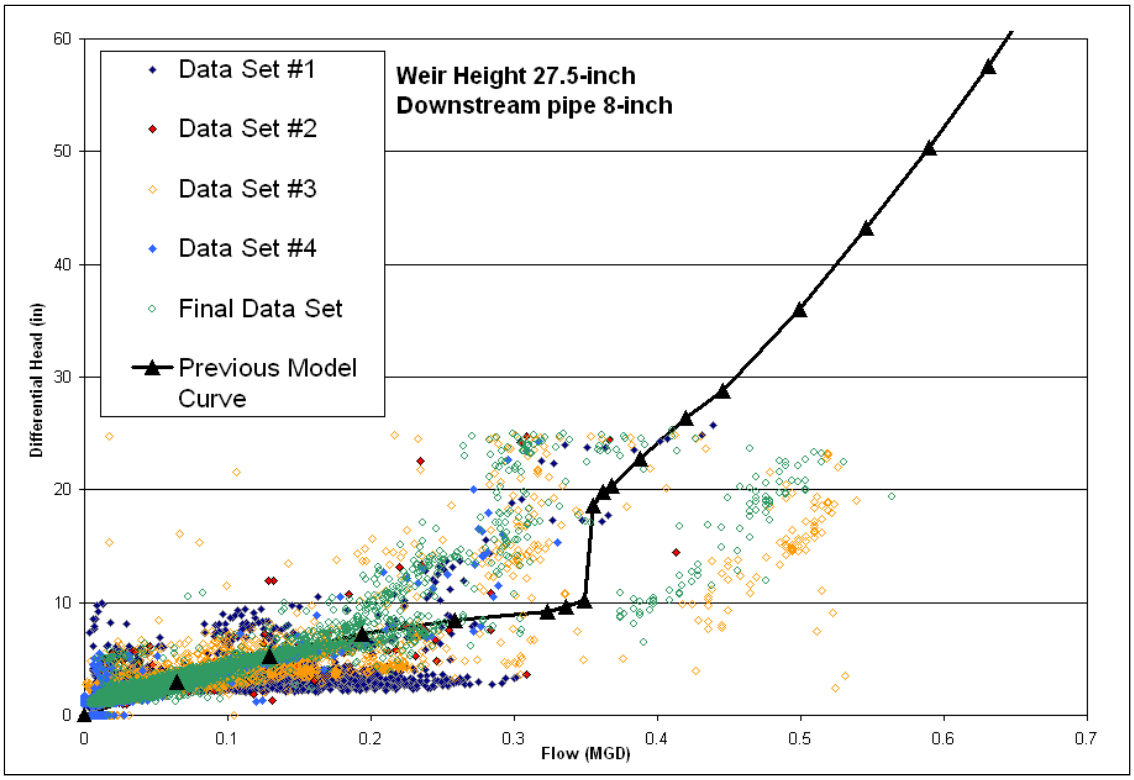

Figure 3-24. NPDES140 Basin HydroBrake curve

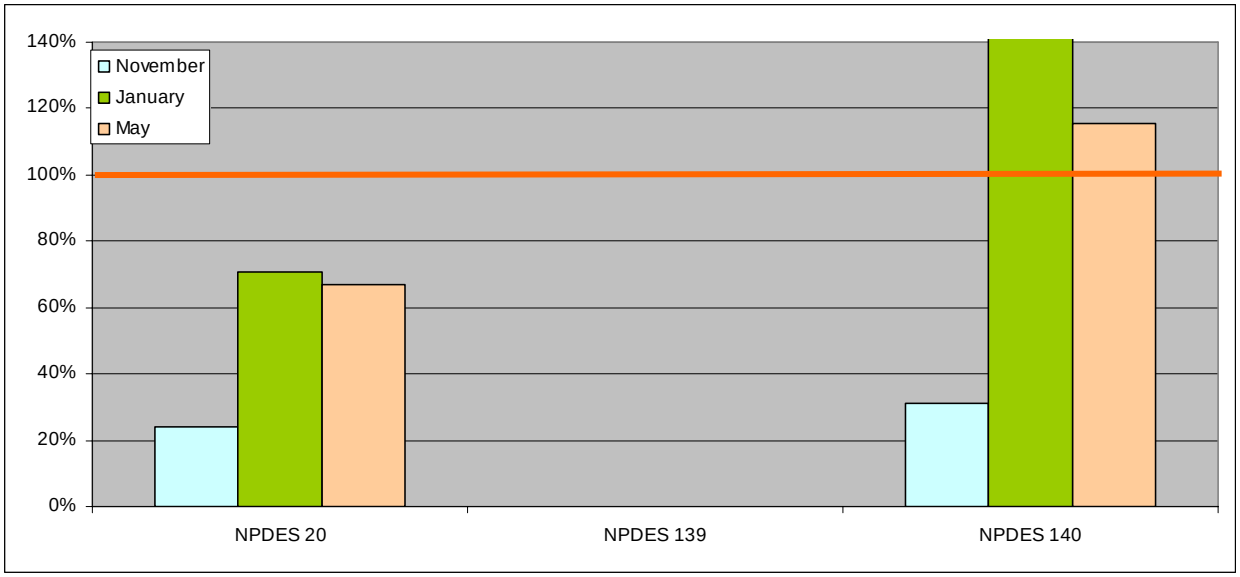

Figure 3-25. Storage utilization in Montlake Basin for major events

SCADA Data: Pump Station 13

SPU monitors PS 13 via its SCADA system. The SCADA system records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on-off levels, and in conjunction with drawdown test results to calculate the pump station flow rate.

Data quality was classified as "Good" for the Phase 1 monitoring period as operations were consistent throughout the monitoring period.

SCADA Data: Pump Station 15

SPU monitors PS 15 via its SCADA system. The SCADA system records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on-off levels, and in conjunction with drawdown test results to calculate the pump station flow rate.

Data quality was classified as "Good" for the Phase 1 monitoring period as operations were consistent throughout the monitoring period.

SCADA Data: Pump Station 25

SPU monitors PS 25 via its SCADA system. The SCADA system records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on-off levels, and in conjunction with drawdown test results to calculate the pump station flow rate.

Data quality was classified as "Good" for the Phase 1 monitoring period as operations were consistent throughout the monitoring period.

3.10.7 Recommendations for Additional Data Collection

No additional sites were identified for monitoring in Montlake during the 2009–2010 wet weather season. Meters currently installed will continue to collect data during the upcoming wet season.

3.11 North Union Bay Basin

The North Union Bay Basin, with an area of 988 acres, consists of the NPDES018 and NPDES019 Subcatchments. Flow originates in the northern part of the NPDES018(B) Subcatchment and flows southwest toward the King County system. A weir located between NPDES018(B) and NPDES018(A) Subcatchments directs high flows toward NPDES018(A) Subcatchment. The NPDES018(A) Subcatchment joins the King County system west of the Windermere Basin and continues to flow west, where it is joined with flows from the NPDES018(B) Subcatchment and pumped flows from the NPDES019 Basin. RG 04 monitors rainfall in the NPDES018(B) Subcatchment; RG 03 monitors rainfall in the NPDES018(A) Subcatchment and NPDES019 Basin. ADS monitors three overflow points within the basin. Three permanent stations and 25 temporary meters monitor combined sewage flow.

All related site information, photographs, and data representation are included in Appendix L. The basin schematic is located in Appendix B.

3.11.1 NPDES018(A) Subcatchment

NPDES018(A) Subcatchment is located in the southern part of the NPDES018 Subcatchment. A weir is located between NPDES018(A) and NPDES018(B) Subcatchments. Flow from the NPDES018(B) Subcatchment can overflow to NPDES018(A) Subcatchment at this point. The Subcatchments collectively cover an area of approximately 911 acres, of which NPDES018(B) Subcatchment covers about 769 acres. Six temporary meters and one permanent meter to verify overflows monitored NPDES018(A) Subcatchment. The NPDES018(A) Subcatchment contains CSO Facility 25, which consists of a HydroBrake and in-line storage tank. The permanent meter is designated as a wet weather site; thus, only the level data are finalized.

NUB18_024-059A

NUB18_024-059A is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the flow within the King County CSS line downstream from the Belvoir pump station and upstream from the connection from the NPDES018(A) Subcatchment. No alternative location was investigated at this location.

The meter is located in the same structure as meter NUB18_024-059B; it was placed in the pipe that enters the structure from the east. Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at low flows. All data are suitable for use in model calibration.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data within the King County trunk line.

NUB18_024-059B

NUB18_024-059B is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the hydraulics of the CSO Facility 25. No alternative location was investigated at this location.

The meter is located in the same structure as meter NUB18_024-059A; it was placed in the pipe that enters the structure from the northeast. The meter is directly downstream from the HydroBrake at the CSO Facility 25. The primary purpose for the meter is to characterize the HydroBrake at NUB18_024-072A. The data at the site captured a consistent dry weather diurnal pattern. During storm events, the meter is surcharged as the flow in the King County system rises above the invert of this pipe. Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at low flows. All data are suitable for use in model calibration.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydraulics of the CSO Facility 36.

NUB18_024-072A

NUB18_024-072A is a temporary monitoring installation that records level only. The site was installed to characterize both the HydroBrake hydraulics and storage utilization for CSO Facility 25. No alternative location was investigated at this location.

The meter is located upstream from the HydroBrake in the CSO Facility 25. The data at the site captured a consistent dry weather level pattern. During storm events, the level data were consistent and corresponded with the CSO weir overflowing. Level data within the storage tank did not indicate that the high-flow bypass weir was ever overtopped. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain level data to characterize the HydroBrake, and the CSO Facility 25 hydraulics.

NUB18_025-001A

NUB18_025-001A is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the hydraulics of the weir at NUB18_016-197A. The site was chosen after review of alternative locations at MH 025-002.

The meter is located downstream from the side weir at structure NUB18_016-197A that discharges flow from the NPDES018(B) Subcatchment to the NPDES018(A) Subcatchment. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during wet weather and lack of data gaps. Data indicated a side sewer connection upstream from the meter and downstream from the weir at 016-197. However, the velocities during non-peak usage were too low to be recorded, which resulted in significant dropouts. All wet weather data are suitable for use in model calibration.

The meter was removed at the end of the Phase 1 monitoring period as it was determined that sufficient suitable data had been collected for the purposes of model calibration. It has been recommended that SPU block the weir at structure 016-197.

NUB18_025-018A

NUB18_025-018A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northwestern part of the NPDES018(A) Subcatchment. The site was chosen after review of alternative locations at MH 025-019.

The meter is located upstream from CSO Facility 25. Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at high flows. All data are suitable for use in model calibration.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the Subcatchment.

NUB18_025-025A

NUB18_025-025A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northeastern part of the NPDES018(A)

Subcatchment. The site was chosen after review of alternative locations at MH 025-024A (labeled in the inspected sites as NUB18_025-384A in ZFM2).

The meter is located upstream from CSO Facility 25. Data quality was classified as "Good" for the Phase 1 monitoring period because several hydraulic jumps occurred at the meter as the flow depth increased. All data are suitable for use in model calibration.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the Subcatchment. The meter was unaffected by flows entering the system at 025-001.

