Combined Sewer Overflow Program

Long-Term Control Plan

Volume 3
Flow Monitoring Plan

2009–2010

RESTORE OUR WATERS
SEATTLE PUBLIC UTILITIES
COMBINED SEWER OVERFLOW REDUCTION

December 2010

CSO Long Term Control Plan
Quality Management System Planning Document

Quality Assurance Project Plan

SPU CSO Reduction Program

CSO Long-Term Control Plan

Flow Monitoring Plan – Phase 3 (October 1, 2009 through May 31, 2010)

Prepared by

CH2M HILL
Brown and Caldwell
GHD

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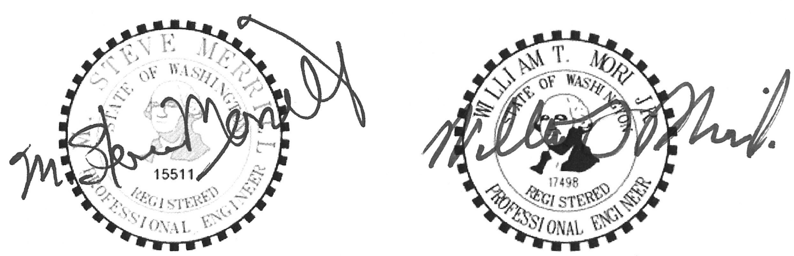
Seattle Public Utilities
Seattle , Washington

This document is part of the Science Information Quality System providing in one place a clear, concise, and complete plan for environmental data management and its quality objectives, and for identifying key project personnel.



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

1. TITLE AND APPROVAL SHEET

Quality Assurance Project Plan

Flow Monitoring Plan 2009 - 2010 Phase 3

Internal Review and Approval

Title (Name)	Signature	Date
Ed Mirabella, CSO LTCP Project Manager		12-17-09
Ben Marré, CSO LTCP Flow Monitoring Study Project Manager		12/17/2009
Tai Ovbeibo, CSO LTCP Systems Model Manager		12/17/09
Mike Hinson, Field Technical Lead		12/17/09
Laura Reed, Data Quality Lead		12/17/09

External Review and Approval

Title (Name)	Signature	Date
Steve Merrill PE, Brown and Caldwell, Consultant Monitoring Manager		12/17/09
Bill Mori PE, CH2M Hill, Consultant Project Manager		12/17/09

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Distribution List

Title:	Name (Affiliation):	Telephone. No.:	No. of copies:
SPU CSO LTCP Project Manager	Ed Mirabella	206-684-5959, j.edward.mirabella@seattle.gov	1 (paper) 1 (electronic)
SPU CSO LTCP Flow Monitoring Study Project Manager	Ben Marré	206-684-7597, ben.marre@seattle.gov	1 (paper) 1 (electronic)
SPU CSO LTCP Systems Model Manager	Tai Ovbiebo	206-684-8648, tai.ovbiebo@seattle.gov	1 (paper) 1 (electronic)
SPU Field Technical Lead	Mike Hinson	206-733-9134, michael.hinson@seattle.gov	1 (paper) 1 (electronic)
SPU Data Quality Lead	Laura Reed	206-615-0551, laura.reed@seattle.gov	1 (paper) 1 (electronic)
SPU CSO LTCP Systems Model	Joseph Pang	206-733-9613, joseph.pang@seattle.gov	1 (paper) 1 (electronic)
SPU CSO Program Library			1 (paper) 1 (electronic)

Acronyms

ADS	ADS Environmental Services
BMP	Best Management Practice
CSO	Combined Sewer Overflow
DQI	Data Quality Indicator
DQO	Data Quality Objective
Ecology	Washington State Department of Ecology
EPA	Environmental Protection Agency
FTP	File Transfer Protocol
GIS	Geographic Information System
GSI	Green Stormwater Infrastructure
Intelliserve	Web-based data management tool used by ADS for analyzing and storing flow monitoring data
LTCP	Long Term Control Plan
MQO	Measurement Quality Objective
NPDES	National Pollutant Discharge Elimination System
NSA	Northern Service Area
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
SCADA	Supervisory Control and Acquisition Data
SIC	Science Information Catalog
SIMS	Science Information Management System
SOP	Standard Operating Procedure
SPU	Seattle Public Utilities
ZFM2	Data management software used by Stantec for the analysis and storage of flow monitoring data

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Note – Appendices B through H will be supplied in electronic pdf format files on enclosed CD.

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Quality Assurance Project Plan

Flow Monitoring Plan 2009 - 2010

This Flow Monitoring Plan describes the quality assurance process for flow monitoring of the combined sewer system owned and operated by the City of Seattle (the City), as well as elements of the combined system owned and operated by King County. The information in the plan, including monitoring locations, is specific to Monitoring Phase 3 (October 1 2009 through May 31 2020). The flow monitoring data will be used for the Seattle Public Utilities (SPU) Long Term CSO Control Plan. The primary goal of the CSO control program is to implement the most cost-effective controls to reduce water quality impacts from CSOs. The monitoring study will generate data to support decisions for selecting appropriate CSO controls.

This document was developed with guidance from the Washington State Department of Ecology, Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology 2004) and Environmental Protection Agency's Guidance for Long Term Control Plan, Guidance for Monitoring and Modeling. A cross-walk with the Environmental Protection Agency Quality Assurance Project Plan (QAPP) format is included in Table T-6.

This Plan is organized and presented using the following elements:

I. Goals and objectives of the study,

II. Type, quality, and quantity of data needed to meet the objectives,

III. Sampling and measurement procedures needed to acquire those data,

IV. Study implementation Quality Assurance/Quality Control (QA/QC) procedures to ensure the QAPP is implemented as prescribed, and

V. Assessment procedures to determine if the data conform to the specified criteria will satisfy the project objectives and the analysis and format for presentation of the results.

Large tables that will be used often during the project life have been located in a Tables section. These tables are noted with a "T" prefix.

A series of Standard Operating Procedures (SOPs) will be developed to provide guidance to users of this Plan. The proposed list of SOPs is presented in Table T-7.

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Element I. Goals and Objectives of the Study

This element covers basic project management, including project history and objectives, roles and responsibilities of participants, and other factors to ensure that the project has a defined goal and clear outcomes understood by all the participants. This element includes the following sections:

Section 3 – Background,

Section 4 – Project Description, and

Section 5 – Organization and Schedule.

3. Background

Seattle Public Utilities is currently in the process of implementing a program to reduce combined sewer overflows (CSOs). A Long Term Control Plan (LTCP) will be prepared in accordance with EPA wet weather planning guidelines to develop a CSO control program to meet regulatory requirements. SPU is undertaking flow monitoring of the combined sewer system over two wet weather seasons to obtain data for system characterization and hydraulic model calibration. This plan covers Monitoring Phase 3 (October 1 2009 through May 31 2010). The monitoring that was undertaken in Phase 1 (1 October 2009 through May 31 2009) and Phase 2 (June 1 2009 through September 30 2009) was covered in the 2008-2009 Flow Monitoring Plan.

SPU currently maintains permanent monitoring equipment of NPDES basin overflow structures and/or outfall pipes within the NPDES basins. These monitors provide data to comply with their wastewater permit requirements and to quantify combined sewer overflow volumes, and are referred to as permanent monitoring locations. In September and October 2008, SPU installed a network of temporary monitoring locations in the tributary basins to these permitted NPDES overflow points. The majority of these temporary monitors will remain in place for Monitoring Phase 3. In addition to the previously installed monitors, SPU will be installing new temporary monitors in approximately 60 locations throughout the sewer system.

3.1. The Problem

3.1.1. Driver

The Washington State Department of Ecology (Ecology) administers the City of Seattle's (the City's) National Pollutant Discharge Elimination System (NPDES) permit for combined sewer overflow (CSO) outfalls. The City's 1998 CSO NPDES permit required the City to install automatic flow monitoring equipment, submit monthly and annual reports of overflow frequencies and volumes to Ecology and to develop a CSO Reduction Plan Amendment.

In 2001, the City prepared a CSO Reduction Plan with the following objectives:

- Control CSO's to an average of one untreated discharge per CSO site per year
- Develop a plan that is technically feasible and financially responsible
- Coordinate the CSO Program with King County's wastewater program
- Coordinate with affected communities.

The 2001 Plan describes a series of projects intended to comply with regulatory requirements through a mix of Best Management Practices (BMP's), off-line storage and structural modifications to existing facilities. In 2005, the Amendment was updated for cost and schedule, and incorporated into the City's 2005 NPDES permit.

The City is currently updating the 2001 Plan with its 2010 CSO Plan Amendment which focuses on reducing combined sewer overflows (CSOs) at its most critical and sensitive sites through a cost-effective blend of traditional and sustainable infrastructure. The 2010 Plan Amendment will present an aggressive schedule for constructing CSO Reduction Projects in the Windermere, Genesee and Henderson Basins; Green Sustainable Infrastructure in Ballard, North Union Bay and Interbay; and construction of CSO Retrofit Projects throughout the City to improve CSO control. The Plan Amendment will also identify the need for CSO Reduction Projects in the remaining basins not covered in the 2005 update and will provide a high-level analysis of the types of projects to be constructed along with budget and schedule forecasts. This information will be used in the development of the 2015 CSO Long Term Control Plan, which will address the City's overall plan to control all of its CSO's to meet regulatory requirements. A 2010 CSO Plan Update will be submitted in May 2010 describing the City's CSO Control progress.

3.1.2. Decision-making

The flow monitoring team includes members from SPU, Stantec, ADS, CH2M HILL, Brown and Caldwell and GHD. The team members will be evaluating the monitoring data weekly during the project. Bi-monthly review meetings will be the primary mechanisms for discussions and decisions from the project team. Issues expected to be discussed include verification that data being collected is meeting the project objectives, relocating monitors, replacing monitors and issuing work orders to verify hydraulics at suspect sites, or to perform maintenance of the monitors or rain gages. These tasks and work orders will be recorded in an actions items list in Google documents to ensure that they are undertaken within an appropriate timeframe and that their progress can be tracked. The action item list will be accessible by all of the team members.

For the flow monitors, consistency with previous readings will impact when field crews are mobilized to verify the depth and velocity measurements. If flow is laminar with low variability in depth, a bias of 0.25 inches will most likely be considered acceptable for depth and a bias of 20% considered acceptable in the velocity. If the site exhibits a greater variation in the velocity or depth (such as sites impacted by lift stations), the threshold for mobilizing field personnel may be increased. Depth-velocity scatter graphs will be reviewed to determine if field verification is required.

Further details on the decision making process is provided in Section 5.

3.2. Study Area

This Flow Monitoring Plan addresses monitoring taking place within both the City of Seattle and King County sewer systems. The previous monitoring effort (Phase 1 and Phase 2) focused on twelve CSO basins (Ballard, Delridge, Duwamish, Fremont, Interbay, Leschi, Madison Park/Union Bay, Magnolia, Montlake, North Union Bay, Portage Bay and West Seattle). Of the 150 sites installed in the twelve basins, approximately 100 sites will remain in place for Monitoring Phase 3. This includes monitors in all of the CSO basins except for West Seattle and Magnolia (where permanent monitors will be sufficient).

Approximately 60 new sites will installed for Monitoring Phase 3. There are 3 categories of meters added for Phase 3:

1. Meters installed in the City and Country system for purposes of collaborating on a systems model.

2. Meters installed in the storm drainage system for purposes of characterizing stormwater flows in NPDES basins.

3. Meters installed in NPDES basins where additional data is required for system characterization.

Temporary flow monitoring for the Alaskan Way Viaduct project and the Windermere, Genesee and Henderson basins are performed under a separate SPU project and are not included in this plan.

The areas that are being monitored are served by either a combined or partially separated sewer system. In combined areas, wastewater and runoff from directly connected rooftops, streets and area drains are conveyed to the King County mainline system and ultimately to the King County West Point Treatment Plant. In partially separated areas the runoff from streets and some rooftops is conveyed via the storm drainage system to local water bodies. An overview map of the study area is shown in Drawing 1. A system wide schematic is included in Appendix A, along with detailed schematics of the twelve CSO basins.