NPDES018A_MH025380

NPDES018A_MH025380 is a permanent monitoring installation that records both level and velocity. The site is classified as a wet weather site because it is expected to provide good quality level data only; thus, only level data are finalized for the meter. The site was installed to determine if CSO events were occurring from the NPDES018(A) Subcatchment.

The meter is located at the upstream end of the storage tank within CSO Facility 25. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

This monitoring installation is a permanent installation; it should continue to be screened for the Phases 2–3 monitoring period.

KC_025-050A

KC_025-050A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows going to the Belvoir pump station. The site was chosen after review of alternative locations at MH 025-060.

The meter is located upstream from the King County Belvoir pump station. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydraulics of the Belvoir pump station.

3.11.2 NPDES018(B) Subcatchment

NPDES018(B) Subcatchment is located in the northern part of the NPDES018 Subcatchment. Nineteen temporary meters and one permanent meter to verify overflows monitored the Subcatchment. Six meters were removed during the Phase 1 monitoring period. The permanent meter is designated as a wet weather site; thus, only the level data are finalized. The Subcatchment contains CSO Facility 24 that which consists of a HydroBrake an in-line storage tank.

NUB18_007-061A

NUB18_007-061A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northwestern part of the NPDES018(B) Subcatchment. No alternative location was investigated at this location.

The meter is the farthest north in the basin. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

The meter was removed at the end of the Phase 1 monitoring period as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_007-094A

NUB18_007-094A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northeastern part of the NPDES018(B) Subcatchment. The site was chosen after review of alternative locations at MHs 007-093 and 007-095.

The meter is upstream from meter NUB18_007-436A. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The total flow from two upstream temporary monitoring locations (NUB18_007-094A and NUB18_007-183A) was compared to the downstream flow at NUB18_007-436A. The flow balance determined that the calculated flows from this temporary monitoring location were within the correct range.

The meter was removed at the end of the Phase 1 monitoring period as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_007-183A

NUB18_007-183A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northeastern part of the NPDES018(B) Subcatchment. No alternative location was investigated at this location.

The meter is upstream from meter NUB18_007-436A. The meter was replaced on 1/8/2009 due to a meter malfunction. After the meter was installed, two different site signatures were captured at the site due to system hydraulics. The Monitor-Level Intelligence (MLI) was turned off at the meter on 2/25/2009. With MLI turned on, the meter "learns" the hydraulic profile of its environment; then the meter will continuously reference this "learned" profile to detect flow changes immediately. By turning off the MLI feature, the meter collects raw data and does not try to auto-correlate the data to the learned profile. The data collected after the MLI was turned off was improved for storm events; however, a wide scatter was still seen at low flows. Data quality was classified as "Good" for the Phase 1 monitoring period because the dry weather data had a variable diurnal pattern (inconsistent signature). All wet weather data are suitable for use in model calibration.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The total flow from two upstream temporary monitoring locations (NUB18_007-094A and NUB18_007-183A) was compared to the downstream flow at NUB18_007-436A. The flow balance determined that the calculated flows from this temporary monitoring location were within the correct range.

The meter was removed at the end of the Phase 1 monitoring period as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_007-436A

NUB18_007-436A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northeastern part of the NPDES018(B) Subcatchment. The site was chosen after review of alternative locations at MHs 007-051 and 007-093.

The meter is downstream from meter NUB18_007-094A and NUB18_007-183A. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The total flow from two upstream temporary monitoring locations (NUB18_007-094A and NUB18_007-183A) was compared to the downstream flow at NUB18_007-436A. The flow balance determined that the calculated flows from this temporary monitoring location were within the correct range.

The meter was removed at the end of the Phase 1 monitoring period as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_007-438A

NUB18_007-438A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for part of the northwestern part of the NPDES018(B) Subcatchment. The site was chosen after review of alternative locations at MHs 007-073, 007-066, 007-085, and 016-051.

Quality of the level data collected at the location was classified as "Good" (that is, no data gaps, and ultrasonic vs. pressure measurement of depths align well). However, the relationship between level and velocity data was not clear or consistent due to the unusual hydraulics at the monitoring location. Consequently, the quality of the flow data calculated using the level and velocity measurements collected during the Phase 1 monitoring period was classified as "Poor."

The site was not conducive to collecting data suitable for model calibration due to the site hydraulics and was removed on 2/6/2009. It was determined that downstream meter NUB18_016-510A could be used to determine the hydrology for the Subcatchment; no additional meter was installed.

NUB18_016-021A

NUB18_016-021A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the western part of the NPDES018(B) Subcatchment. The site was chosen after review of alternative locations at MH 016-031.

The meter is located upstream from site NUB18_016-076A; it is also located in the same structure as NUB18_016-021B. The meter was placed in the pipe that enters the structure from the west. Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at low flows. All data are suitable for use in model calibration.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The total flow from two upstream temporary monitoring locations (NUB18_016-021A and NUB18_016-021B) was compared to the downstream flow at NUB18_016-076A. The flow balance determined that the calculated flows from this temporary monitoring location were within the correct range.

Based on the flow balance results, the meter was removed on 4/1/2009 because sufficient data had been collected to characterize this part of the basin. The data at meter NUB18_016-076A will be used for model calibration to subsequent events.

NUB18_016-021B

NUB18_016-021B is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the western part of the NPDES018(B) Subcatchment. The site was chosen after review of alternative location at MH 016-031.

The meter is located upstream from site NUB18_016-076A; it is also located in the same structure as NUB18_016-021A. The meter was placed in the pipe that enters the structure from the northwest. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period because low flow data exhibit significant ramping over the meter resulting in wide scatter of velocity with depth. All wet weather data are suitable for use in model calibration.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The total flow from two upstream temporary monitoring locations (NUB18_016-021A and NU018_016-021B) was compared to the downstream flow at NUB18_016-076A. The flow balance determined that the calculated flows from this temporary monitoring location were within the correct range.

Based on the flow balance results, the meter was removed on 4/1/2009 because sufficient data had been collected to characterize this part of the basin. The data at meter NUB18_016-076A will be used for model calibration to subsequent events.

NUB18_016-076A

NUB18_016-076A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northeastern part of the NPDES018(B) Subcatchment. The site was chosen after review of alternative locations at MHs 016-021 and 016-031.

The meter is downstream from NUB18_016-021A and NUB18_016-021B. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The total flow from two upstream temporary monitoring locations (NUB018_007-021A and NUB18_016-021B) was compared to the downstream flow at NUB18_016-076A. The flow balance determined that the calculated flows from this temporary monitoring location were within the correct range.

The meter replaced the meters at structure MH 016-021 based on the flow balance results. The meter was removed at the end of the Phase 1 monitoring period as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_016-078A

NUB18_016-078A is a temporary monitoring installation that records both level and velocity. The primary purpose of the site was to measure depth of flow at the weir within the structure. A secondary purpose of the site was to measure flows that entered the system upstream and to characterize hydrology. No alternative location was investigated at this location.

The meter is upstream from CSO Facility 24. The meter was a reverse install with the velocity probe pointing downstream. The probe was also placed on the same band as meter NUB18_016-078B to ensure that the velocity gradient within the deep flow was captured correctly. The level and velocity data at the site correlated well with meter NUB18_016-078B; however, the velocity probe was a reverse install. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period due to the velocity probe being a reverse install. All data are suitable for use in model calibration.

After reviewing the data, it was determined that the meter at structure 016-510 was capturing the same flow data as the monitor; thus, it was decided that the meter needed only a level-only meter to measure flow depths at the weir structure. On 1/7/2008, the meter was removed and replaced with a level-only meter at NUB18_016-078C.

NUB18_016-078B

NU018_016-078B is a temporary monitoring installation that records both level and velocity. The primary purpose of the site was to measure depth of flow at the weir within the structure. A secondary purpose of the site was to measure flows that entered the system upstream and to characterize hydrology. No alternative location was investigated at this location.

The meter was upstream from CSO Facility 24 with a reverse install, with the velocity probe pointing downstream. The probe was also placed on the same band as meter NUB018_016-078A to ensure that the velocity gradient within the deep flow was captured correctly. The level and velocity data at the site correlated well with meter NUB18_016-078A; however, the velocity probe was a reverse install. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period due to the velocity probe being a reverse install. All data are suitable for use in model calibration.

After reviewing the data, it was determined that the meter at structure 016-510 was capturing the same flow data as the monitor; thus, it was decided that the meter needed only a level-only meter to measure flow depths at the weir structure. On 1/7/2008, the meter was removed and replaced with a level-only meter at NUB18_016-078C.

NUB18_016-078C

NUB18_016-078C is a temporary monitoring installation that records level only. The site was installed to measure level at the high-flow bypass weir. No alternative location was investigated at this location.

The monitor is on the downstream end of the weir structure. Flows that overtop the weir flow into the northern end of CSO Facility 25. The meter is set to read zero when the water overtops the weir; however, during storm events the level reaches zero and then drops to (-) 30 inches. The level will remain at this depth until it suddenly returns to zero and then to a normal depth of (-) 17 inches. The meter captures the time frame when the weir is overtopped; however, the actual flow over the weir cannot be calculated due to the length of the weir and the data collection process. The level data at the site correlated well with the weir being overtopped; however, the total depths of high flows were not collected. Consequently, the quality of the data was classified as "Some Limitations" for the Phase 1 monitoring period.

A meter was installed at the downstream structure NUB18_016-508B to measure flow that overtops this weir. The data collected by the NUB18_016-078C monitor will be used to confirm when flow overtops the weir, and the downstream meter will be used to measure the actual flow that overtops the weir.

The monitor was removed at the end of the Phase 1 monitoring period as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_016-083A

NUB18_016-083A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the remaining eastern part of the NPDES018(B) Subcatchment. The site was chosen after review of alternative locations at MH 016-082.

The meter is upstream from structure NUB18_016-078A. Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at low flows. All data are suitable for use in model calibration.

The meter was removed at the end of the Phase 1 monitoring period as it was determined that sufficient suitable data had been collected for the purposes of model calibration.

NUB18_016-197A

NUB18_016-197A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows leaving NPDES018(B) Subcatchment. No alternative location was investigated at this location.

The meter is downstream from meter NUB18_016-518A. An overflow weir is located in the structure just downstream from the meter. The weir diverts high flows into NPDES018(A) Subcatchment; the weir is the only hydraulic connection between NPDES018(B) and NPDES018(A) Subcatchments. The flow data indicate that high flows surcharge the weir, causing a siphon effect until depth of flow drops below the top of the weir. Data quality was classified as "Good" for the Phase 1 monitoring because of the siphon effect on depth at the meter. All data are suitable for use in model calibration.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydraulics of CSO Facility 24. It has been recommended that SPU consider blocking the weir at this structure.

NUB18_016-505A

NUB18_016-505A is a temporary monitoring installation that records level only. The site was installed to characterize the HydroBrake and storage utilization at CSO Facility 24. No alternative location was investigated at this location.

The monitor is located on the bench at 17.5 inches at the HydroBrake in CSO Facility 24. The data at the site captured a consistent dry weather level pattern. During storm events, the level data were consistent and corresponded with the levels seen at the north end of the storage tank. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain level data to characterize the HydroBrake and the CSO Facility 24 hydraulics.

NUB18_016-508A

NUB18_016-508A is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the hydraulics of the overflow pipe at structure NU018_016-510A. No alternative location was investigated at this location.

The meter was installed on 2/25/2009; it is located in the discharge pipe for the overflow pipe at structure 016-510A. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during wet weather and lack of data gaps. There is no flow within this pipe under low flow conditions.

The meter will replace the meters at structure NUB18_016-078C for the Phases 2–3 monitoring period.

NUB18_016-508B

NUB18_016-508B is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the hydraulics of the weir at structure 016-078 and to characterize storage utilization of the storage tanks at CSO Facility 24 in conjunction with the meter at NUB18_016-505A. The site was chosen after review of alternative locations at 016-525.

The meter was installed on 2/25/2009; it is located downstream from meter NUB18_016-078C. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable

response of the data during wet weather and lack of data gaps. There is no flow within this pipe under low-flow conditions.

The meter will replace the meters at structure NUB18_016-078C for the Phases 2–3 monitoring period.

NUB18_016-510A

NUB18_016-510A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northern part of the NPDES018(B) Subcatchment. The site was chosen after review of alternative locations at MH 016-511.

The meter is downstream from structure NUB18_016-078C; it is located in the main sewer pipe that directs dry weather flow around the storage tank to the HydroBrake on the south end of the CSO Facility 24. An overflow pipe is located on the shelf of the structure downstream from the monitor. The overflow pipe diverts flows to the north end of the storage tank when the HydroBrake starts to back up flows in the system. Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydraulics of CSO Facility 24.

NUB18_016-518A

NUB18_016-518A is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the HydroBrake at the CSO Facility 24. No alternative location was investigated at this location.

The monitor is located on the downstream side from the HydroBrake at CSO Facility 24. During storm events, the meter shows consistent flow patterns resulting from its location downstream from the HydroBrake. Data quality was classified as "Good" for the Phase 1 monitoring period because dry weather data have a variable diurnal pattern as downstream sediment is washed out during storm events. All data are suitable for use in characterizing the HydroBrake.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydraulics of the CSO Facility 36.

NUB18_016-525A

NUB18_016-525A is a temporary monitoring installation that records level only. The storage conduits at CSO Facility 24 are very long (>1,000 linear feet); thus, this monitor was used in conjunction with the monitor at NUB18_016-505A to characterize storage utilization within the storage conduits. The site was chosen after review of alternative locations at MH 016-508.

The monitor is located within the storage tanks at CSO Facility 24; thus, no dry weather levels were recorded. The data collected at the site captured a consistent wet weather level pattern. During storm events, the level data were consistent and corresponded with overflows that occurred at NUB18_016-078C. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during wet weather and lack of data gaps.

The monitor was removed on 2/4/2009 and replaced with meter NUB18_016-508A/B to obtain better flow data related to the upstream weirs. The new NUB18_016-508B meter will be used in conjunction with the meter at NUB18_016-505A to characterize storage utilization within the storage tanks.

NPDES018B_MH016509

NPDES018A_MH016509 is a permanent monitoring installation that records both level and velocity. The site is classified as a wet weather site because it is expected to provide good quality level data only; thus, only level data are finalized for the meter. The site was installed to determine if CSO events were occurring from the NPDES018(A) Subcatchment. No overflows were recorded during the Phase 1 monitoring period.

The meter is located at the upstream side from the storage tank within CSO Facility 24. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

This monitoring installation is a permanent installation; it should continue to be screened for the Phases 2–3 monitoring period.

3.11.3 NPDES019 Basin

NPDES019 Basin is located outside of the North Union Bay modeling basin. NPDES019 Basin flow data are included in the monitoring program to determine the hydraulic boundary condition for long-term simulation modeling. One permanent meter to verify overflows monitored the approximately 74-acre basin. The permanent meter is designated as a wet weather site; thus, only the level data are finalized. No CSS control facilities are located within this basin; however, PS 35 drains the basin.

NPDES019_MH015237

NPDES019_MH015237 is a permanent monitoring installation that records both level and velocity. The site is classified as a wet weather site because it is expected to provide good quality level data only; thus, only level data are finalized for the meter. The site was installed to determine if CSO events were occurring from PS 35.

The meter is located downstream from PS 35. The level data are used to alarm for CSO events and to calculate the volume of CSOs. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

This monitoring installation is a permanent installation; it should continue to be screened for the Phases 2–3 monitoring period.

3.11.4 Combined Sewer Overflows

ADS reported that three CSOs occurred in the North Union Bay Basin during the Phase 1 monitoring period; Table 3-13 lists the CSOs that occurred during the Phase 1 monitoring period.

Table 3-13. 2008–2009 Combined Sewer Overflows in North Union Bay Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
18A	11/8/2008	4:45	142,212
	5/5/2009	1:30	34,726
	5/19/2009	1:30	57,132

Table 3-13. 2008–2009 Combined Sewer Overflows in North Union Bay Basin 10/1/2008–5/31/2009			
NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
18B	--		--
19	--		--

Figure 3-26 shows the maximum water level recorded at each of the overflow structures in the basin as a percentage of the weir height.

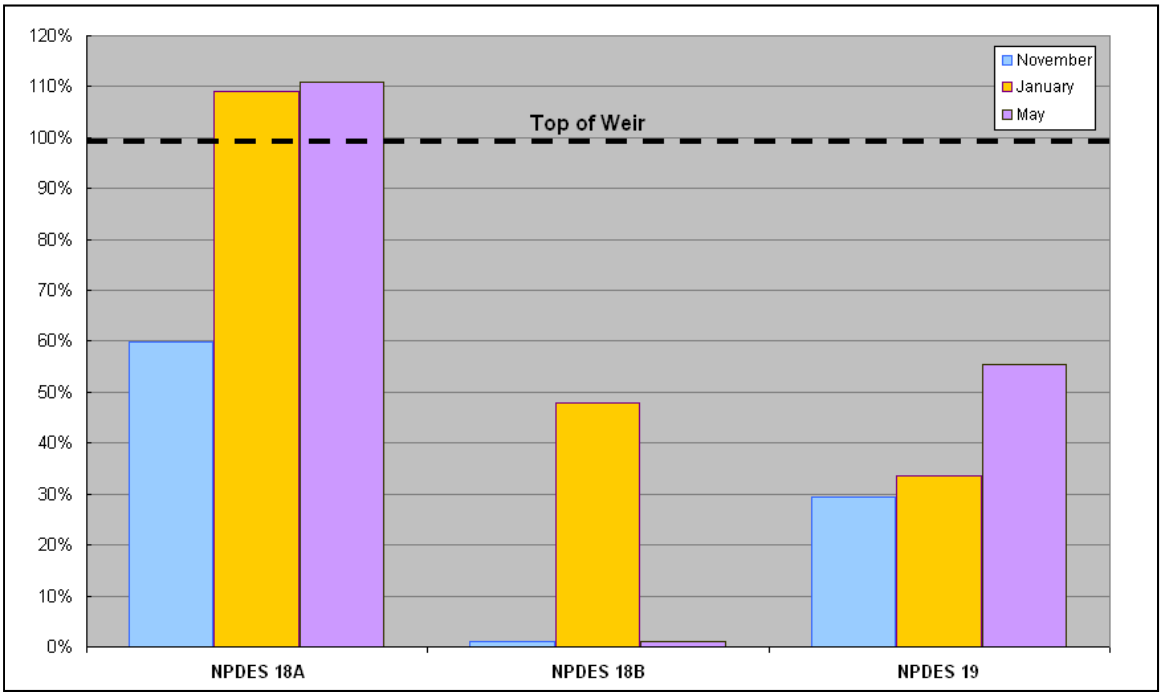

Figure 3-26. Storage utilization in North Union Bay for major events

3.11.5 Facility Operations

CSO facilities 24 and 25 are located within the North Union Bay Basin. Control Facility 24 is located in the NPDES018(B) Subcatchment and consists of a HydroBrake and two offline storage tanks. Control Facility 25 is located in the NPDES018(A) Subcatchment and consists of a HydroBrake and a single in-line storage tank. The CSO facility in the NPDES019 Basin consists of an overflow weir at the overflow structure.

NPDES018(A) Subcatchment

CSO Facility 25 is located within the NPDES018(A) Subcatchment. The facility consists of a HydroBrake located at MH 024-072 at the intersection of NE 41st Street and University Bay Circle N. Figure 3-27 shows the monitor data for the HydroBrake. The structure has an emergency bypass weir located at the HydroBrake. Survey information will be collected to determine if the elevation of the weir is higher or lower than the NPDES018(A) Subcatchment overflow weir.

The storage tanks in the control facility consist of one 72-inch-diameter storage tank with a cunette at the bottom. The meter at MH 024-072 is also used to develop storage utilization for the storage tank. Figure 3-28

provides the storage utilization for the storage tanks during the Phase 1 of the monitoring period. In this storm, the tanks were only 72 percent utilized. The overflow weir for the structure is at the upstream side of the storage tank. The weir is set at an elevation that only allows the tank to be filled to 60 percent prior to overflowing into Lake Washington.