Table T-8 summarizes the overflow frequency of the NPDES basins in the study area from 2004 to 2008. NPDES basins are considered to be controlled if they meet the criteria that an average of one untreated discharge may occur based on the 5-year average of the number of untreated discharge events for each applicable CSO outfall. The 5-year average is based on the preceding five calendar years using the data provided at the time of application for permit renewal.

The basin land uses are summarized in Table T-9 and the basin infrastructure characteristics are summarized in Table T-10. Data in these tables is based on the system wide model basins. Summaries of land use and infrastructure characteristics for the NPDES basins can be found in the 2008 – 2009 Flow Monitoring Plan.

A summary of the CSO facilities, outfalls, pump stations and other key structures that are being assessed during the Monitoring Phase 3 can be found in Table T-11, Table T-12, Table T-13 and Table T-14.

3.3. Parameters of Concern

This section discusses the parameters of concern for flow monitors, rain gauges and the SCADA system. The parameters of concern are the entities that can be directly measured or calculated from measurements.

3.3.1. Flow Monitors

The key flow monitoring parameters include velocity, water surface levels and flow rates.

Ultrasonic or pressure sensors are used to measure depth in pipes, hydraulic control structures or detention tanks. Velocity is typically measured using an ultrasonic sensor which 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 and are reported in Section 9.1. Instrument measurement technology is discussed in Section 9.2.

Flow rates can be determined using a combination of measured velocity and flow area. Water surface levels can be measured directly using an ultrasonic instrument where free surface conditions exist, or by using pressure as a proxy. For this study, flow rates are typically determined by measuring the depth within a cross section of flow and the average velocity with that cross section. The flow rate is calculated by multiplying the area of flow by the average velocity (continuity equation). Combined Sewer Overflows are typically measured by applying weir equations to the measured depth over a weir.

During the monitoring period, site verifications will be performed to ensure the monitors are accurately measuring both velocity and depth. Site gain (peak to average velocity ratio) and any depth adjustments will be evaluated throughout the monitoring period. Measurement quality is reviewed and validated according to the SPU Hydraulics SOP HYDR Q1100- Data Review, Assessment, Validation & Verification (refer to Appendix H).

3.3.2. Rain Gages

The parameters of concern for rain gages include the depth of measurement. Measurement quality is reviewed and validated according to the SPU Meteorology SOP METR Q1100 - Data Validation (refer Appendix H).

3.3.3. SCADA Systems

SPU monitors all pump stations and two CSO facilities using a SCADA system. The parameters of concern for the monitoring of pump stations are wet well level, pump on and off cycles, pump run times and alarms. The parameter of concern for the CSO facilities is level in the control chamber and storage tanks.

Level sensors will be positioned in a specific location within the wet-well or CSO facility so the cleaning and calibration will have the least impact on the instrument bias. SPU pump stations are not equipped with flow meters. As a result, flow through the pump stations will be based on wet-well levels and pump station on/off cycles. Data will be recorded at the highest possible resolution available from the SCADA system (between 90 and 120 seconds).

4. PROJECT DESCRIPTION

This section presents the goals and objectives of the flow monitoring study. It describes the boundaries, target populations and practical constraints of the study; and specifies the information and data required to meet the study objectives.

4.1. Study Goals

The goal of the CSO LTCP is to develop and submit to Ecology a single plan by July 2014 that performs the project development (monitoring, modeling and planning) and preliminary engineering for all the 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 regulatory 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 combined sewer system for two wet seasons, October 1, 2008 through May 31, 2010. The collected data must accurately represent the conditions throughout the combined sewer system. The data will be used to characterize the hydrologic and hydraulic performance of the combined sewer system and support development of the LTCP.

4.2. Study Objectives

The objectives of the Flow Monitoring Project are as follows.

- Adequately and accurately characterize the hydrologic and hydraulic performance of the combined sewer system 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 hydrologic response of a subcatchment to rainfall.
    - Hydraulic performance is defined as the operating characteristics of structures and facilities in the combined sewer system, including in-line and off-line 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 3 storm events of recurrence interval between 6 month and 1 year at any duration, and a minimum of 2 storm events of recurrence interval between 1 year and 10 year 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.

These objectives relate directly to the study success factors discussed in Section 5.3.2.

4.3. Information Requirements

The key flow data information that is being collected and assessed as part of this study is:

- Flow monitoring data from permanent monitoring locations
- Flow monitoring data from a network of temporary monitoring locations

This data will be used to characterize the performance of the combined sewer system, supplemented by information from the following sources:

- Detailed data from SPU's network of rain gages
- Pump station operation data including historic levels and pump run-times. Pump station drawdown tests will be used to estimate pumped flow from these data.
- SCADA data from the King County regional combined sewer conveyance system

- Flow monitoring data from King County
- Sewer pipeline connectivity for model development (GIS data supplemented by survey and as-built information).

4.4. Study Boundaries

This section describes spatial and temporal boundaries of the problem, the scale of decision-making when appropriate, the characteristics that define the population of interest, and any practical constraints on data collection.

4.4.1. Spatial Boundary

The study area covers the majority of the City of Seattle. The new sites for Monitoring Phase 3 are generally located in the trunk main or storm drainage system. The sites that were installed in Monitoring Phase 1 and will remain in place for Phase 3 are located within ten CSO basins; Ballard, Delridge, Duwamish, Fremont, Interbay, Leschi, Montlake, North Union Bay, Portage Bay and Union Bay/ Madison Park. The temporary meters that were installed in Magnolia and West Seattle will be removed prior to Monitoring Phase 3 as they have collected suitable data for system characterization and model calibration.

The Alaskan Way Viaduct project and the Windermere, Genesee and Henderson CSO basins are not included in this study.

4.4.2. Temporal Boundaries

The temporal boundaries covered by this monitoring plan are from October 1 2009 through May 31 2010. Flow monitoring performed during Phase 1 (October 1 2008 through May 31 2009) and Phase 2 (June 1 2009 through September 30 2009) was covered in a separate flow monitoring plan. The temporal boundaries of the Monitoring Phase 3 may be adjusted as needed as determined by the project team. A Phase 2 and 3 flow monitoring data report will be prepared based on flow monitoring data from June 2009 to May 2010. The flow monitoring data report will be used by data analysts and modelers to assist in the calibration of the basin models and the system wide model.

4.4.3. Target Populations

The target population for this study is:

1. Hydrologic response of subcatchments within the basins

Monitors whose purpose is to characterize the hydrologic response of subcatchments are used to break up the NPDES basins into smaller areas (monitoring sub-basins), allowing for more refined model calibration and validation. The goal for each of these locations is to determine flow through a specific point. The hydrologic monitors are located outside the influence of hydraulic control structures to minimize backwater or other hydraulic conditions that interfere with measurement of the hydrologic response of the tributary area. Approximately 100 of the 150 sites installed during Phase 1 will remain in place during Phase 3. Meters that obtained suitable data have been removed or relocated to alternate sites within the system.

2. Hydraulic performance of CSO control structures within the basins

The second category of monitors is used to develop an understanding of the hydraulic performance of detention or control structures in the system, and to develop stage-discharge curves for the hydrobrakes, sluice gates and weirs located throughout the basins. A large number of the meters installed for this purpose during Phase 1 monitoring will remain in place during Phase 3 monitoring in order to capture more data for characterization of hydraulic structures.

3. Hydrologic and hydraulic response of catchments within the system wide model

The third category of monitors will be installed for Monitoring Phase 3 and their purpose is to characterize the hydrologic response of subcatchments for areas within the system wide model. These monitors generally have much larger tributary areas than the first two categories of monitors, as the calibration basins for the system wide model will be much larger than for the CSO basins. Once the system wide model is calibrated it will be used to develop boundary conditions for the CSO basin models and to provide input to King County and SPU system wide models.

4. Capture data on flows in the storm drainage system at key locations

The final category of monitors will be installed at key locations in the storm drainage system. These monitors will determine the flow in the storm drainage system. Meters will be installed in areas where treatment facilities are being considered in order to assist in sizing alternatives, and also in areas where the storm drainage system may have spare capacity or influence overflows in the combined sewer system.

4.4.4. Practical Constraints

Practical constraints in the implementation of the flow monitoring plan include both physical site constraints and equipment constraints. These include:

- Many of the monitoring sites are located in the active roadway and require traffic control measures.
- Many site selections were constrained by pipe configurations, slope, and/or hydraulic conditions.
- Some of the monitoring locations have difficulty with wireless communications. This results in the data requiring periodic manual collection.
- Over time the monitors may drift, particularly the pressure depth sensor. Quality control measures are in place to identify and adjust for drift to improve accuracy.
- Debris and silt build-up in the system will influence the data recorded by the monitors. The occurrence of debris and silt is document during site inspections and visits. Such material is removed by cleaning prior to and after monitor installation, or by “scrubbing” the monitors during maintenance visits. If the problem persists, alternatives sites will be re viewed to avoid the problem.

5. Organization and Schedule

This section describes the roles & responsibilities of the study team, the study timeline and schedule.

5.1. Roles & Responsibilities

The team consists of representatives from key groups with a role in data collection or use, and often those with a critical interest or stake in the problem. This section includes the names, duties, and responsibilities of all key team participants. This includes internal and external team members. The organizational structure is designed to provide project control and proper quality assurance/quality control (QA/QC) for the field investigation.

The roles of key individuals involved in the study are provided in Table 1. A detailed description of the lines of authority and reporting between these individuals and organizations is presented in Figure 1 and the responsibility associated with each role is outlined in Table 1.

Table 1. Study Team contact information.

Role	Name	Organization	Telephone No.
SPU Quality Assurance Facilitator	Amy Minichillo	SPU	206-684-0974
SPU CSO LTCP Project Manager	Ed Mirabella	SPU	206-684-5959
SPU CSO LTP Flow Monitoring Study Project Manager	Ben Marré	SPU	206-684-7597
SPU Field Technical Lead	Mike Hinson	SPU	206-733-9134
SPU Data Quality Lead	Laura Reed	SPU	206-615-0551
Regulatory CSO NPDES Reporting	Mike Hinson	SPU	206-733-9134
LTCP Consultant Team Project Manager	Bill Mori	CH2M HILL	425-785-9258
Project QA Coordinator	Steve Merrill	Brown and Caldwell	206-749-2293
ADS Project Manager	Mike Pina	ADS	206-762-5070
ADS Field Supervisor	Sean Winder	ADS	206-762-5070
ADS Data Manager	Gillian Woodward	ADS	206-255-6905
Stantec Project Manager	Roger Jacobsen	Stantec	614-486-4383
Stantec Field Supervisor	Chris Hurd	Stantec	513-582-7446
Stantec Data Manager	John Barton	Stantec	513-260-1768
LTCP Consultant Monitoring and Modeling Manager	Steve Merrill	Brown and Caldwell	206-749-2293
Data Screener (Delridge, Duwamish, West Seattle, North Union Bay)	Santtu Winter	CH2M HILL	425-233-3126
Data Screener (Ballard, Fremont, Magnolia, Interbay, Montlake)	Karen Younge	SPU	206-684-5975
Data Screener (Leschi, Madison Park)	Abdimalik Aar	SPU	206-615-1444
Data Screener (Portage Bay, System Wide Model Sites)	Victoria Zeledon	Brown and Caldwell	206-749-2306
Data Analyst (Leschi, Interbay)	Robin Lee	Brown and Caldwell	206-749-2205
Data Analyst (Montlake, Madison Park)	Angela Dwyer	Brown and Caldwell	206-749-2277
Data Analyst (Ballard, Fremont)	Tony Dubin	Brown and Caldwell	206-749-2266
Data Analyst (Delridge, Duwamish)	Hong Zhang	CH2M HILL	
Data Analyst (Portage Bay, North Union Bay)	David Jacobs	GHD	206-441-9385
SPU Rain Gage Manager	Brian Morgenroth	SPU	206-615-1705