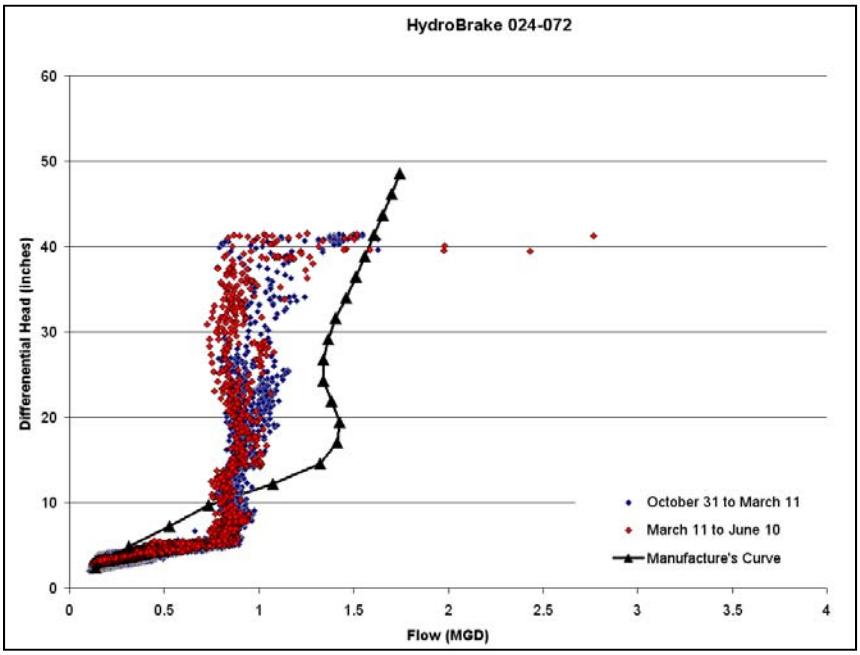

Figure 3-27. NPDES018(A) HydroBrake characterization

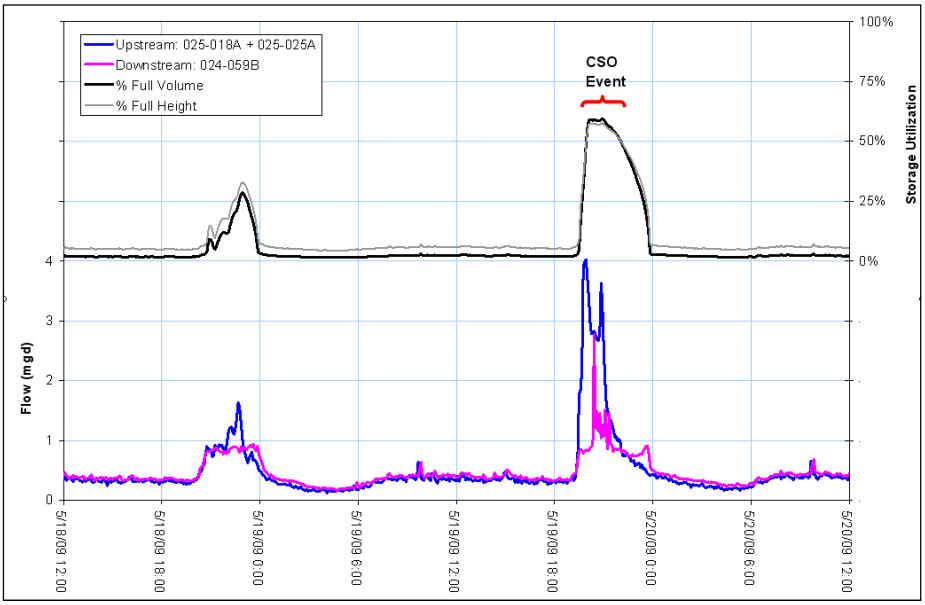

Figure 3-28. Storage utilization NPDES018(A)

NPDES018(B) Subcatchment

The NPDES overflow for NPDES018(B) Subcatchment is located on the north end of the storage tanks at MH 025-380. Once the flow depth reaches the weir elevation, flow is diverted to the 54-inch discharge pipe into the storm drain system, which discharges to Lake Washington.

CSO Facility 24 is located within the NPDES018(B) Subcatchment. The facility consists of a HydroBrake located at MH 016-505 at street address 4875 39th Avenue NE. Figure 3-29 shows the monitor data for the HydroBrake. The structure has an emergency bypass weir located at the HydroBrake; the data indicate that this weir was not overtopped during the review period.

The storage tanks in the control facility consist of two square 10-foot by 10-foot pipes. The meter at MH 016-505 is also used to develop storage utilization for the storage tank. Figure 3-30 provides the storage utilization for the storage tanks. In this storm, the tanks were only 60 percent utilized. If the storage tank fills up, flow overtops the emergency bypass weir at the HydroBrake and continues downstream to MH 016-518.

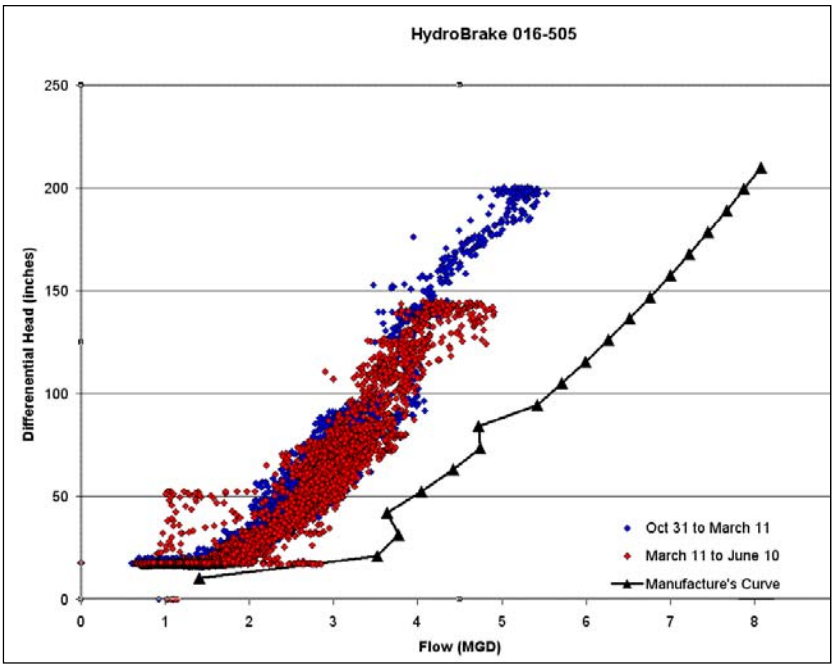

Figure 3-29. NPDES018(B) Subcatchment HydroBrake characterization

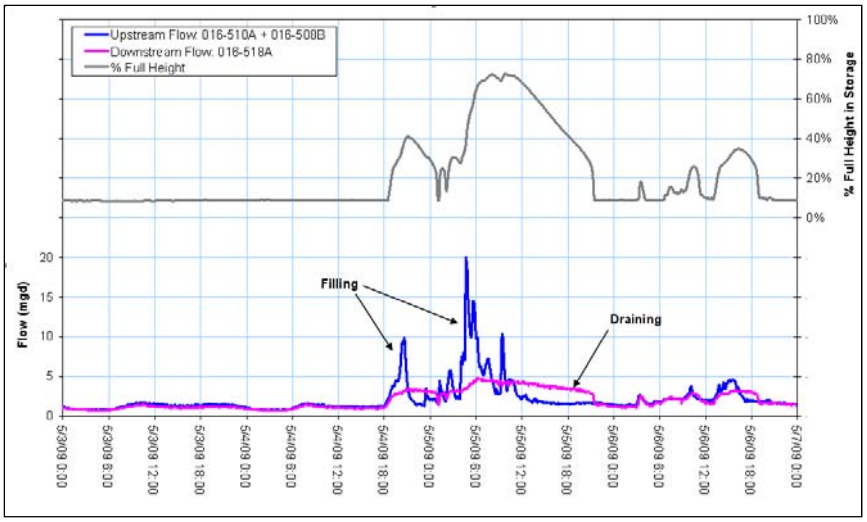

Figure 3-30. Storage utilization NPDES018(B)

Under normal flow conditions, the storage tank fills up from the HydroBrake (south end of storage tank) back into the storage tank. In high-flow conditions, the storage tank starts filling from the north as weirs at MHs 016-078 and 016-510 are overtopped and direct flow toward the storage tank. The NPDES overflow for NPDES018(B) Subcatchment is located on the north end of the storage tanks at MH 016-509. The weir in this structure is 34.5 inches long and at a height of 44.89 inches above pipe invert. Once the flow depth reaches this elevation, flow is diverted to the 54-inch discharge pipe into the storm drain system, which discharges to Lake Washington.

Pump Stations 35, 48, and 55

SPU monitors PSs 35, 48, and 55 via its SCADA system. The SCADA system records wet well level and pump run times. Data are available at 90- to 120-second resolution. Currently, it is not planned to include the pump stations in the North Union Bay model.

Data collected during Phase 1 monitoring included the pump on-off states and the wet well depth. These data were plotted versus time and rainfall for review. Review consisted of observing the normal rise and fall of wet well elevation with time during wet and dry weather. In general, no anomalies in operation were noted that could not be explained by response to rainfall.

3.11.6 Recommendations for Additional Data Collection

All sites that were not removed during the Phase 1 monitoring period should remain in place throughout the 2009–2010 wet season monitoring period. No additional sites within the North Union Bay Basin have been identified for the 2009–2010 wet weather season.

3.12 Portage Bay/Lake Union Basin

The Portage Bay/Lake Union Basin, approximately 233 acres in area, consists of six NPDES basins: NPDES127, NPDES130, NPDES132, NPDES135, NPDES138, and NPDES175. Flow originates in the NPDES138 Basin and is pumped north toward the NPDES135 Basin via the Shelby Street pump station (PS 20). At the NPDES135 Overflow Structure, dry weather flow changes direction and flows south. As the flow heads south, the NPDES132, NPDES130, NPDES175, and NPDES127 Basins all contribute flow to the trunk line heading toward the King County system. Under normal flow conditions, the flow collected within the basin discharges into the system that runs west along Mercer Street and flows into the Elliott West CSO tunnel. Under high-flow conditions, CSOs flow through CSO outfalls into Portage Bay and Lake Union via the six overflow structures located in the Portage Bay/Lake Union Basin.

RG 03 monitors rainfall in the NPDES138, NPDES135, NPDES132, and NPDES130 Basins, and RG 20 monitors rainfall for NPDES175 and NPDES127 Basins. ADS monitors six overflow points within the Portage Bay/Lake Union Basin.

Six permanent meters and 23 temporary meters monitor combined sewage flow. All related site information, photographs, and data representation are included in Appendix M; a basin schematic is contained within Appendix B.

3.12.1 NPDES127 Basin

NPDES127 Basin is located downstream from the NPDES175 Basin. The basin is approximately 13 acres in area. One permanent meter to verify overflows monitors the basin. The permanent meter is designated as a wet weather site; thus, only the level data are finalized. No CSS control facilities are located within this basin.

NPDES127_MH036146A

NPDES127_036146A is a permanent monitoring installation that records both level and velocity. The site is classified as a wet weather site because it is expected to provide good quality level data only; thus, only level data are finalized for the meter. The site was installed to determine when CSO events were occurring and to quantify the overflow volumes from the NPDES127 Basin.

The site is located downstream from the NPDES175 Basin, but it is not located within the main combined sewer trunk line for the basin. The level data are used to alarm for CSO events and to calculate the volume of CSOs. Quality of the level data was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data.

This monitoring installation is a permanent installation; it should continue to be screened for the Phases 2–3 monitoring period.

3.12.2 NPDES130 Basin

NPDES130 Basin is located downstream from the NPDES132 Basin. The basin is approximately 9 acres in area, and one temporary meter and one permanent meter to verify overflows monitors it. The permanent meter is designated as a dry weather site; thus, level and velocity data are finalized. No CSS control facilities are located within this basin.

PB130_030-133A

PB130_030-133A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the eastern part of the NPDES132 Basin. The site was chosen after review of an alternative location at MH 030-134.

The meter is located downstream from site PB130_DWF-030410 on a side line that enters the main basin sewer. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

PB130_DWF-030410

PB130_DWF-030410 is a permanent monitoring installation that records both level and velocity. The site is classified as a dry weather site because it is expected to provide good quality velocity and level data; thus, both level and velocity data are finalized for the meter. The site was installed to determine if CSO events are occurring from the NPDES130 Basin and to quantify them.

The meter is located in the main combined sewer pipe downstream from structure 030-416. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation.

Flow balancing was undertaken as described in the section for monitoring location PB132_DWF-030416. Another flow balance was performed using the total flow from two upstream monitoring locations (PB130_DWF-030410 and PB130_030-133A) compared to the downstream flow at PB175_DWF-030348. The flow balance determined that the calculated flows from the three meters were within the correct range.