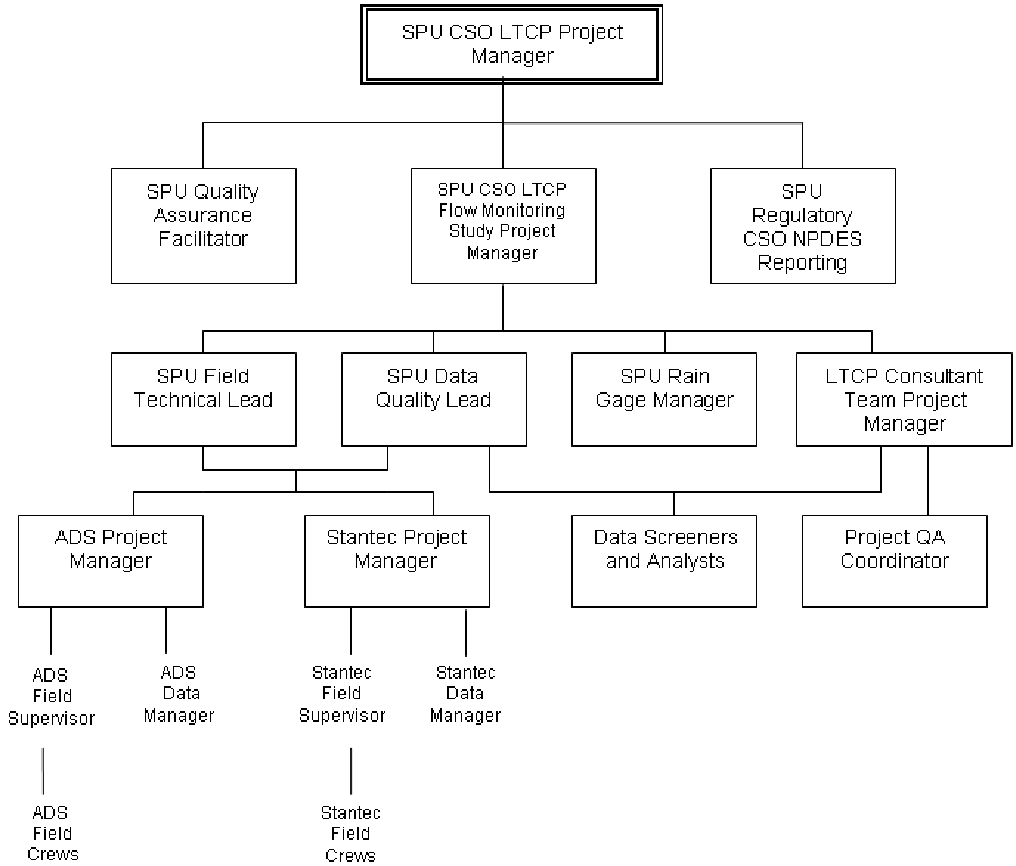

Figure 1. Organization chart illustrating study organization & lines of communication.

A description of the detailed responsibility of each role is outline below in Table 2.

Table 2.Roles & Responsibilities

Roles & responsibilities
SPU Quality Assurance Facilitator - Responsible for management and oversight of the SPU Quality Management System Program. Oversees the development of QA guidance for the QMS program. Monitors the effectiveness of the program quality system. Reviews and approves all QAPPs, internal QA audits, corrective actions, reports, work plans, and contracts. Enforces corrective action, as required. Ensures SPU personnel are fully trained and adequately staffed.
SPU CSO LTCP Project Manager - Responsible for ensuring tasks and other requirements for the Long Term Control Plan are executed on time and are of acceptable quality. Monitors and assesses the quality of work. Coordinates attendance at conference calls, training, meetings, and related project activities. Enforces corrective action requirements.
SPU CSO LTCP Flow Monitoring Program Project Manager - Responsible for verifying that the Flow Monitoring Plan is followed and the project is producing data of known and acceptable quality. Ensures adequate training and supervision of all monitoring and data collection activities.
SPU Data Quality Lead - Responsible for the acquisition, verification, and transfer of flow monitoring data to the SPU database, and for the verification and transfer of rain gage data to the SPU database. Oversees data management for the study. Ensures data is submitted according to work plan specifications. Manages and implements the LTCP Action items list. Provides the point of contact to resolve issues related to the data.

Roles & responsibilities
SPU Field Technical Leader – Responsible for the coordination of field work with ADS and Stantec, manages the procurement of equipment and purchasing
SPU Regulatory CSO NPDES Reporting - Responsible for preparing and submitting CSO reporting for NPDES permit compliance.
LTCP Consultant Project Manager - Responsible for the project management and contract administration; identifying, receiving, and maintaining project quality assurance records; for coordinating with the QA Coordinator to resolve QA-related issues. Enforces corrective action.
LTCP Consultant Project QA Coordinator - Provides quality assurance technical expertise in the subject matter area to facilitate the development, implementation, and maintenance of the QAPP. Notifies the Project Manager of particular circumstances which may adversely affect the quality of data. Responsible for validation and verification of data collected.
Project Manager (ADS & Stantec) - Responsible for insuring flow monitoring services meet needs of the project. Attends meetings with project team and coordinates transfer of data and other information among project team.
Field Supervisor (ADS & Stantec) - Responsible for supervising all aspects of field work including the installation, maintenance and relocation of monitors and undertaking field measurements to verify monitoring data. Coordinates with SPU Field Technical Leader and is responsible for field scheduling, staffing, and ensuring that staff are appropriately trained.
Data Manager (ADS & Stantec) - Responsible for the acquisition, verification, and transfer of data to the SPU database. Oversees data management for the study. Ensures data are submitted according to work plan specifications. Provides the point of contact to resolve issues related to the data.
LTCP Data Screeners (SPU, CH2M HILL and Brown and Caldwelll) – Responsible for the ongoing review of flow monitoring data. Attends workshops with the project team. Identifies data gaps, meter inadequacies and other issues and coordinates with the SPU Data Quality Lead.
LTCP Data Analysts (CH2M HILL, Brown and Caldwell, GHD) – Responsible for ongoing review and assessment of flow monitoring data including identification of meter discrepancies, assessment of suitability of data for modeling purposes and other issues. Presents workshops with the project team.
SPU Rain Gage Manager - Oversees rain gage data management for the study. Ensures data are submitted according to work plan specifications.

5.2. Special Training Needs/Certification

This section identifies and describes any specialized training or certifications needed by personnel in order to complete the study or task successfully.

Special training for personnel installing and maintaining monitoring equipment includes:

- Confined Space Entry – Confined Spaces Training will be obtained by all personnel entering maintenance holes and other confined spaces

- Flagger training and a valid certification card is required for sites requiring traffic control

- Field personnel installing and maintaining the monitoring equipment must be *Field Certified*. Analysts for ADS and Stantec complete Data Analyst Certifications that require approximately 10 hours of specialized training, supplemented by 24 weeks of supervised practical training, and followed by competency testing. Health and Safety Plans are included in Appendix F and G.

5.3. Timeline/study schedule

This section specifies the relevant deadlines for the study, and the ongoing requirements throughout the duration of the study, as outlined in Table 3.

Table 3. Project Schedule

Date	Responsibility	Project Element
June – August 2009	SPU, LTCP Consultant Team	Determine list of alternative temporary meter installation locations
July – October 2009	Stantec	Inspect alternative temporary meter locations
July –October 2009	Stantec, SPU, LTCP Consultant Team	Review inspection results and approve final locations for temporary meter installation
July – October 2009	Stantec	Install temporary meters
October 2009	Stantec/ SPU	Initial 2-week data collection
October 2009	SPU, LTCP Consultant Team	Initial data review and monitoring workshop
October – November 2009	LTCP Consultant Team	Prepare draft and final flow monitoring plan
October 2009 to May 2010; twice per week*	Stantec	Upload preliminary data from temporary meters for review
October 2009 to May 2010; on the 28th of each month.**	ADS	Upload finalized data for the previous month for permanent CSO sites and rain gages
October 2009 to May 2010; once per week*	SPU, LTCP Consultant Team	Check data and prepare checklist commenting on data quality.
October 2009 to May 2010; once every two weeks	SPU	Deliver SPU SCADA data to data screeners
November 2000 to May 2010*	SPU	Prepare and distribute summary report for each week of data review
November 2009 to June 2010; every second month*	Stantec, SPU, LTCP Consultant Team	Monitoring workshops to review adequacy of data for model calibration
December 2009 to May 2010; every second month	King County	Deliver King County SCADA data to SPU
July – August 2010	SPU, LTCP Consultant Team	Prepare final, comprehensive data report (draft, final versions) based on 2009-10 monitoring period

** Regular data review may be decreased if warranted by overall high data quality or periods of decreased precipitation, and agreed to by project team*

***During the first 6 months of data collection, data submittals by Stantec will include preliminary data to be finalized after the first 6 months of monitoring.*

5.3.1. Study Deliverables

The key study deliverables and their anticipated schedule are outlined in Table 4.

Table 4. Study Deliverables

Date	Responsibility	Project Deliverable
June – August 2009	SPU, LTCP Consultant Team	Determine list of alternative temporary meter installation locations
July – October 2009	Stantec	Inspect alternative temporary meter locations
July –October 2009	Stantec, SPU, LTCP Consultant Team	Review inspection results and approve final locations for temporary meter installation
July – October 2009	Stantec	Install temporary meters
October 2009	Stantec/ SPU	Initial 2-week data collection
October 2009	SPU, LTCP Consultant Team	Initial data review and monitoring workshop
October – November 2009	Brown and Caldwell	Prepare draft and final flow monitoring plan
November 2009 to April 2010; twice per week*	Stantec	Upload preliminary data from temporary meters for review
November 2009 to September 2010; on	ADS	Upload finalized data for the previous month for permanent

Date	Responsibility	Project Deliverable
the 28th of each month.**		CSO sites and rain gages
November 2009 to April 2010; twice per week*	SPU, LTCP Consultant Team	Check data and prepare checklist commenting on data quality.
November 2009 to April 2010*	SPU	Prepare and distribute summary report for each week of data review
November 2009 to June 2010; every second month*	Stantec, SPU, LTCP Consultant Team	Monitoring workshops to review adequacy of data for model calibration
July – August 2010	SPU, LTCP Consultant Team	Prepare final, comprehensive data report (draft, final versions) based on 2009-10 monitoring period

** Regular data review may be decreased if warranted by overall high data quality or periods of decreased precipitation, and agreed to by project team*

***During the first 6 months of data collection, monthly data submittals will include preliminary data to be finalized after the first 6 months of monitoring.*

5.3.2. Study Success Factors

The critical success factor is to obtain sufficient rainfall depth, level, velocity and operational data to adequately and accurately characterize the hydrologic and hydraulic performance of the combined sewer system. As defined in Section 4.2, the project objectives include capturing data for model calibration before, during and after storms in the following categories:

- Smaller storms with recurrence interval between 6 months and 1 year at any duration
- Larger storms with recurrence interval between 1 year and 10 year at any duration

The criteria for determining whether the data is suitable for model calibration are discussed in Section 13 and 14. It is desirable to capture data from at least two storms in each of the above-mentioned categories under a range of antecedent moisture conditions. It is also desirable to capture data from large storms that cause all of the basin outfalls to overflow; storms in this category would benefit model calibration but may not occur and are not a critical success factor.

Relationships between parameters within the basin model, such as average dry weather flow, diurnal patterns, peak wet weather flow rates, wet weather hydrologic responses, and the resultant CSO flows will be developed based on the data collected during this study. Additionally the relationship between pressure head and discharge for each hydrobrake and sluice gate will be developed using data from this study. These two series of relationships are needed to develop and calibrate hydraulic models, and to quantify uncertainty associated with the model.

Element II. Type, Quality and Quantity of Data Needed

This element describes the type, quality, and quantity of data needed to meet the study objectives and includes:

> Section 6 - Quality Objectives, which describe the type and quality of data needed to meet the study goals and objectives, and
>
> Section 7 - Sampling Process Design, which determines the quantity of data needed

6. Quality Objectives

This section describes the study data quality and measurement quality objectives, which describe the type and quality of data needed to meet the study goals and objectives.

Data Quality Objectives (DQOs) are qualitative and quantitative statements developed using the data quality objectives process that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors. These will be used as the basis for establishing the quality and quantity of data needed to support decisions.

Once established, DQOs become the basis for the measurement quality objectives (MQOs) that are used specifically to address analytical performance.

Measurement Quality Objectives (MQOs) are "acceptance criteria" for the quality attributes measured by the study data quality indicators (DQIs). During study planning, measurement quality objectives are established as quantitative measures of performance against selected data quality indicators, such as precision, bias, representativeness, completeness, comparability, and sensitivity. By extrapolation, data that meets defined MQOs are considered acceptable for use in study decision making.

Flow monitoring equipment can be shown under laboratory conditions to meet quality standards for instrumentation. In the field, however, site conditions influence the quality of the data collected and various tools, such as scattergraphs, flow balancing and field verifications build confidence in the flow data quality.

6.1. Data Quality Objectives

The Data Quality Objectives (DQOs) specify how good a decision must be, but do not directly set criteria for the quality of the data or express data quality characteristics. The outputs of a Decision (or Data) Quality Objectives (DQO) Process are needed to determine the number of samples that must be taken and analyzed.

6.1.1. Data Quality Objectives Process

The goal of the Flow Monitoring Study is to gather rainfall depth, operational data, and level and velocity data in the combined sewer system during Monitoring Phase 3. The collected information will be used to calibrate a hydrologic and hydraulic computer model and the analyze the performance of uncontrolled NPDES basins, and to develop a system wide model. To accomplish this goal, multiple flow monitors will be deployed to allow characterization of flows from various sections with potentially different characteristics, as well as to define performance of auxiliary structures. A review of the sewer system within the basins together with consideration of financial obligations led to the specification of a study including 171 velocity and or depth monitors installed during Phase 1, of which 56 were removed prior to Monitoring Phase 3. 50 new velocity and or depth monitors were added to the study for Monitoring Phase 3. After preliminary sites were identified for monitor location, each site was reviewed in the field and inspected by Stantec to insure placing monitors at locations that would maximize the probability of collecting accurate data. The location process is described further in Section 7.

6.1.2. Objectives Established to Insure Quality

The model calibration process requires accurate velocity, depth, and corresponding rainfall data over a series of several rainfall events. SPU established the following data quality objectives in the Stantec contract to insure collection of quality data.

Stantec shall designate a lead data analyst (DA) who will oversee the data quality assurance /quality control (QA/QC) of the flow monitoring data. Stantec shall be expected to provide at least 95% usable data (number of usable data points divided by total number of data points collected). Data that is unusable shall include missing data points, inaccurate data points due to failed or mis-reading sensor(s), data that cannot be corrected, or data that is skewed/inaccurate due to debris or upstream hydraulic conditions (e.g., bend, orifice, drop maintenance hole, etc.).

Stantec will be responsible for the following activities:

1. Weekly review of flow monitoring data, including flow-time series and level-velocity scattergraphs

2. Prompt review of data from all sites immediately following a rain event

3. Maintaining a database that flags and records notes in invalid or questionable velocity, depth, or flow data

4. Reconstituting identified invalid or questionable depth or velocity data that has a reasonably repeatable hydraulic depth and velocity relationship

5. Maintaining a database that flags and records notes on reconstituted data

6. Issuing service requests in the event that a flow monitor needs service

7. Contacting SPU in case there are maintenance issues (e.g., debris build-up) that need to be resolved to provide usable data

8. Performing field confirmation of the equipment as-needed

9. Ensuring that all time stamps are adjusted correctly for daylight savings time changes

10. Maintaining a database field for all data points indicating whether the data is raw, QC'd or finalized.

All activities initiated by the data analyst shall be documented, and the data analyst shall also document when service requests have been completed (including services provided by City staff, such as sewer maintenance). In addition, Stantec will be responsible for responding to data inquiries from the City and/or its Consultants within 48 business hours. In the event of a data inquiry, Stantec shall review the data immediately, dispatch a field crew (if necessary), and resolve the problem (if one exists) within 72 hours of field identification of the issue.

Stantec shall submit QA/QC'd data with notes and flags to the City and/or its Consultants every two weeks, no more than one week following collection of the data. Stantec shall send its lead data analyst to monthly flow monitoring workshops with the City and/or its Consultants for each group of 20-50 sites. During each workshop, Stantec shall be prepared to discuss the data QA/QC activities, field activities, data issues with any of the sites, recommendations to resolve new data issues, and progress resolving previously identified data issues.

Stantec shall also be prepared to provide alternative suggestions for monitoring if site hydraulic conditions present major obstacles to collecting good data. The monthly workshop schedule will be modified for periods of minimal monitor maintenance.

6.2. Measurement Quality Objectives

Measurement quality objectives (MQOs) specify how good the data must be in order to meet the objectives of the study. MQOs are the performance or acceptance thresholds or goals for the study's data, based primarily on the data quality indicators.

Another name for MQOs is measurement performance criteria (MPC). For existing data, these correspond to acceptance criteria. MQOs are used to select procedures for sampling, analysis, and quality control (QC).

Of the six principal data quality indicators, precision, bias, and sensitivity are quantitative measures; representativeness and comparability are qualitative; completeness is a combination of both qualitative and quantitative measures; and accuracy is a combination of precision and bias.

6.2.1. Precision

Precision is a statistical measure of the variability of a measurement when a collection or an analysis is repeated and includes components of random error. It is strictly defined as the degree of mutual agreement among independent measurements as the result of repeated application of the same process under similar conditions. Or expressed another way, precision is a measure of the closeness with which multiple readings of a given sample agree with each other.

For this flow monitoring study, velocity and depth scattergraphs will be reviewed to evaluate the precision of the data set. However, because the physical entities being measured (depth and velocity) change with each sample point taken, the data set as a whole must be viewed for relative precision, rather than the preciseness of each point to another. While the meter and sensor technology is highly repeatable (see equipment specification sheets in Appendix B), data collected from flow metering sites indicates varying relationships between depth and velocity (the relationship referred to as the hydraulic signature). The hydraulic signature is expected to stay fairly constant during a period of dry weather. However, debris in the system and the transitioning presence of silt are just some of the factors that result in this signature changing. Such changes in data signature will be a key focus of the bi-weekly and monthly data reviews discussed in Section 10. Sites that show patterns inconsistent or invalid shifts (a data set on a scattergraph that moves vertically or horizontally usually indicates a fault with either the depth or velocity sensing device), or reveal no determinate hydraulic signature will be reviewed by the project team and recommendations made for improvement (e.g., modification of O&M procedures, relocation, or removal).

6.2.2. Bias

Bias is a statistical measurement of correctness and includes multiple components of systematic error. A measurement is considered unbiased when the value reported does not differ from the true value. Bias is revealed in flow metering data sets by conducting field verifications. On the depth side, this is a comparison of a manual reading taken with a ruler in the flow against the meter depth reading. On the velocity side, this is a comparison of a manual velocity taken with a handheld velocity meter against the meter peak velocity reading. As part of the standard data analysis procedure, bias adjustments may be applied to the data set upon additional verification and shall be noted in the site commentaries. As a rule of thumb, if the confirmations indicate a bias of less than +/- 0.25" or a +/- less than the +/_ given by the field crew onsite (for example, a site where the flow surface has standing waves may be given a manual measurement confidence of +/- 0.5 0" by the field crew taking the manual reading), then a depth adjustment will not be made to the meter data. If an adjustment is to be made, first an attempt is made to determine if any of the following measurements contribute to that bias – pipe height, offset of ultrasonic sensor to crown of pipe, offset of the pressure sensor. As a rule of thumb, the handheld peak velocity measurement should be within 20% of the meter reading. Adjustments for velocity are affected through the gain value, which is discussed further in Section 10. Discussion of any site confirmations and reviews of bias are included as part of the monthly review process, also discussed in Section 10.

For rain gages, wind is generally the largest source of bias resulting in a volumetric loss of between 2 to 10 percent of the actual rainfall. Rain gage site verifications will be performed to ensure the gages are accurately recording depth.

6.2.3. Representativeness

Representativeness is ensured by a well-defined sampling strategy designed to collect measurements that represent the average properties of the site. This is ensured by collecting a sufficient number of samples to characterize the site or collecting measurements that appropriately define the site characteristics. Means of collection and standard methods used to collect flow measurements are defined in the body of this document. It should be remembered that representative data are defined by the method of collection and the manner in which the method is implemented. Therefore, collecting representative data is dependent upon individual or site-specific facts, including the instrument of choice for measuring a particular flow, survey methods used for instrument placement, determining whether flow is turbulent or laminar, and placement of the sensors in the site.

The duration of this study is approximately 12 months and encompasses both the traditional wet and dry periods of weather in the Pacific Northwest. It is anticipated that the length of the data set over this period of time will be representative of the hydraulic characteristics of each site and include the effects of high groundwater in the antecedent soils. Classification of storm events with respect to historical frequency is included as part of the monthly data reviews discussed in Section 10.

6.2.4. Completeness

Raw Data Completeness defines the total number of missing measurements the utility is willing to accept over a defined period as a result of equipment malfunction. This project established a 5 percent target value (95 percent complete). Missing measurements means the raw data does not exist. Completeness is calculated as:

*Raw Data Completeness Test 1= 100 * (Total Number of Collected Points) ÷ (Total Number of Possible Data Points)*

6.2.5. Comparability

Comparability is generally achieved by the use of standard methods. This makes collected data comparable to other sites or projects that have similarly defined situations. Standardizing methods for the collection of flow data is one of the objectives of this document. Confidence in the comparability of data sets for this project is based on the commitment of project staff to use only approved sampling and analysis methods and QA/QC protocols in accordance with quality system requirements and as described in this Flow Monitoring Plan and in the associated SOPs.

In order to evaluate data comparability, flow balancing analysis is conducted as part of the monthly data reviews to compare data from a given monitor with that from upstream and downstream monitors. In addition, data screening and monthly data reviews look for any changes in site data signatures as expressed by level-velocity scattergraphs.

6.2.6. Sensitivity

Sensitivity of measurements is addressed by using industry standard equipment. Sensitivity and reporting limits for the equipment used in this study are given in equipment specifications included in Appendix B.

7. Sampling Process Design (Experimental Design)

The purpose of this section is to provide a description and justification for the selection of monitoring locations. The required data to meet the project objectives described in Section 4.2 will be gathered from the following categories of monitoring locations:

- Permanent monitors that were existing prior to this study (pre October 2008)
- Temporary monitors installed for Monitoring Phase 1 and remaining in place for Monitoring Phase 3.
- Temporary monitors installed for Monitoring Phase 3
- SCADA data from SPU and King County lift stations
- Flow monitors operated by other studies or agencies (such as King County)
- Rainfall data from nearby SPU rain gages

With the exception of the rain gages, all of these categories of monitoring locations will monitor velocity and level and/or pressure. Monitoring within each specific category is further described in the following sections.

7.1. Permanent Monitoring Locations

The City of Seattle's CSO system is permitted through Washington State Department of Ecology. There are a total of 92 permitted outfalls listed on the permit, but 2 have been removed (39 and 63), and NPDES 150 has been combined with NPDES 151 into a single entity (named NPDES 150/151) for reporting purposes, since the permit was issued on Nov 30, 2005. At NPDES 150/151, a single overflow point exists, discharging to a single outfall pipe, which eventually branches into two parallel pipes that discharge at the same location. Currently monitoring and reporting is thus undertaken at 89 permitted CSO locations. ADS Environmental currently monitors and reports to SPU on 65 permitted CSO's. The remaining 24 permitted CSOs are monitored by SPU pump station SCADA data points.

Some of the ADS monitors record data during overflow events only but the majority also measure level and velocity during both dry and wet weather. The data from these monitors will also be used in this study to characterize dry and wet weather flows within a basin and supplement the information that will be obtained from the temporary monitors. In some of the smaller basins, the permanent monitors are the only monitors in place.

Data from 50 of the 89 permitted CSO outfalls will be screened and reviewed as part of the LTCP flow monitoring effort. Details of these permanent monitors, including their location, overflow condition and meter type, are summarized in Table T-17.

7.2. Temporary Monitoring Locations

Stantec is responsible for installing and maintaining the network of temporary monitors. A three-step selection process was undertaken to determine suitable locations for the temporary flow monitors.

1. Initial site selection based on GIS mapping

An initial candidate list for the temporary monitoring locations was developed by the team members based on a GIS map review. The GIS review eliminated maintenance holes that were located in inaccessible or inappropriate locations such as busy traffic intersections or private property. For each desired monitoring locations, a minimum of one additional site was identified for inspection in case the preferred candidate location was deemed unsuitable for monitoring.