Data quality was classified as "Good" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

This monitoring installation is a permanent installation; it should continue to be screened for the Phases 2–3 monitoring period.

3.12.3 NPDES132 Basin

NPDES132 Basin is located downstream from the NPDES135 Basin. PS 66 pumps combined flows from the NPDES134 Basin into the main combined sewer line that passes through NPDES132 Basin. Four temporary meters and one permanent meter to verify overflows monitor the basin, which is approximately 114 acres in area. The permanent meter is designated as a dry weather site; thus, both level and velocity data are finalized. No CSS control facilities are located within this basin.

PB132_030-178A

PB132_030-178A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the southeastern part of the NPDES132 Basin. The site was chosen after review of alternative locations at MHs 030-171 and 030-168.

Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at low flows. All data are suitable for use in model calibration.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

PB132_030-179A

PB132_030-179A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the remainder of the southeastern part of the NPDES132 Basin. The site was chosen after review of alternative locations at MH 030-172.

The meter is located upstream from PB132_DWF-030416. Depth of flow level drops during storm events occurred at the meter due perhaps to water splashing on the ultrasonic sensor. Corresponding velocity increases occurred, suggesting that this is a hydraulic phenomenon peculiar to the site. Scatter plots are consistent and repeatable at higher flows. Data quality was classified as "Good" for the Phase 1 monitoring period due to the level drops in storm events. The calculated daily minimum dry weather flow is considered to be high due to pooling in front of the sensors. Wet weather flow and dry weather diurnal peak flows are suitable for model calibration.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

PB132_030-194A

PB132_030-194A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northeastern part of the NPDES132 Basin. The site was chosen after review of alternative locations at MHs 030-191 and 030-195.

The meter is located upstream from the meter at PB132_030-426A. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

PB132_030-426A

PB132_030-426A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northern part of the NPDES132 Basin. The site was chosen after review of an alternative location at MH 030-009.

The meter is located in the main drainage line that originates at the NPDES138 Basin. The data correlate well with the upstream PSs 20 and 66. On 12/18/2008, a new pressure probe was installed due to a sensor failure; no significant storm data were lost. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps during significant events.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

PB132_DWF-030416

PB132_DWF-030416 is a permanent monitoring installation that records both level and velocity. The site is classified as a dry weather site because it was expected to provide good quality velocity and level data; thus, both level and velocity data are finalized for the meter. The site was installed to determine if CSO events were occurring from the NPDES132 Basin and to quantify them.

The meter is located at the CSO 132 overflow weir structure. The CSO facility consists of an overflow pipe located on the maintenance hole bench. The site is located within the main combined sewer line downstream

from the NPDES135 Basin CSO facility. Upstream PSs 20 and 64 influence the site. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation.

Flow balancing was undertaken using the data from this permanent monitoring installation during Phase 1 monitoring. The following flow balancing occurred at this location:

- The total flow from three upstream temporary monitoring locations (PB132_030-426A, PB132_030-178A, and PB132_030-179A) was compared to the downstream flow at PB132_DWF-030416. The flow balance indicated that the calculated flows from this permanent monitoring location were underestimated.
- The total flow from this meter was compared to the downstream flow at PB130_DWF-030410. The flow balance also indicated that the calculated flows from this permanent monitoring location were underestimated.
- Another flow balance was performed using the same total flow from three upstream temporary monitoring locations (PB132_030-426A, PB132_030-178A, and PB132_030-179A). However, this time the flows were compared to the downstream flow at PB130_DWF-030410. This flow balance determined that the calculated flows from the PB130_DWF-030410 monitoring location were within the correct range.

Based on the flow balances, it was determined that the meter at this location (PB132_DWF-030416) should be used for level only, and that the meter at 030-410 would be used to calculate the flow and characterize hydrology for both NPDES130 and NPDES132 Basins.

Data quality was classified as "Some Limitations" for the Phase 1 monitoring period. Because the level data have consistent and repeatable response and lack data gaps, the data are suitable for use in model calibration. The velocity data are underestimating flows based on the flow balances and are not suitable for use in model calibration.

This monitoring installation is a permanent installation; it should continue to be screened for the Phases 2–3 monitoring period. The installation should be removed from the dry weather list so that velocity is no longer finalized.

3.12.4 NPDES135 Basin

NPDES135 Basin is the farthest basin to the north in the Portage Bay/Lake Union Basin and separates Portage Bay and Lake Union. Flows from the NPDES138 Basin are pumped northwest toward NPDES Basin. As the flows pass through the basin, they are redirected south toward the King County system at Mercer Street. One temporary meter and one permanent meter to verify overflows monitor the basin, which is approximately 17 acres in area. The permanent meter is designated a wet weather site; thus, only the level data are finalized. No CSS control facilities are located within the basin.

PB135_023-239A

PB135_023-239A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows to characterize the hydraulics of PS 20 and the area between NPDES138 and NPDES135 Basins. No alternative location was investigated at this location.

The meter is located within the NPDES135 Basin downstream from PS 20. The data at the site correlate with the flow pulses from the upstream pump station. The meter captured a consistent dry weather diurnal pattern even though influenced by the upstream pump station. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydraulics of PS 20 and to further characterize the basin area between the pump station and the overflow.

NPDES135_MH023208

NPDES135_MH023208 is a permanent monitoring installation that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide good quality velocity data; thus, only level data are finalized for the meter. The site was installed to determine if CSO events were occurring from the NPDES135 Basin and to quantify them.

The meter is located at the NPDES135 Basin overflow weir structure downstream from the PS 20 force main. Upstream pump operations directly influence the meter. Flow enters the site from the southeast through an 18-inch-diameter pipe. The flow leaves the structure to the southwest. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Data quality was classified as "Excellent" for the Phase 1 monitoring period. The level data have a consistent and repeatable response and lack of data gaps; the data are suitable for use in model calibration.

The monitoring installation is a permanent installation; it should continue to be screened for the Phases 2–3 monitoring period.

3.12.5 NPDES138 Basin

NPDES138 Basin, with an area of approximately 45 acres, is located in the northeastern part of the Portage Bay/Lake Union Basin and on the western shore of Portage Bay. Six temporary meters and one permanent meter to verify overflows monitor the basin. The permanent meter collects adequate level data during wet weather and dry weather; thus, the level data collected is finalized. In the basin, CSO Facility 36, consisting of a HydroBrake and two offline storage tanks, controls CSOs.

PB138_023-188B

PB138_023-188B is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and to characterize the hydrology for the western part of the NPDES138 Basin. The site was chosen after review of alternative locations at MH 023-418.

The meter is located in the same structure as meter PB138_023-188C; it was placed in the pipe that enters the structure from the west. The structure is upstream from the CSO Facility 36. Depths greater than the ultrasonic depth range will be based on the depth reported at meter PB138_023-188C located in the adjacent pipe. The level data from meter PB138_023-188C will be adjusted by adding 4.75 inches to account for the different pipe inverts. During storm events, the meter became surcharged, and the velocity dropped to near zero as the flow backed up at the HydroBrake. The data show a consistent surcharge relationship between large storm events. Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at low flows. All data are suitable for use in model calibration. Smaller storm events with peak flow data that do not cause surcharging at the meter will be used for hydrology model calibration. The larger storm event data will be used to calibrate the hydraulics of the storage facility.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

PB138_023-188C

PB138_023-188C is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the hydrology of the northwestern part of the NPDES138 Basin. The site was chosen after review of alternative locations at MHs 023-187 and 023-418.

The meter is located in the same structure as meter PB138_023-188B; the meter was placed in the pipe that enters the structure from the north. The structure is upstream from the CSO Facility 36. The data at the site captured a consistent dry weather diurnal pattern. During storm events, the meter became surcharged and the velocity dropped to near zero as the flow backed up at the HydroBrake. The data show a consistent surcharge relationship between large storm events. Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at low flows. All data are suitable for use in model calibration.

Smaller storm events with peak flow data that do not cause surcharging at the meter will be used for hydrology model calibration. The larger storm event data will be used to calibrate the hydraulics of the storage facility.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

PB138_023-191A

PB138_023-191A is a temporary monitoring installation that records both level and velocity. The site was installed to characterize the hydraulics of the CSO Facility 36. No alternative location was investigated at this location.

The meter is located on the downstream side of the HydroBrake at CSO Facility 36. The primary purpose for the meter was to characterize the HydroBrake at MH 023-434. Four hydraulic conditions are occurring simultaneously within the structure: (1) the structure receives flow from the upstream HydroBrake, (2) the structure receives flow from the PS 67 force main, (3) under normal conditions the structure directs flow toward the Shelby Street PS 20, and (4) under high flow conditions the structure has a high-flow bypass weir that directs flow toward the NPDES138 Basin overflow weir and outfall. Flows that go over the high-flow bypass weir are initially redirected back toward PS 67; however, when the pump station is inundated, overflows through the NPDES138 Basin outfall occur. Two scenarios can cause the high-flow bypass weir in structure 023-191 to overflow. First, PS 20 can malfunction, causing the depth of flow in the structure to rise and go over the weir. Second, the storage tank high-flow bypass weir at structure 023-434 can overflow, sending excess flow toward the structure. If PS 20 can retain the excess flow, no overflow over the weir in structure 023-191 occurs; however, if the excess flow cannot be retained by the pump station, the weir will overflow.

The data at the site captured a consistent dry weather diurnal pattern and showed consistent patterns of pump station discharge flows because it was located downstream from pump stations. During storm events, the meter showed consistent flow patterns resulting from the downstream HydroBrake and the upstream pump station and an overflow. Data quality was classified as "Good" for the Phase 1 monitoring period; the meter captured the different hydraulic conditions occurring within the structure. All data are suitable for use in characterizing the HydroBrake.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydraulics of CSO Facility 36.

PB138_023-434A

PB138_023-434A is a temporary monitoring installation that records level only. The site was installed to characterize the HydroBrake at CSO Facility 36 and to be used in conjunction with upstream meters to develop hydraulics for the storage tank weirs. The site was chosen after review of alternative locations at MH 023-418.

The meter is located at the HydroBrake in CSO Facility 36. The data at the site captured a consistent dry weather level pattern. During storm events, the level data were consistent and corresponded with the storage tank weir and the high-flow bypass weir overflowing. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain level data to characterize the HydroBrake and the CSO Facility 36 hydraulics.

PB138_023-438A

PB138_023-438A is a temporary monitoring installation that records level only. The site was installed to characterize storage utilization in storm events at CSO Facility 36. No alternative location was investigated at this location.

The meter is located within the storage tanks at CSO Facility 36; thus, no dry weather levels were recorded at the meter. The meter was relocated within the storage tanks on 11/3/2008 for better data readings. There were no other significant maintenance issues or data gaps during the review period. During storm events, the level data were consistent and corresponded with the meter at structure 023-434. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable data response during wet weather and lack of data gaps.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain level data to characterize the HydroBrake and the CSO Facility 36 hydraulics.

PB138_030-352A

PB138_030-352A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the southern part of the NPDES138 Basin. The site was chosen after review of alternative locations at MH 023-188.