2. Revised site selection based on field inspections

A field inspection was undertaken by Stantec, SPU and Brown and Caldwell to evaluate the initial candidate list. Each preliminary site was evaluated for its suitability for flow monitor installation. Potential alternative sites were also investigated in case the hydraulics at the preferred sites were not suitable. Sites were deemed unsuitable for monitor installation for a variety of reasons including:

- Maintenance holes located in busy roads, commercial parking lots, near residences or with landscaping
- Maintenance holes located in inaccessible locations with no vehicular access

- Maintenance holes that were unable to be located in the field or had been sealed or built over

3. Final site selection based on maintenance hole inspections

Stantec staff undertook maintenance hole inspections to determine whether the selected sites were suitable for monitor installations based on site hydraulics. Many of the sites were eliminated based on the maintenance hole inspections. Reasons for eliminating sites included:

- Pipes with inconsistent gradients, such as steep pipe sections located upstream of flatter sections that would cause an overestimation of velocity
- Drop maintenance holes
- Pipes with lateral connections causing turbulence
- Pipes with very rough flow
- Pipes with roots or other obstructions causing turbulence ahead of the probe
- Cracked or offset pipes
- Pipes with silt
- Maintenance holes in which maintenance is difficult such as deep maintenance holes or poor maintenance hole shape
- Surcharged maintenance holes

The results of Stantec's site inspections were evaluated by the project team and a final list of monitor locations was approved for installation by SPU. A complete list of all sites inspected for Monitoring Phase 3 is included in Table T-15. The table includes whether they were approved for installation, designated as an alternate or rejected because they were not suitable sites for monitoring.

The location, purpose, and site characteristics of the temporary monitors are described in Table T-18 and Table T-19. Table T-18 describes the temporary monitors that are located within the NPDES basins. Table T-19 contains information for temporary monitoring locations that were installed for the system wide model.

During the course of the study, temporary monitors may be removed if the study team determines that they have captured sufficient data or that the data captured is not suitable for model calibration. These monitors will be relocated to alternate sites in the system. Sites that were removed are noted in Table T-18.

7.3. SCADA Monitoring Locations

SCADA data will be obtained from SPU pumping stations to supplement the calibration and verification of the model. This data will consist of wet-well level at a one-minute data resolution, and pump run time data. SCADA data is also collected from the detention tank and control structures in the Delridge basin.

SPU will also complete draw down tests for the pumping station to determine their capacities. The SCADA data and draw down test results will be used to calculate flow hydrographs for use in model calibration.

7.4. King County Monitoring Locations

King County maintains a network of monitors throughout their trunk sewer system at pump stations and regulator stations. Data from the existing King County monitors will be collected from these locations to supplement the data from temporary monitors for model calibration.

7.5. Rainfall Monitoring Locations

SPU maintains a network of rain gages throughout the city. Thiessen Polygons were created for the SPU rain gages. During the screening of data for the Monitoring Phase 1, nine of the 17 existing gages were assigned to assist the screening process. Data from additional gages may be used in the model development and calibration. The data from these gages is expected to be suitable for model calibration and analysis. The location of the rain gages is shown in Drawing 2, and details of the rain gages are shown in Table T-22.

Element III. Sampling and Measurement Procedures

This element describes the sampling and measurement procedures needed to acquire the data and includes:

Section 8 – Sampling (Field Procedures), which describes the sample collection procedures required to obtain the data

Section 9 – Measurement Procedures and Technology, which describes the different types of equipment that will be used to obtain the data

8. Sampling (Field) Procedures

This section describes the procedures for sample collection during the flow monitoring study. Samples for this study consist of depth, level, and velocity measurements of combined sewer flow, and rain gage data.

8.1. Sample Collection Procedures

Installation of flow monitors by Stantec will be documented using standard site install reports. The installation sheets will be stored in ZFM2.

Ongoing site visits by Stantec or ADS personnel (e.g., site verification visits requested through work orders to verify accuracy) will be recorded using site visit logs. Site verification visits will include comparing actual depth measurements to the monitor depth and comparison of peak velocity to monitor peak velocity. Site visits will conform to the SOPs that are provided in Appendix H. Site visit logs will be stored in Intelliserve (ADS) and ZFM2 (Stantec).

Adjustments to monitoring equipment or changes to the site reported on the site visit logs will also be recorded in weekly data summary reports by SPU. Monthly data reports will also record any adjustments to the site.

8.2. Sample Handling & Custody

The data is collected by automatic flow monitors in-situ and there are no handling or custody issues of note.

9. Measurement Procedures & Technology

This section describes the measurement procedures and technology that will be used in the flow monitoring study.

9.1. Measurement Procedures

Data from the flow monitors will be recorded at 5-minute intervals in order to achieve high-resolution data that is suitable for model calibration. A longer recording interval could potentially miss peak flows particularly for the monitors with small contributing areas. Data from SPU Rain gages are reported in finalized format in one-minute data collection intervals.

Comparisons will be made between manual field measurements (known as confirmations) and monitor values to ensure that the monitors are recording reasonable data. Confirmations are obtained in-situ at the sensor location in the pipe. Manual depth measurements will be taken with a ruler and manual velocity measurements by a calibrated, portable velocity meter. A velocity profile across varying depths will be obtained if sufficient depth of flow exists in the pipe (greater than 5 inches). If there is insufficient depth, the average velocity of the flow is assumed to be 0.9 of the peak velocity of the flow measured.

Measurement procedures are described in the *ADS Quality Assurance and Implementation Plan* (Appendix D) and the *Stantec Data Analysis and Meter Installation Manuals* (Appendix E). The SPU SOPs shown in Table T-7 will be followed when and where they are applicable. The full text of each of these SOPs can be found in Appendix H. Specifications and descriptions of the measurement methods for the flow meters used in this project can be found in Appendix B.

9.2. Measurement Technology

This section describes provides a brief description of the different types of meters that will be used in this study. These include the ADS Flowshark, ADS Flowshark Pulse, ISCO 2150 Flow Module, ISCO 2210 Flow Module and the ISCO4230 Bubbler.

Each meter includes data acquisition sensors and battery-powered microcomputers. The microcomputers include a processor unit, data storage and a built-in clock to control and synchronize sensor recordings. The monitors will be programmed to acquire and store level and velocity readings at 5-minute intervals. A laptop computer or direct download via wireless communications will be used to retrieve and store data from the monitors.

Specification sheets for each of the different types of monitors are included in Appendix B.

9.2.1. ADS Flowshark

The ADS FlowShark is an area-velocity flow monitor that measures depth and velocity; the continuity equation is used to calculate flow. There are three types of data acquisition sensors 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, which is 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, us 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 ulstrasonic depth sensor. It is also used to record depth in surcharged maintenance holes where the ultrasonic depth measurement cannot be used.

Velocity is measured using the ADS V-3 digital Doppler velocity sensor. This sensor measures 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.

9.2.2. ADS Flowshark Pulse

The ADS Flowshark Pulse meters have gated cross correlation technology with digital pattern detention to measure velocity at multiple depths in the flow profile. They also have an upward looking ultrasonic sensor to directly measure depth. The Pulse meters were used at sites where hydraulic conditions are not suitable for general purpose meters, such as sites with large diameter pipes low or velocity. Pulse meters are typically prone to sedimentation. However, during Phase 1 and 2 it was found that rotating the sensors and using a crown mounted ultra for depth measurements allowed better use of these meters in sites prone to sedimentation.

9.2.3. 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 that is built on digital electronics, so the analog level is digitized in the sensor itself to overcome electromagnetic interference. The level is measured by a pressure sensor within the AV probe. The probe is factory calibrated for 10-foot span at different temperatures which eliminates drift in the level signal.

9.2.4. ISCO 2151 Intrinsically Safe Area Velocity Flow Meter

The ISCO 2151 is the intrinsically safe version of the 2100 Area Velocity Flow Meter. It uses continuous-wave Doppler technology to measure mean velocity. The sensors transmits an ultrasonic pulse and measures the frequency shift of pulses reflected by air bubbles or particles in the flow. A differential pressure transducer is used to measure level depth which is then used to calculate the flow area.

9.2.5. ISCO 2110 Ultrasonic Flow Module

The ISCO 2110 Ultrasonic Flow module provide non-contact liquid level measurement. The ultrasonic level sensor is mounted above the flow transmits sounds waves, which 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.

9.2.6. ISCO 4230 Bubbler

The ISCO 4230 Bubbler uses and 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 study, the ISCO bubbler meter will be used to measure depth in structures where there is a restriction on electronic signals from in-stream sensors.

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Element IV. Quality Assurance/ Quality Control Procedures

This element describes the study implementation Quality Assurance/Quality Control (QA/QC) procedures to ensure the QAPP is implemented as prescribed. It includes the following sections:

Section 10 –Quality Control,

Section 11 – Data Management and Documentation Procedures, and

Section 12 – Audits and Reports.

10.Quality Control

It is critical to the project to ensure that the collected data is suitable for its intended purpose and that appropriate measures are in place to identify unsuitable data and replace or relocate monitors that are not collecting suitable data. SPU is committed to obtaining high-quality data for the project through both internal and external processes. This commitment is evident in the following:

- Evaluating each site prior to meter installation to ensure data would meet project objectives and suitable hydraulic conditions existed
- Obtaining input and review from the primary users of the data (modeling, engineering, maintenance, etc.).
- Requiring regular download and access to the data through ADS *Intelliserve* and ZFM2, and requiring all users to be trained in accessing the data.
- On-going review of the data in triplicate by SPU, the flow monitoring contractor and the consultant throughout the monitoring period to ensure the monitors are collecting accurate and reliable data.
- Requiring regular and periodic data review at various levels of detail.
- Establishing benchmark decision points throughout the project where collected data will be evaluated in meeting the project objectives.
- Establishing protocols by which to resolve and correct data quality issues. These protocols are discussed in Section 12.
- Maintaining an action items list using Google documents to ensure that all outstanding issues are prioritized and addressed

Two weeks after installation of the new meters, an assessment of the quality and suitability of the data to support the project objectives will be made. Adjustments to monitoring locations or methodology may be made in coordination with the project team members. Flow balancing will also be performed as an additional level of quality control.

Throughout the monitoring period, Stantec, SPU,CH2M HILL, Brown and Caldwell and GHD will review the data, and classify it according to the criteria outlined in Section 14. Inconsistent or apparent changes in hydraulic conditions will result in a work order to visit the site to verify the accuracy of the monitor; poor depth or velocity values will be flagged.

The protocol that will be used to guide the weekly and biweekly review of the data, including the data review template that will be used, is included in Appendix C. Google documents will be utilized to maintain and update an action items list.

At conclusion of the project, the preliminary data will be post-processed to adjust the data to the verification visits. A minimum of two velocity and depth verifications will be performed at each site. Site verifications will include comparing actual depth measurements to the monitor depth. The profile of velocity measurements at varying depths will be used to determine average velocity. The site's gain (peak to average velocity ratio) will be determined for each site.

The flow monitoring and data assessment procedure is shown in Figure 2. Additional quality control procedures are documented in the ADS Quality Assurance and Implementation Plan provided in Appendix D and the Stantec Data Analysis and Meter Installation Manuals (Appendix E) and the SOPs (Appendix H).