The meter is located upstream from the CSO Facility 36 and south of the meters located at structure 023-188. The data at the site captured a consistent dry weather diurnal pattern. During storm events, the meter becomes surcharged, and the velocity drops to near zero as the flow backs up at the HydroBrake. The data show a consistent surcharge relationship between large storm events. Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at low flows. All data are suitable for use in model calibration.

The meter location is used to characterize the hydrology of the southern part of the basin. Smaller storm events with peak flow data that do not cause surcharging at the meter will be used for hydrology model calibration. The larger storm event data will be used to calibrate the hydraulics of the storage facility.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

NPDES138_MH023192A

NPDES138_MH023192A is a permanent monitoring installation that records both level and velocity. The site is classified as a wet weather site because it is not expected to provide good quality velocity data; thus, only level data are finalized for the meter. The site was installed to identify and quantify CSO events occurring from the NPDES138 Basin.

The meter is located at the NPDES138 Basin overflow weir structure downstream from CSO Facility 36. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Level data quality was classified as "Excellent" for the Phase 1 monitoring period. The level data have a consistent and repeatable response and lack of data gaps; the data are suitable for use in model calibration.

This monitoring installation is a permanent installation; it should continue to be screened for the Phases 2–3 monitoring period.

3.12.6 NPDES175 Basin

NPDES175 Basin is located downstream from the NPDES130 Basin. The approximately 68-acre basin was monitored by five temporary meters and one permanent meter to verify overflows within the basin. An additional seven meters were installed in the controlled basin south of the NPDES175 Basin. The meters connect to the main trunk pipe downstream from the CSO structure but are close enough to potentially have an impact on overflows at the structure. A total of four temporary meters were permanently removed during the review period. The permanent meter is designated as a dry weather site; thus, level and velocity data are finalized. No CSS control facilities are located within this basin.

PB175_030-072A

PB175_030-072A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northeastern part of the NPDES175 Basin. The site was chosen after review of alternative locations at MHs 030-071, 030-074, 030-075, 030-096, and 030-101.

The meter is located upstream from site PB175_DWF-030348. The quality of the level data collected at the location was classified as "Good" (that is, no data gaps, and ultrasonic vs. pressure measurement of depths align well). However, the relationship between level and velocity data was not clear or consistent due to the unusual hydraulics at the monitoring location. Consequently, the quality of the flow data calculated using the level and velocity measurements collected during the Phase 1 monitoring period was classified as "Poor."

The site was not conducive to collecting data suitable for model calibration due to the site hydraulics. Therefore, the meter was removed on 11/21/2008 and new meters located at 030-074A/B and 030-096.

PB175_030-074A

PB175_030-074A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northeastern part of the NPDES175 Basin. No alternative location was investigated at this location.

The meter is located upstream from site PB175_030-072A; it is also located in the same structure as PB175_030-074B and was placed in the pipe that enters the structure from the northeast. A hydraulic jump occurs around 2.5 inches of flow depth, but wet weather flow data quality is not significantly altered due to the hydraulic jump. Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at low flows. The meter was removed due to miscommunication. Structure 030-074 initially had a BG meter (two sensors installed with one data logger) installed. Meter PB175_030-074B was designated for

removal due to the hydraulic conditions producing poor data; however, both the A and B meters were inadvertently removed. This issue was discussed in the January 2009 data review workshop, and the meter was re-installed on 3/16/2009. As a consequence, the large storm event in January 2009 was not recorded. This event, however, is not considered usable for model calibration due to the antecedent snowmelt period in December 2008 and early January 2009. The meter recorded suitable data in the periods crucial to model calibration. All data are suitable for use in model calibration.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

PB175_030-074B

PB175_030-074B is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northeastern part of the NPDES175 Basin. The site was chosen after review of alternative locations at MHs 030-071, 030-072, 030-075, 030-096, and 030-101.

The meter is located at the same structure as PB175_030-074A; it was placed in the pipe that enters the structure from the east. The quality of the level data collected at the location for the Phase 1 monitoring period was "Good" (that is, no data gaps, and ultrasonic vs. pressure measurement of depths align well). However, the relationship between level and velocity data was not clear or consistent due to ramping over the meter at the monitoring location. Consequently, the quality of the flow data calculated using the level and velocity measurements collected during the Phase 1 monitoring was classified as "Poor."

The site was not conducive to collecting data suitable for model calibration due to the site hydraulics. Therefore, the meter was removed on 12/5/2008 and relocated to PB175_030-096A.

PB175_030-096A

PB175_030-096A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the northeastern part of the NPDES175 Basin. The site was chosen after review of alternative locations at MHs 030-071, 030-072, 030-075, 030-074, and 030-101.

The meter is located upstream from site PB175_030-074B. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of their consistent and repeatable response during dry and wet weather and lack of data gaps. However, the meter was not installed until 1/16/2009.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

PB175_036-046A

PB175_036-046A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the area to the south and east of the NPDES175 Basin overflow location. The site was chosen after review of alternative locations at MHs 036-040, 036-047, and 036-048.

The meter is located upstream from site PB175_036-581A; it is also located in the same structure as PB175_036-046B. The meter was placed in the pipe that enters the structure from the northeast. The velocity data are overestimated at level depths great then 6.5 inches due to unusual hydraulics at the monitoring location. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period because at depths greater than 6.5 inches the meter was overestimating flows. All data at flow depths less than 6.5 inches

are suitable for use in model calibration. Due to this limitation, only smaller storm events should be utilized if this meter is used for model calibration.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The total flow from two upstream temporary monitoring locations (PB175_036-046A and PB175_036-046B) was compared to the downstream flow at PB175_036-581A. The flow balance determined that the calculated flows from this temporary monitoring location were within the correct range for flows associated with levels less than 6.5 inches at meter PB175_036-046A. At levels greater than 6.5 inches at PB175_036-046A, the combined upstream meters in the flow balance were overestimating flows. After reviewing the data, it appears that the overestimation is due to meter PB175_036-046A.

Based on the flow balance results, it is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period, and the data at meter PB175_036-581A be used for model calibration for events that produce a flow depth greater than 6.5 inches and to all subsequent events.

PB175_036-046B

PB175_036-046B is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the southeastern part of the NPDES175 Basin. The site was chosen after review of alternative locations at MHs 036-040, 036-059, and 036-060.

The meter is located at the same structure as PB175_036-046A, and it was placed in the pipe that enters the structure from the southeast. During storm events, the meter becomes surcharged as the flow backs up due to increased flow in the adjacent 036-046A pipe. Level dropouts occurred in the 5/5/2009 storm event due to the ultrasonic meter becoming surcharged and the meter not properly switching to pressure depth data. Data quality was classified as "Some Limitations" for the Phase 1 monitoring period due to level drops that occurred during the larger May 2009 storm events. All other data are suitable for use in model calibration.

Flow balancing was undertaken as discussed in section PB175_036-046A. The flow balance determined that the calculated flows from this temporary monitoring location were within the correct range for flows associated with levels less than 6.5 inches at meter PB175_036-046A. At levels greater than 6.5 inches at PB175_036-046A, the combined upstream meters in the flow balance were overestimating flows. After reviewing the data, it appears that the overestimation is due to meter PB175_036-046A and that meter PB175_036-046B accurately measures level and velocity.

Based on the flow balance results, it is recommended that this monitoring installation be removed for the Phases 2–3 monitoring period and the data at meter PB175_036-581A be used for model calibration to subsequent events.

PB175_036-581A

PB175_036-581A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the southeastern part of the NPDES175 Basin. The site was chosen after review of alternative locations at MHs 036-585, 036-586, and 036-584.

The meter is located downstream from the meters at PB175_036-046A/B. The meter was placed in a 30-inch-diameter pipe upstream from an 18-inch-diameter pipe. During storm events, the scattergraph indicated a downstream flow constriction. Data quality was classified as "Good" for the Phase 1 monitoring period due to the wide scatter at low flows. All data are suitable for use in model calibration.

Flow balancing was undertaken as discussed in section PB175_036-046A and PB175_036-046B. Based on the flow balance results, it is recommended that the upstream meters (PB175_036-046A/B) be removed and that

this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the upstream basin.

PB175_036-585A

PB175_036-585A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the southeastern part of the NPDES175 Basin. The site was chosen after review of alternative locations at MHs 036-581 and 036-586.

The meter is located upstream from site PB175_036-581A; it is also located in the same structure as PB175_036-585B. It was placed in the pipe that enters the structure from the south. The quality of the level data collected at the location was "Good" (that is, no data gaps, and ultrasonic vs. pressure measurement of depths align well). However, the relationship between level and velocity data was not clear or consistent due to the unusual hydraulics at the monitoring location. Consequently, the quality of the flow data calculated using the level and velocity measurements collected for the Phase 1 monitoring period was classified as "Poor."

The site was not conducive to collecting data suitable for model calibration due to the site hydraulics. Therefore, the meter was removed on 11/14/2008 and relocated to 036-581A.

PB175_036-585B

PB175_036-585B is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows and characterize hydrology for the flows entering the system downstream from meter PB175_036-585A. The site was chosen after review of alternative locations at MH 036-581.

The meter is located within the same structure as PB175_036-585A, and it was placed in the pipe that enters the structure from the southeast. The quality of the level data collected at the location for the Phase 1 monitoring period was classified as "Good" (that is, no data gaps, and ultrasonic vs. pressure measurement of depths align well). However, the relationship between level and velocity data was not clear or consistent due to the unusual hydraulics at the monitoring location. Consequently, the quality of the flow data calculated using the level and velocity measurements collected for the Phase 1 monitoring period was classified as "Poor."

The site was not conducive to collecting data suitable for model calibration due to the site hydraulics. Therefore, the meter was removed on 11/14/2008 and relocated to 036-581A.

PB175_DWF-030348

PB175_DWF-030348 is a permanent monitoring installation that records both level and velocity. The site is classified as a dry weather site because it is expected to provide good quality velocity and level data; thus, both level and velocity data are finalized for the meter. The site was installed to determine if CSO events were occurring and to quantify overflow volumes from the NPDES175 Basin.

The meter is located within the main sewer trunk line directly downstream from the PB130_DWF-030410. The level data are used to alarm for CSO events and to calculate the volume of CSOs using a weir equation. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps.

Flow balancing was undertaken as described in the section for monitoring location SPU_030-358A and PB130_DWF-030410. The flow balances determined that the calculated flows from the two meters were within the correct range.

This monitoring installation is a permanent installation; it should continue to be screened for the Phases 2–3 monitoring period.

SPU_030-080A

SPU_030-080A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows in the parallel sewer trunk line leaving the Portage Bay/Lake Union Basin. No alternative location was investigated at this location.

The meter is located in East Lake Avenue on a line parallel to the main sewer trunk line for the Portage Bay/Lake Union Basin. Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during dry and wet weather and lack of data gaps. Meter SPU_030-080A was removed on 12/2/2008 due to miscommunication. The meter was inadvertently removed at the same time as meter PB175_030-074A/B. This issue was discussed in the January 2009 data review workshop, and the meter was re-installed on 2/12/2009. As a consequence, the large storm event in January 2009 was not recorded. This event, however, is not considered usable for model calibration due to the antecedent snowmelt period in December 2008 and early January 2009. The meter recorded suitable data in the periods crucial to model calibration.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period to obtain more data to characterize the hydrology of the basin.