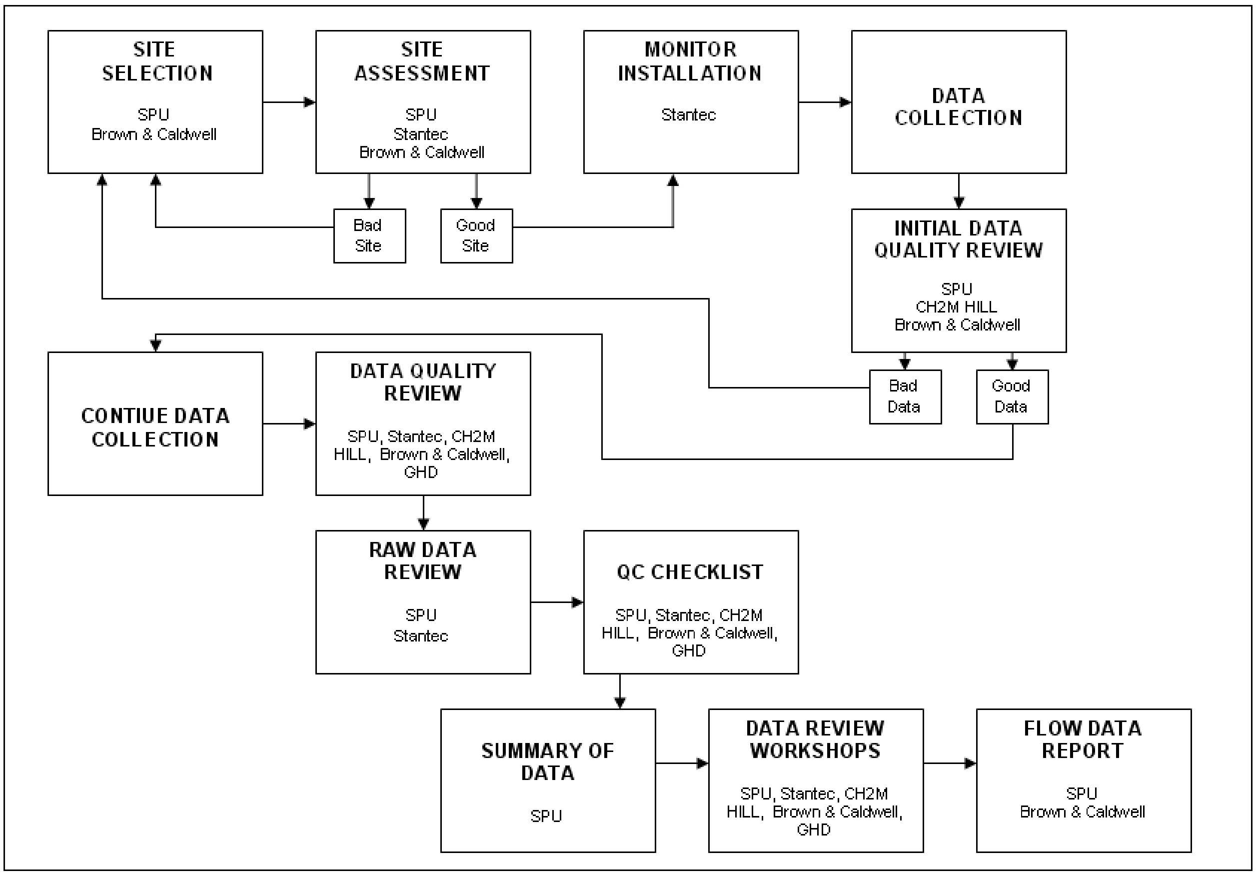

Figure 2. Flow Monitoring and Data Assessment Procedure

11. Data Management & Documentation Procedures

This section discusses data management, which addresses the path of data from recording in the field or laboratory to final use and archiving. The data management and documentation strategy combines the use of Standard Operating Procedures (SOPs) that specify documentation needs and provide for consistency when collecting, assessing, and documenting environmental data and electronic storage of all documents and records on servers that are regularly backed up.

11.1. Data Management Tools

Intelliserve, ZFM2 and SPU's FTP site will be used for viewing the data and maintaining site records throughout the study period.

Documents will be archived in portable document format (pdf) on the City of Seattle's Science Information Catalog (SIC), an Oracle Portal-based document library. Data will be managed and archived in the City's Science Information Management System (SIMS), an Oracle-based information management system. These documents will be retained for a minimum of 5 years.

11.1.1. Intelliserve

Intelliserve is a web-based information management system that displays the ADS flow monitoring network and enables the user to graphically view data. It contains raw unadjusted data from the permanent flow monitoring locations. ADS will load site data daily from sites with wireless communications and twice weekly from sites with manual communications.

11.1.2. ZFM2

ZFM2 is a Microsoft Access based program developed by Stantec for the purposes of storing and analyzing flow monitoring data. It will be used for reviewing the data from the temporary monitoring locations. ZFM2 contains both raw and adjusted data for each site, as well as site photos, site sheets and records of any maintenance issues or modifications to the sites. Stantec will load site data to the FTP site twice weekly throughout the monitoring period. Reviewers of the data will be able to download the updated data from the SPU FTP site.

11.1.3. SPU FTP Site

SPU will set up an FTP site for the transfer of data between project team members. The FTP site will include ZFM2 updates, as well as SCADA data, and other key information related to the study.

11.2. Document and Records

The purpose of this section is to describe the information to be included in data reports and to identify all project records and documents that will be produced. In addition, this section describes the requirements for final disposition of records and documents, including location and length of retention period.

SPU will prepare a summary report for each week of data. These weekly reports will include an evaluation of the data in terms of data completeness and quality. It will also include screening comments and any actions that need to be undertaken, such as maintenance or meter replacement. A summary report will also be produced outlining the status and percent complete of the data.

At the conclusion of the monitoring, a flow data report will be produced. Additional information on the flow data report is provided in Section 15.

11.3. Revisions to the QAPP

In the event that significant changes to this QAPP are required prior to the completion of the study, a revised version of the document shall be prepared and submitted to the Principle Investigator for review. The approved version of the QAPP shall remain in effect until the revised version has been approved.

Expedited Changes to the QAPP should be approved before implementation to reflect changes in study organization, tasks, schedules, objectives, and methods, address deficiencies and non-conformance, improve operational efficiency and accommodate unique or unanticipated circumstances. Requests for expedited changes are directed from the Study Manager to the Principle Investigator in writing. They are effective immediately upon approval by the Principle Investigator and Quality Assurance Coordinator, or their designees, and any regulatory authority if needed.

Justifications, summaries, and details of expedited changes to the QAPP will be documented and distributed to all persons on the QAPP distribution list by the Principle Investigator. Expedited changes will be reviewed, approved, and incorporated into a revised QAPP during the annual revision process or within 120 days of the initial approval in cases of significant changes.

12. Audits and Reports

This section discusses assessment, response actions, and corrective actions to ensure all data is being collected as described in this Plan.

12.1. Assessments and Response Actions

Field, analytical, and data management activities will be evaluated based on the schedule below.

Table 5. Assessment and response action schedule.

Assessment Activity	Approximate Schedule	Responsible Party	Scope	Response Requirements
Monitoring Site Investigation	Prior to monitor installation	SPU, Stantec, Brown and Caldwell	Investigate proposed flow monitoring sites for adequate hydraulic conditions.	Identify potential monitoring locations
Monitoring Site Installation	Following Initial Investigation	Stantec	Install monitors	Prepare site installation sheets and upload to ZFM2
Data Screening	Twice per week	SPU, Stantec, CH2M HILL, Brown and Caldwell, GHD	Perform data collection (via Intelliserve or ZFM2) and review for comparison with previous data. Check all readings for consistency and screen for deviations in the flow patterns.	Address issues identified in audit with site visits, as necessary. Provide monthly data report summarizing data and corrective actions.
Data Entry Audit	Twice per week	SPU Data Manager	Review raw data and prepare summary report for each week of data collected.	Notify ADS/ Stantec if data issues identified. Provide weekly summary report on data quality, identifying issues/maintenance related to meter operation and data quality.

Assessment Activity	Approximate Schedule	Responsible Party	Scope	Response Requirements
Detailed data Inspection and Workshop	Once every two months	SPU, Stantec, CH2M HILL, Brown and Caldwell, GHD	Review data to ensure quality meets project objectives and modeling needs.	Prepare meeting minutes and copy of presentation materials.

12.2. Deficiencies, Nonconformances and Corrective Action

Deficiencies are defined as unauthorized deviation from procedures documented in the QAPP. Nonconformances are deficiencies that affect quality and render the data unacceptable or indeterminate. Deficiencies related to flow monitoring systems include, but are not limited to, monitor malfunctions, loss of electronic data, heavy sedimentation, and vandalism. Depending on the type of deficiency, amount and timing of data lost, and possible corrective actions, a deficiency may not be a nonconformance.

The procedures in place to limit and identify deficiencies and non-conformances, and to implement corrective actions, were outlined in Section 3.1.2.

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Element V. Assessment Procedures

This element describes the assessment procedures implemented after data collection is complete to determine if the data conform to the specified criteria and will satisfy the study objectives and if so, the analysis and format for presentation of the results. It includes:

Section 13 - Data Validation & Verification,

Section 14, Data Quality (Usability) Assessment, and

Section 15 – Data Analysis and Presentation.

Sections 13 and 14 describe the procedures used to determine if the data is suitable for use in model calibration and the types of adjustments that can be made to the raw data. The result of sections 13 and 14 are data of known and documented quality, we answer the question; *are the data of sufficient quality and quantity to meet the use for which they are intended*.

During data review, verification, and validation, results are either accepted or adjusted and report as adjusted data, or classified as not useable. Whether or not the data can be adjusted will depend on the site and the conditions at the time that the data needs to be adjusted (e.g. dry or wet weather).

During the data usability assessment, data that are believed to be of poor quality and cannot be adjusted would not normally be used to support model calibration.

13. Data Verification and Validation

This section discusses data review, verification, and validation procedures used as part of the Long Term Control Plan Flow Monitoring program.

13.1. Data Review, Verification, and Validation

This section discusses how data are reviewed and decisions made regarding accepting, rejecting, or qualifying data.

For the purposes of this document, data verification is a systematic process for evaluating performance and compliance of a set of data to ascertain its completeness, correctness, and consistency using the methods and criteria defined in the QAPP. Validation means those processes taken independently of the data-generation processes to evaluate the technical usability of the verified data with respect to the planned objectives or intention of the study. Additionally, validation can provide a level of overall confidence in the reporting of the data based on the methods used.

All data obtained from flow monitors will be reviewed using ZFM2 software. In order to account for data gaps, or periods where the data is incorrect or suspect, data may be edited in ZFM2. The procedures for data editing are outlined in Stantec's *Data Analysis* manual. The following situations describe data gaps that are editable and can be corrected or infilled with data from another time period:

- Level Adjusts; site visits may identify that a pipe diameter was incorrectly recorded. Following verification of the correct diameter, the raw data in ZFM2 can be adjusted to account for the difference in level

- Daily Pattern; during dry weather the daily pattern from another dry period can be substituted where data is missing

- Missing velocity; when the level data appears to be correct and of sufficient quality, the missing velocity can be filled in using the implied Manning's curve

- Data 'pops'; spurious depth and velocity measurements can be caused by site conditions or monitor errors. These can be removed from the raw data.

- Peak Velocity Limited: meters were initially installed with a velocity recording range of 0 to 10 feet per second (fps). It may be found that certain sites exhibit peak velocities above that range necessitating a reset of the meter electronics to measure higher velocities. The previously measured velocities that were restricted to 10 fps will be adjusted based on subsequent data with a higher measurement range

The following situations describe data gaps or inconsistencies that cannot be edited. In these cases, the data will be classified as unusable for the time in question. The monitor may still record usable data at other times.

- Level swings (non-linear drift)

- Insufficient data to establish a pattern; some sites may not produce a repeatable daily or weekly pattern due to the inability to measure low velocities.

- Velocity during surcharge; if the velocity does not record during a period of surcharge it is not possible to estimate the velocity from the level data

- Missing level and velocity during rainfall

All data obtained from field measurements will be reviewed and verified for conformance to project requirements, and then validated against the data quality objectives which are listed in Section 6. Only those data that are supported by appropriate quality control data and meet the measurement performance specification defined for this project will be considered acceptable and used in the project.

14. Data Quality (Usability) Assessment

This section describes the process for determining the data usability. Usability is defined as a qualitative decision process whereby the decision-makers evaluate the achievement of measurement quality objectives and determine whether the data may be used for the intended purpose.

Raw Data Review and QC Checklist (weekly) reviews will be performed using raw data available on *Intelliserve* and ZFM2. During these reviews, hydrographs and scattergraphs will be assessed for data completeness and usability for the modeling objective. Special attention is paid to changes in the data signature, missing data, and data response during wet weather events. The results of these reviews are compiled in weekly and weekly data review forms. Examples of the forms used to perform Raw Data Review and QC Checklist can be found in Appendix C. Where raw data is not sufficient, the data may be adjusted as described in Section 13.1.

In some cases, the data captured from a site may not be suitable for model calibration due to the site hydraulics. In these situations, the project team may determine that the meter should be removed or relocated to an alternate location in the study area in order to capture more useable data.

The data obtained from each of the monitoring locations will be classified for its suitability for use in model calibration, as described below:

- **Excellent**: Data is reliable for modeling with no critical exceptions
- **Good**: Data is reliable for modeling with noted exceptions, noted edits, slight degree of error, or some missing data
- **Some Limitations**: Modeler must take into account the limitations of the data when calibrating, however some important aspects of the data are still suitable for model calibration
- **Poor**: Data may provide some useful modeling information, but should be used with caution for calibration. Sites with a persistent poor rating will be removed and alternative sites considered or alternative methods to provide relevant data will be explored

Flow monitoring locations classified as 'Excellent' meet the following criteria:

- ❑ No data gaps during significant rainfall periods
- ❑ Meter shows consistent response to snow melt, if applicable
- ❑ Scatter graph is narrow without many outliers in both dry and wet weather periods
- ❑ Scatter graph deviations from a Manning's relationship are repeatable and explainable
- ❑ Site signature does not significantly change over the monitoring period
- ❑ Response of flow to rainfall is consistent across the entire monitoring period
- ❑ Diurnal pattern is clear and repeatable (if the site is intended to be used for dry weather flow calibration)
- ❑ Where applicable, flow balancing shows that the meter is within the right range

Flow monitoring locations classified as 'Good' meet the following criteria:

- ❑ No data gaps during significant rainfall periods
- ❑ Meter has captured all or most of the significant rainfall events
- ❑ Wet weather scatter graph is narrow
- ❑ Scatter graph deviations from a Manning's relationship are repeatable and explainable
- ❑ Diurnal pattern is clear and repeatable (if the site is intended to be used for dry weather flow calibration)
- ❑ Where applicable, flow balancing shows that the meter is within the right range

Flow monitoring locations classified as 'Some Limitations' meet the following criteria:

- ❑ Meter may have not recorded all significant events
- ❑ Periods of suitable data exist, particularly during wet weather events
- ❑ Meter had to be replaced
- ❑ Dry weather flow data may not show clear pattern due to site hydraulics

- Wet weather scatter graph is narrow
- Scatter graph may be thick with scatter except in peak wet weather events
- Scatter graph deviations from a Manning's relationship are repeatable and explainable
- Dry weather scatter graph may exhibit significant scatter due to change in site hydraulics or meter intelligence (locking on to multiple velocities or ramping at low flows)
- Where applicable flow balancing shows that the meter is in the right range in wet weather events
- Meter exhibited sensor failure or debris fouling

Flow monitoring locations classified as 'Poor' would have some or all of the following characteristics

- Significant data gaps during wet weather
- Site hydraulics may preclude collection of trust worthy data
- Dry weather flow data does not show clear pattern (if the site is intended to be used for dry weather calibration)
- Wet weather flow data does not show clear pattern
- No clear diurnal pattern (if site is intended to be used for dry weather calibration)
- Scatter graph is thick with scatter
- Scatter graph is unusual with no clear pattern (i.e. horizontal line)
- Where applicable, flow balancing shows that the meter may be over or under estimating

The data from each of the locations will be assessed and re-classified periodically during the monitoring period. These classifications will be discussed and reviewed if necessary at the monthly review meetings. Meters at locations that are classified as 'Poor' will be removed or re-located to alternate locations as decided by the project team. Removing meters that are classified as 'Poor' will allow these meters to be re-installed at alternative sites in the study area.

15. Data Analysis & Presentation

At the conclusion of the flow monitoring plan, a flow data report will be prepared summarizing the results of the flow monitoring. The flow data report will be a reference document for modelers and other users of the flow monitoring data and will provide a summary of the flow monitoring sites, and an assessment of the data captured and its suitability for use in model calibration. The data report will also highlight any limitations on the use of the data.

The flow data report will include information on the location and purpose of each monitoring location and a description of the type of equipment installed, including a record of any configuration changes or significant down times, and a summary of the monitoring results. This will include discussion of extent of scatter, Manning's analysis, hydraulic phenomena and flow response to rainfall. CSO events during the study period will be discussed in addition to performance at key structures such as hydrobrakes, storage and pumping station, and flow balancing. The data report will also identify the suitability of the data from each location for hydrologic and hydraulic modeling efforts. Finally, dry and wet weather periods that are suitable for use in model calibration will be identified.

References

Ecology (2004). Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Publication No. 04-03-030 Revision of Publication No. 01-03-003. http://www.ecy.wa.gov/pubs/0403030.pdf. July 2004.

Seattle Public Utilities (2008). 2008 Combined Sewer Overflow Annual Report

Seattle Public Utilities. NPDES Permitted Combined Sewer Overflow (CSO) Mapbook

Seattle Public Utilities (2009). Quality Assurance Project Plan. Flow Monitoring Plan 2008-2009

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List of Revisions

The current list of revisions for this QAPP follows.

Revision Number	Effective Date	Review Status	Revised by	Revision Summary
R0D1	10/12/2009	Draft	Angela Dwyer	Created Draft Plan
R0D2	11/9/2009	Draft	Angela Dwyer	Incorporated SPU Review Comments
R1D0	12/14/2009	Approved	Angela Dwyer	SPU final review comments incorporated

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Tables

Table T-6. Quality assurance planning document cross-walk.

Washington Department of Ecology	Environmental Protection Agency
1. Title Page with Approvals	A1 Title and Approval Sheet
2. Table of Contents and Distribution List	A2 Table of Contents A3 Distribution List
I. Goals and objectives of the study	
3. Background	A5 Problem Definition/Background
4. Project Description	A6 Project/Task Description
5. Organization and Schedule	A4 Project/Task Organization
II. Type, quality, and quantity of data needed	
6. Quality Objectives	A7 Quality Objectives and Criteria for Measurement Data
7. Sampling Process Design (Experimental Design)	B1 Sampling Process Design (Experimental Design)
III. Sampling and measurement procedures to acquire those data	
8. Sampling Procedures	B2 Sampling Methods B3 Sample Handling and Custody
9. Measurement Procedures	B4 Analytical Methods
IV. Study implementation QA/ QC procedures to ensure Plan is followed	
10. Quality Control	B5 Quality Control B6 Instrument/Equipment Testing, Inspection, and Maintenance B7 Instrument/Equipment Calibration and Frequency B8 Inspection/Acceptance of Supplies and Consumables
11. Data Management Procedures	B10 Data Management
12. Audits and Reports	C1 Assessments and Response Actions C2 Reports to Management
V. Assessment procedures to ensure that study objectives are met	
13. Data Verification and Validation	D1 Data Review, Verification, and Validation D2 Verification and Validation Methods
14. Data Quality (Usability) Assessment	D3 Reconciliation with User Requirements
15. Data Analysis and Presentation	

Table T-7. Standard Operating Procedures (SOPs)

Field Category	SOP No.	Standard Operating Procedure
HYDR – Hydraulics Program	C3100_R1D0	Piped Flow Gravity
	C3110_R1D0	Piped Flow Gravity: Equipment and Site Selection
	C3120_R1D0	Piped Flow Gravity: Equipment Installation
	C3130_R1D0	Piped Flow Gravity: Field Calibration and Maintenance
	C3140_R1D0	Piped Glow Gravity: Field Inspections
	Q1100_R1D0	Data Validation (review and verifications, validation, assessment)
METR – Meteorology	Q1100_R0D7	Data Validation (review and verification, validation, assessment)
	Q1200_R0D3	Data Management (retrieval through archiving)
	Q1300_R0D2	Data Requests

Table T-8. NPDES Basin Summary

Basin	NPDES Basin	2004-08 Annual Overflow Frequency*	Receiving Waters*
Ballard	150/151	12.8	Salmon Bay
	152	12.4	Salmon Bay
Delridge	99	3.8	West Waterway
	168	4.8	Longfellow Creek
	169	2.8	Longfellow Creek
	170	0.4	Longfellow Creek
Duwamish	107	2.2	East Waterway
	111	3.8	Duwamish River
Fremont	147	29.6	Lake Union
	148	0.0	Lake Union
	174	10.8	Lake Union
Interbay	68	2.0	Elliot Bay
Leschi	26	0.2	Lake Washington
	27	0.0	Lake Washington
	28	17.0	Lake Washington
	29	3.8	Lake Washington
	30	4.4	Lake Washington
	31	9.0	Lake Washington
	32	11.6	Lake Washington
	33	0.2	Lake Washington
	34	1.8	Lake Washington
	35	0.4	Lake Washington
	36	2.4	Lake Washington
Madison Park/ Union Bay	22	0.4	Union Bay
	24	0.2	Lake Washington
	25	3.0	Lake Washington
Montlake	20	2.0	Ship Canal
	139	1.4	Ship Canal
	140	0.4	Ship Canal
North Union Bay	18	4.2	Union Bay
	19	0.2	Union Bay
Portage Bay	127	1.0	Lake Union
	130	2.6	Lake Union
	132	0.8	Lake Union
	135	0.2	Lake Union
	138	2.4	Portage Bay
	175	1.2	Lake Union

* Information obtained from Seattle Public Utilities Combined Sewer Overflow Annual Report 2008

Table T-9. Land Use by Model Basin

Model Basin	Basin Area (acres)*	Residential (%)	Commercial (%)	Industrial (%)	Other (%)^
004-315	606	87	13	0	0
005-116	364	93	7	0	0
009-023N	17	100	0	0	0
009-023S	703	100	0	0	0
010-126	279	79	21	0	0
010-127	292	98	2	0	0
011-248	1284	77	10	13	1
011-299	354	66	2	32	0
012-165	708	89	4	7	0
012-172	573	79	15	6	0
015-077	983	93	4	0	3
015-272	924	88	10	0	2
020-170	350	90	2	8	0
021-055	378	74	6	20	0
021-056	1176	61	23	9	7
021-376	455	73	22	5	0
021-406	862	76	15	1	8
024-017	1368	92	8	0	0
025-042	1055	99	1	0	0
027-120E	670	94	3	3	0
027-120W	196	100	0	0	0
027-503	298	36	3	61	0
031-026	75	99	0	0	0
031-054	471	98	2	0	0
031-062	812	94	6	0	0
031-131	47	95	5	0	0
031-132	564	99	1	0	0
034-028N	98	22	78	0	0
034-028S	208	2	98	0	0
034-293	258	69	17	14	0
035-205	317	42	58	0	0
035-307	642	56	37	3	4
035-584	439	11	81	5	4
035-588	581	72	23	5	0
038-072	628	98	2	0	0
039-697	368	7	81	9	3
044-502	475	19	34	45	2
044-601	318	0	8	92	0
047-130	531	97	3	0	0
047N-037	194	92	8	0	0
048-004	53	100	0	0	0
048-439	297	90	8	2	0
050-072	438	24	4	71	0
050-096	317	0	0	100	0

Model Basin	Basin Area (acres)*	Residential (%)	Commercial (%)	Industrial (%)	Other (%)^
052-087	431	81	19	0	0
052-109	135	97	3	0	0
052-440	1137	69	17	5	9
053-030	145	100	0	0	0
053-034	269	96	4	0	0
055-132	311	11	3	86	0
055-136	1480	89	7	4	0
055-268	72	61	2	37	0
055-323	419	0	0	100	0
055-326	95	79	0	21	0
055-389	473	81	19	1	0
056-074	409	20	0	80	0
056-156	741	12	0	88	0
057-294	352	87	4	10	0
058-094	299	85	15	0	0
058-104	250	99	1	0	0
059-164-a	314	94	6	0	0
059-164-b	281	84	16	0	0
059-445	741	87	13	0	0
060-002	52	100	0	0	0
060-101	403	89	11	0	0
063-014	189	99	0	0	0
063-058	291	0	6	94	0
064-188-a	317	94	0	6	0
064-188-b	858	17	2	67	15
068-108	102	100	0	0	0
068-143-a	671	93	7	0	0
068-143-b	233	96	4	0	0
068-474	45	100	0	0	0
069-408	463	80	0	0	20
070-109-a	670	37	6	57	0
070-109-b	426	54	24	21	0
070-168	337	97	1	2	0
071-391	686	1	0	44	55
071-395N	295	84	1	3	12
071-395S	313	17	12	71	0
073-125	809	88	12	0	0
075-022	283	100	0	0	0
075-023	253	99	1	0	0
075-168	566	97	3	0	0
075-509	78	100	0	0	0
076-218	176	88	12	0	0
080-330	581	93	7	0	0
080-335	307	91	9	0	0
080-365	368	89	4	0	7
081-348-a	459	85	4	0	11