SPU_030-358A

SPU_030-358A is a temporary monitoring installation that records both level and velocity. The site was installed to calculate flows in the main sewer trunk line leaving the Portage Bay/Lake Union Basin for comparison with the permanent meter at the NPDES175 Basin, and to estimate flow split between this line and the parallel line discussed above. No alternative location was investigated at this location.

The meter is located in East Lake Avenue on the main sewer trunk line leaving the Portage Bay/Lake Union Basin. Data from 10/21/2008 to 12/2/2008 was recorded using an ADS Pulse meter. Due to high silt levels in the pipe, the data quality was classified as "Poor" for these dates in the Phase 1 monitoring period. On 12/2/2008, the Pulse meter was replaced with an ADS FlowShark rotated out of the silt layer. The quality of data collected using the ADS FlowShark during Phase 1 monitoring period was "Good" due to the presence of silt at the meter location which caused wide scatter patterns at low flows. Based on field visits, the silt is washed downstream during larger storm events. Because of the silt buildup in low flow, only peak wet weather event data are suitable for use in model calibration.

Flow balancing was undertaken using the data from this temporary monitoring installation during Phase 1 monitoring. The total flow from the upstream permanent monitoring location PB175_DWF-030348 was compared to the downstream flow at SPU_030-358A. The flow balance indicated that the calculated flows for peak storm events from this temporary monitoring location were within the correct range.

It is recommended that this monitoring installation remain in place for the Phases 2–3 monitoring period. The meter is required to record flow that may pass over a weir that connects the parallel lines in East Lake Avenue upstream from meters 030-358A and 030-080A.

3.12.7 Combined Sewer Overflows

ADS reported that three CSOs occurred in the Portage Bay/Lake Union Basin during the Phase 1 monitoring period; Table 3-14 lists the CSOs reported during the Phase 1 monitoring period. Due to a monitor malfunction, it has been estimated that a brief overflow occurred at the NPDES135 Basin during the intense

rainfall event on 5/19/2009. SPU estimated the volume of that event using data from an upstream temporary monitor.

Table 3-14. 2008–2009 Combined Sewer Overflows in Portage Bay/Lake Union Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
127	4/6/2009	1:20	3,509
130	--	--	--
132			
135	5/19/2009	0:10	56
138	11/8/2008	0:20	40,855
	1/7/2009	2:30	246,385
175	--	--	--

Figure 3-31 shows the maximum water level recorded by ADS at each of the overflow structures in the basin as a percentage of the weir height.

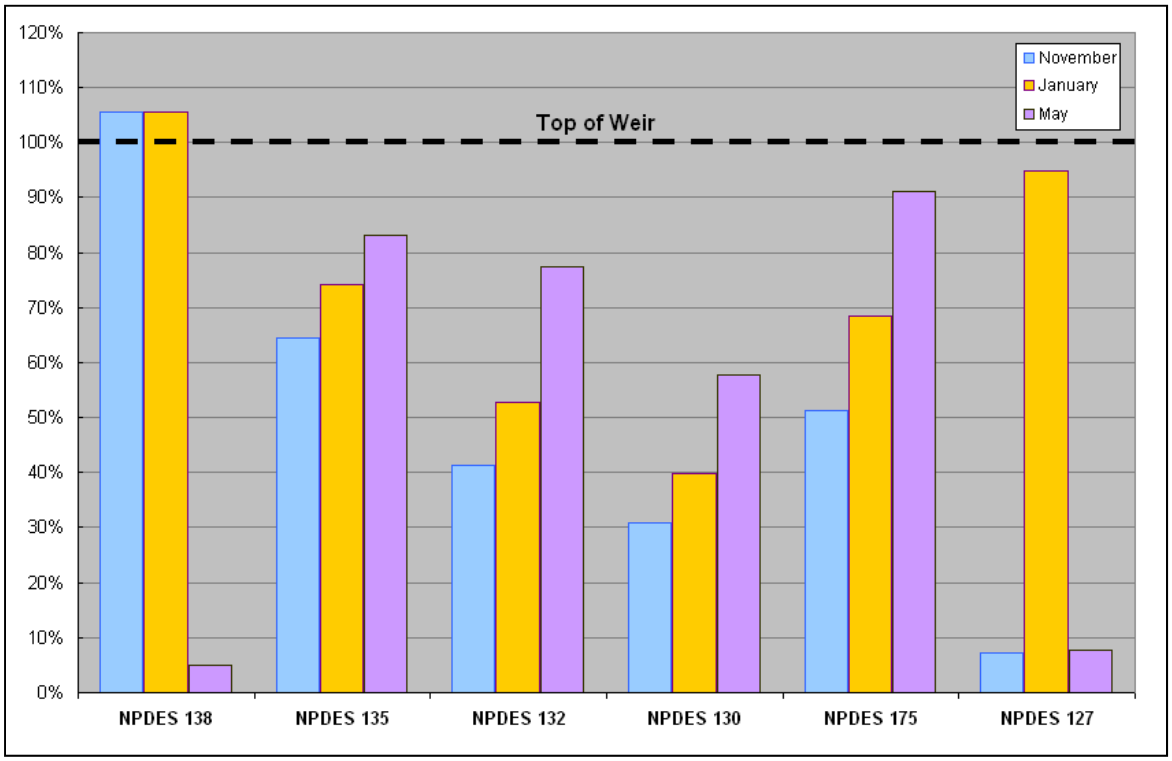

Figure 3-31. Portage Bay overflow structure performance for major events

3.12.8 Facility Operations

CSO Facility 36 is located in the NPDES138 Basin and consists of a HydroBrake and two offline storage structures. The remainder of the CSO facilities in the Portage Bay/Lake Union Basin consist of overflow weirs at the specific structure.

CSO Facility 36

CSO Facility 36 is located within the NPDES138 Basin. The facility consists of a HydroBrake located at MH 023-434 at the dead-end roadway of Shelby Street. Figure 3-32 shows the monitor data for the HydroBrake. A manufacturer's curve is not available for this HydroBrake. The HydroBrake monitors successfully captured the overflow event that occurred at the site for January 2009 as the horizontal line just below 140 inches shows.

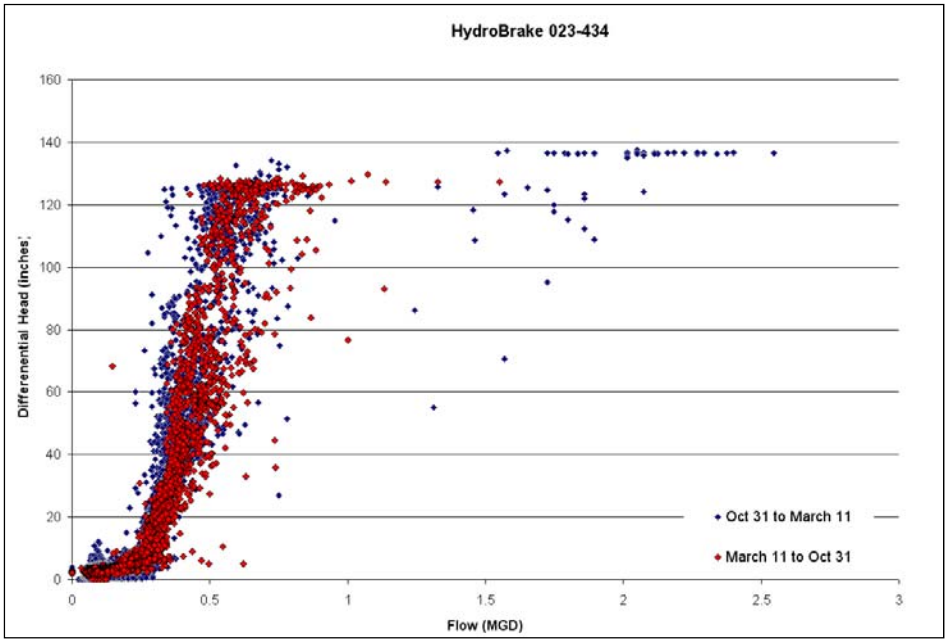

Figure 3-32. NPDES138 HydroBrake characterization

A storage weir and an emergency bypass weir are located within the same structure as the HydroBrake. The flow backs up within the pipe network until the storage weir is overtopped and the flow is diverted into the storage tanks. MH 023-438 measures the depth of storage within the storage tanks. Figure 3-33 shows the storage utilization for the storage tanks. During the 5/5/2009 storm, the tanks were almost 100 percent utilized. A flap gate installed at the outflow from the storage tank prevents flow from entering the storage tank prior to overtopping the weir. If the storage tank fills up, flow will overtop the emergency bypass weir at the HydroBrake and continue downstream to the MH 023-191.

MH 023-191 is located downstream from the HydroBrake structure. Under normal flow conditions, the HydroBrake directs flow toward PS 20. Under high-flow conditions, an emergency bypass weir in this structure is overtopped, and flow is diverted toward the NPDES138 Basin control structure MH 138_023-192. Flow in this structure is initially directed to PS 67, which pumps flows back up into MH 023-191. The NPDES138 overflow weir in this structure is 117 inches long and at 12.98 inches above pipe invert. Once the flow depth reaches this elevation, flow is diverted to the 18-inch wood stave pipe and discharged into Portage Bay.

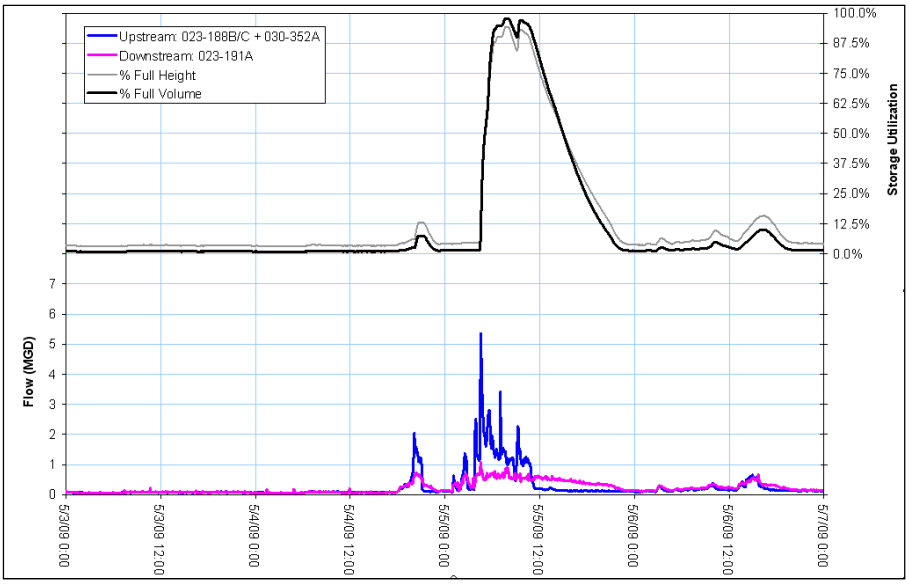

Figure 3-33. NPDES138 storage utilization

Pump Stations 20, 61, 62, 63, 64, 65, 66, and 67

SPU monitors PSs 20, 61, 62, 63, 64, 65, 66, and 67 via its SCADA system. The SCADA system records wet well level and pump run times. Data are available at 90- to 120-second resolution. The SCADA data will be used in model calibration to determine the pump switch on-off levels, and in conjunction with drawdown test results to calculate the pump station flow rate.

Data collected during Phase 1 monitoring included the pump on-off states and the wet well depth. These data were plotted versus time and rainfall for review. Review consisted of observing the normal rise and fall of wet well elevation with time during wet and dry weather. In general, no anomalies in operation that could not be explained by response to rainfall were noted, and the data quality was classified as "Good."

3.12.9 Recommendations for Additional Data Collection

All sites that were not removed during the Phase 1 monitoring period should remain in place throughout the 2009–2010 wet season monitoring period. No additional sites within the Portage Bay/Lake Union Basin have been identified for the 2009–2010 wet weather season. Sites removed during the Phase 1 monitoring period include:

- PB175_030-072A
- PB175_030-074A and B
- PB175_036-585B

3.13 West Seattle Basin

The West Seattle Basin monitored as part of the LTCP consists of the NPDES095 Basin. Temporary and permanent meters monitored the combined sewer flows in the NPDES095 Basin. When the site overflows, it overflows to the west into Puget Sound. RG 05 monitors the rainfall in the West Seattle Basin. ADS monitors one overflow point within the NPDES095 Basin.

One permanent station and three temporary meters, installed during the review period, monitored combined sewage flow. More detailed information on the basin can be found in Appendix N, and a basin schematic is contained in Appendix B. Data from pump stations in the NPDES091 and NPDES094 Basins were screened for quality purposes, but these basins are believed to be controlled and will not be modeled as part of the LTCP.

NPDES095 Basin

NPDES095 Basin, with an area of approximately 20 acres, is located on the shore of Puget Sound near Lincoln Park in West Seattle. One permanent meter monitors the basin to verify overflows. Also, three temporary monitors are located in the NPDES095 Basin, one of which was removed on 1/5/2009.

WS95_075-026A

WS95_075-026A is a temporary monitoring installation that records both level and velocity. The site was chosen after a review of an alternative location at MH 075-024. The level and velocity data are used to characterize hydrology in an area north and east of the NPDES095 Basin that is tributary to the King County Fauntleroy pump station. Correction of overflows at the NPDES095 Basin could involve flow reductions in this area.

Data quality was classified as "Excellent" for the Phase 1 monitoring period because of the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

It is recommended that the monitoring location be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

WS95_075-032A

WS95_075-032A is a temporary monitoring installation that records both level and velocity. The site was chosen after a review of an alternative location at MH 075-033. The level and velocity data are used to calculate the flows leaving the NPDES095 Basin CSO structure. The meter was installed in a pipe with a liner that has an irregular shape.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

It is recommended that the monitoring location be removed for the Phases 2–3 monitoring period as sufficient data have been collected.

WS95_075-036A

WS95_075-036A is a temporary monitoring installation that records both level and velocity. No alternative monitoring locations were considered for WS95_075-036A. The level and velocity data are used to calculate the flows from the NPDES095 Basin as a backup to the permanent meter one pipe length downstream.

Data quality was classified as "Excellent" for the Phase 1 monitoring period due to the consistent and repeatable response of the data during both dry and wet weather and lack of data gaps.

Flow balancing was undertaken using data from this temporary monitoring location and data from the permanent monitoring location at WS95_DWF-075035. The flow balance indicated that the data from the permanent location matched the data at this location with minimal error and could be used to calculate flows from the basin and for hydrology characterization.

The meter was removed 1/5/2009 due to their redundancy with excellent quality data from the permanent monitoring location.

WS95_DWF-075035

WS95_DWF-075035 is a permanent monitoring installation that records both level and velocity. The site provides depth data to quantify overflows at NPDES095 and velocity data for calculation of flow. Data quality was classified as "Excellent" for the Phase 1 monitoring period. The meter should continue to be screened for the Phases 2–3 monitoring period. The meter should continue to be screened for the Phases 2–3 monitoring period.

3.13.1 Combined Sewer Overflows

ADS reported that three CSOs occurred in the West Seattle Basin during the Phase 1 monitoring period; Table 3-15 lists the CSOs that occurred during the Phase 1 monitoring period.

Table 3-15. 2008–2009 Combined Sewer Overflows in West Seattle Basin
10/1/2008–5/31/2009

NPDES outfall	End date of overflow	Duration (hrs:min)	Volume (gal)
95	1/7/2009	7:35	222,708
	5/5/2009	0:55	31,612
	5/19/2009	0:10	5,711

3.13.2 Facility Operations

The CSO facilities in the West Seattle Basin consist of one overflow weir as described above. No HydroBrakes, pump stations, or storage tanks are located in the NPDES095 Basin. Figure 3-34 shows the maximum water level recorded at the overflow structure in the NPDES095 Basin as a percentage of the weir height in the three largest storm events of the monitoring period.

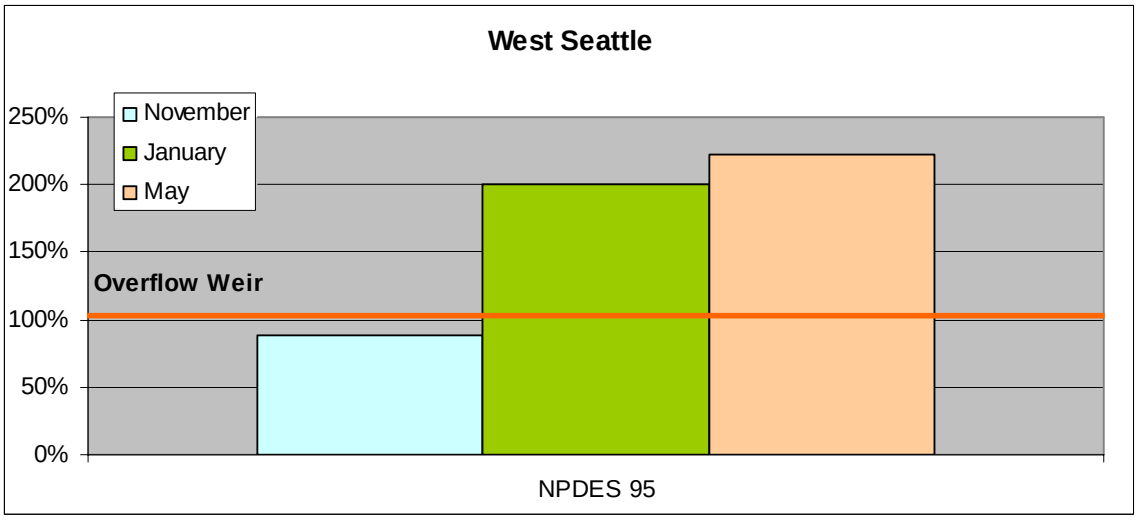

Figure 3-34. Maximum recorded water level recorded in West Seattle Basin for major events

3.13.3 Recommendations for Additional Data Collection

It is recommended that all temporary monitors be removed for the Phases 2–3 monitoring period as sufficient data have been collected for model construction. No additional sites within the West Seattle Basin have been identified for the 2009–2010 wet weather season. The permanent meter should continue to be screened for data quality.

4. SUITABILITY OF DATA FOR HYDROLOGIC AND HYDRAULIC MODELING EFFORTS

This section will not assess whether or not the data are sufficient for model calibration until the second year of data has been collected. This information will be contained in the Seattle Public Utilities LTCP Monitoring Data Report 2009–2010 Monitoring report. SPU will develop the Magnolia and West Seattle Basin models using the Phase 1 monitoring data. The LTCP Consultant team will model the remaining basins using Phases 1, 2 and 3 flow monitoring data for model calibration. This section reviews the data that have been collected through Phase 1.

4.1 Wet Weather Model Calibration Periods

Section 3.1 lists seven storm events that occurred during the Phase 1 monitoring period. Of the seven storm events, all but the January 2009 storm event can be used for model calibration. Due to antecedent snowfall, the January 2009 storm event may not be suitable for model calibration. The storm events that occurred in November 2008 and the two storm events in May 2009 are the larger events that caused overflows in several basins. For some areas, the smaller events in February, March and April of 2009 may be needed to avoid backwater conditions.

4.2 Dry Weather Model Calibration Periods

The monitoring data collected from dry weather periods from 10/1/2008 through 5/31/2009 are suitable for estimating dry weather flow (DWF) patterns using ZFM2. The three-dry weather periods have been identified:

- September 2008 (if meter installed)
- End of October 2008
- End of May 2009 (if meter not removed)

Where the meter data are unavailable or do not provide DWF, estimates will be used with a suitable addition for dry weather infiltration estimated from the meters in the basin.

4.3 Future Monitoring for Phase 3 2009–2010 Wet Weather Season

SPU will continue to maintain permanent monitors at NPDES basin overflow structures and/or outfall pipes within the NPDES basins. The majority of the 150 temporary monitors will remain in place for the 2009–2010 monitoring period, with the exception of Magnolia and West Seattle monitors. It has been determined that the West Seattle and Magnolia basin models be performed by SPU.

Approximately 60 new sites will be installed for the Phase 3 2009–2010 monitoring period. These sites are generally located in areas tributary to the King County system or within the stormwater system. The areas that are being monitored are served primarily by a CSS, which conveys wastewater and runoff from directly connected rooftops, streets, and area drains to the King County mainline system and ultimately to the King County West Point Treatment Plant.

Conclusions from the Phase 1 flow monitoring will be deferred until the end of Phase 3, and an additional wet weather season monitoring data will be collected. This section of the report will be completed upon completion of the Phase 3 monitoring period.

5. REFERENCES

MGS Engineering Consultants. Analysis of Precipitation-Frequency and Storm Characteristics for the City of Seattle. December 2003.

Seattle Public Utilities. Quality Assurance Project Plan (QAPP). Long-Term Control Plan: Flow Monitoring Plan 2008–2009. July, 16, 2009.

Environmental Protection Agency (EPA). Combined Sewer Overflows: Guidance Document for Long-Term Control Plan. September 1, 1995.

Environmental Protection Agency (EPA). Combined Sewer Overflows: Guidance for Monitoring and Modeling. January 1, 1999.

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APPENDIX A: PRECIPITATION ANALYSIS

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APPENDIX B: BASIN SCHEMATICS

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APPENDIX C: BALLARD DATA SITE SHEETS

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APPENDIX D: DELRIDGE/LONGFELLOW DATA SITE SHEETS

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APPENDIX F: FREMONT/WALLINGFORD DATA SITE SHEETS

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APPENDIX I: MADISON PARK/UNION BAY DATA SITE SHEETS

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APPENDIX M: PORTAGE BAY/LAKE UNION DATA SITE SHEETS

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APPENDIX N: WEST SEATTLE DATA SITE SHEETS

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