Model Basin	Basin Area (acres)*	Residential (%)	Commercial (%)	Industrial (%)	Other (%)^
081-348-b	413	100	0	0	0
223-001N	1021	99	1	0	0
223-001S	1640	93	7	0	0
228-243	1974	89	10	0	1
228-245	1886	82	15	0	3
232-385	1500	70	26	0	4
235-198	375	99	1	0	0
235-555	810	99	1	0	0
305-016	110	88	0	12	0
305-021	548	88	11	1	0
305-023	361	36	1	17	46
311-031	524	99	0	0	1
NSA-Arboretum	314	100	0	0	0
NSA-Green_Lake	260	100	0	0	0
NSA-KC	281	2	5	93	0
NSA-KC1	11	0	48	52	0
NSA-Sandpoint	332	100	0	0	0
NSA-UW	524	1	2	0	97

* Based on SPU Zoning Shapefile (2005)

^ 'Other' includes land zoned 'Major Institutions'

Table T-10. Infrastructure Characteristics by Model Basin

Model Basin	Basin Area (acres)*	Combined (%)^	Partially Separated (%)^	Separated (%)^
004-315	606	88	1	**11**
005-116	364	99	1	**0**
009-023N	17	0	100	**0**
009-023S	703	0	11	**89**
010-126	279	2	85	**13**
010-127	292	74	14	**12**
011-248	1284	56	44	**0**
011-299	354	100	0	**0**
012-165	708	45	55	**0**
012-172	573	58	42	**0**
015-077	983	7	93	**0**
015-272	924	88	11	**0**
020-170	350	88	12	**0**
021-055	378	0	100	**0**
021-056	1176	45	55	**0**
021-376	455	41	59	**0**
021-406	862	98	2	**0**
024-017	1368	86	8	**6**
025-042	1055	0	98	**1**
027-120E	670	7	93	**0**
027-120W	196	7	82	**11**
027-503	298	76	24	**0**
031-026	75	17	81	**2**
031-054	471	5	93	**1**
031-062	812	52	48	**1**
031-131	47	91	9	**0**
031-132	564	87	13	**0**
034-028N	98	93	7	**0**
034-028S	208	99	1	**0**
034-293	258	100	0	**0**
035-205	317	83	17	**0**
035-307	642	22	78	**0**
035-584	439	76	24	**0**
035-588	581	80	20	**0**
038-072	628	1	87	**12**
039-697	368	67	33	**0**
044-502	475	67	33	**0**
044-601	318	75	25	**0**
047-130	531	0	100	**0**
047N-037	194	0	100	**0**
048-004	53	0	100	**0**
048-439	297	25	75	**0**
050-072	438	7	93	**0**
050-096	317	50	50	**0**
052-087	431	0	100	**0**

Model Basin	Basin Area (acres)*	Combined (%)^	Partially Separated (%)^	Separated (%)^
052-109	135	32	59	**9**
052-440	1137	44	56	**0**
053-030	145	0	100	**0**
053-034	269	0	100	**0**
055-132	311	12	88	**0**
055-136	1480	33	50	**17**
055-268	72	56	44	**0**
055-323	419	0	100	**0**
055-326	95	65	35	**0**
055-389	473	92	6	**1**
056-074	409	1	98	**1**
056-156	741	22	77	**0**
057-294	352	1	69	**30**
058-094	299	1	95	**5**
058-104	250	68	6	**26**
059-164-a	314	14	57	**29**
059-164-b	281	0	100	**0**
059-445	741	2	83	**15**
060-002	52	0	100	**0**
060-101	403	0	100	**0**
063-014	189	20	80	**0**
063-058	291	83	17	**0**
064-188-a	317	72	28	**0**
064-188-b	725	0	37	**63**
068-108	102	0	100	**0**
068-143-a	671	2	95	**3**
068-143-b	233	3	96	**2**
068-474	45	0	100	**0**
069-408	463	34	66	**0**
070-109-a	670	38	26	**36**
070-109-b	426	5	26	**69**
070-168	337	1	65	**34**
071-391[#]	686	14	27	**3**
071-395N	295	52	38	**9**
071-395S	313	69	31	**0**
073-125	809	7	91	**3**
075-022	283	0	100	**0**
075-023	253	0	15	**85**
075-168	566	33	56	**11**
075-509	78	0	12	**88**
076-218	176	68	32	**0**
080-330	581	0	100	**0**
080-335	307	2	88	**10**
080-365	368	9	38	**52**
081-348-a	459	0	61	**39**
081-348-b	413	0	95	**5**

Model Basin	Basin Area (acres)*	Combined (%)^	Partially Separated (%)^	Separated (%)^
223-001N	1021	0	0	**100**
223-001S	1640	0	0	**100**
228-243	1974	0	0	**100**
228-245	1886	0	0	**100**
232-385	1500	0	0	**100**
235-198	375	0	50	**50**
235-555	810	0	0	**100**
305-016	110	43	57	**0**
305-021	548	3	95	**2**
305-023#	361	21	33	**1**
311-031	524	0	9	**91**
NSA-Arboretum	314	3	4	**93**
NSA-Green_Lake	260	98	2	**0**
NSA-KC	281	95	5	**0**
NSA-KC1	11	100	0	**0**
NSA-Sandpoint	332	0	0	**100**
NSA-UW	**524**	**1**	**99**	**0**

^ Based on SPU Sewer Classification Areas Shapefile (1997)

Part of basin is outside area covered by SPU Sewer Classification Areas Shapefle, percentages do not sum to 100%

Table T-11. CSO Facility Information

Basin	NPDES Basin	CSO Facility ID	Facility Location*	Facility Description*
Ballard	150/151	-	24th Ave NW and NW Market Street and	Overflow weir
	152	-	NW 28th Ave NW and NW Market Street	Overflow weir
Delridge	99	34	26th Ave SW and SW Andover Street	Flow control structure with hydrobrake, overflow structure with two weirs and offline storage facility, consisting of 565 feet x 84-inch pipe (162,643 gallon capacity). This system also incorporates first flush diversion of the storm water system to the sanitary system to prevent pollutants that have settled in the storm system from entering Elliot Bay
	168	2	Delridge Way SW and SW Orchard Street	Overflow weirs, hydrobrake, gate valves, control chamber and detention tank (1.6 million gallon capacity)
	169	3	22nd Ave SW and SW Henderson Street	Overflow weirs, hydrobrake, gate valves, control chamber and detention tank (1.6 million gallon capacity) and CSO facility bypass weir (leaping weir)
	170	1	SW Webster Street and 24th Ave SW	Overflow weir, hydrobrake and offline storage consisting of 530 feet x 96-inch pipe (199,272 gallon capacity)
Duwamish	107	-	E Marginal Way and S Spokane Street	Overflow weir
	111	35	Various locations in Basin 111	Overflow weir, hydrobrake and off-line detention storage limiting flow to King County Pump Station (111H), and a system of 7 overflow weirs throughout the remainder of the basin (111 A-G). Storage facility consists of 68 feet x 24 feet wide x 10 feet high tank (120,000 gallon capacity).
Fremont	147	-	Stone Way N and N 34th Street (147A) and N34th Street and Woodland Park Ave (147B)	Two overflow weirs. A flap gate is installed downstream of 147A to prevent backflow from the KC interceptor
	148	-	NW 41st Street east of 8th Ave NW	Overflow weir
	174	-	2nd Ave NW and NW 36th Street	Overflow weir. A flap gate in the KC interceptor prevents backflow to the overflow weir
Interbay	68A	33	W Boston Street and 15th Ave W	Flow control structure with hydrobrake, flap gate and weir, offline storage and overflow MH with weir. Offline storage consists of 165 feet x 48-inch pipe (15,5008 gallon capacity). Once the storage is full, excess flows are diverted to Basin 68B
	68B	33	15th Ave W and W Armour Street	Flow control structure with hydrobrake and overflow weir, inline detention facility. Offline storage consists of 365 feet x 144-inch pipe (308,708 gallon capacity)
Leschi	26	-	Denny Blaine Park	Overflow weir
	27	-	Metro Pump Station off Lake Washington Blvd south of E Pine Street	Overflow weir
	28	-	Lake Washington Blvd between Madrona Drive and E Pine Street	Overflow weir
	29	18	East side of Lake Washington Blvd at E James Street	Two overflow weirs, hydrobrake and inline storage, consisting of 301 feet x 18-inch pipe (2,209 gallon capacity)
	30	17	East side of Lake Washington Blvd at E Alder Street	Overflow weir, sluice gate and inline storage facility, consisting of 251 feet x 42-inch pipe (15,354 gallon capacity)
	32	16	Lakeside Ave S between S Lane Street and S Dearborn Street	32A - overflow weir, hydrobrake and inline storage facility, consisting of 164 feet x 30-inch pipe (5,188 gallon capacity), 32B – overflow weir.
	33		S Charles Street and Lakeside Ave S	Overflow weir

Basin	NPDES Basin	CSO Facility ID	Facility Location*	Facility Description*
	34	15	Lakeside Ave S between S Charles Street and S Parkland Street, near Pump Station 2	Overflow weir, hydrobrake and offline storage facility. Offline storage consists of 127 feet x 84-inch pipe (36,559 gallon capacity)
	35	14	Upper system between 35th Ave S and 36th Ave S (next to I-90), Lower system S Massachusetts Street	Upper system – two overflow weirs, sluice gate and offline storage facility. Lower system – overflow weir and hydrobrake. Storage facility consists of 55 feet x 72-inch pipe (11,632 gallon capacity)
	36	13	Lake Washington Blvd S near Lake Park Drive S	Overflow weir, hydrobrake and inline storage consisting of 1205 feet x 16-inch pipe (12,586 gallon capacity)
Madison Park/ Union Bay	22	-	Northern end of 39th Ave E at Pump Station 50	Overflow Weir
	24	-	E Lee Street at Pump Station 7	Overflow Weir
	25	-	E Lee Street near intersection with 42nd Ave E	Overflow Weir and inline detention storage consisting of 674 feet x 54-inch pipe and 2,867 feet x 36-inch pipe (197,003 gallon capacity)
Montlake	20	26	Easement east of E Park Drive and north of E Shelby Street	Two overflow weirs associated with lift station. The first weir diverts flow to offline storage, flows overflowing the second weir are directed to outfall. Offline storage consists of parallel 72-inch pipes total length 550 feet (117,590 gallon capacity)
	139	-	16th Ave E and E Calhoun Street	Overflow weir
	140	31	West Park Drive and E Shelby Street	Overflow weir and hydrobrake with offline storage. Stored flows are pumped back to gravity system. Offline storage consists of 36 feet x 120-inch pipe and 25 feet x 54-inch pipe (24,123 gallon capacity)
North Union Bay	18B	24	39th Ave NE and 40th Ave NE	Upstream inflow control chamber, storm overflow control chamber, offline storage and downstream MH with hydrobrake. Offline storage consists of parallel 1000ft x 144-inch pipes (1,691,936 gallon capacity)
	18A	25	NE 41st Street and 36th Ave NE	Upstream flow control MH with overflow weir, inline storage and downstream MH with hydrobrake. Inline storage consists of 743 feet x 72-inch pipe (133,568 gallon capacity)
	19	-	Ne 45th Street in parking lot near QFC	Overflow weir
Portage Bay	127	-	1109 Fairview Ave N	Overflow weir
	130	-	Minor Ave E and E Roanoke Street	Overflow weir
	132	-	Minor Ave E and E Roanoke Street	Overflow weir
	135	-	Fuhrman Ave E and Eastlake Ave E	Overflow weir
	138	36	E Shelby Street and Boyer Ave E	Overflow weirs, hydrobrake, sluice gate, gate valve and offline storage facilities. Storage facility consists of two 132-inch pipes each 89 feet long (126,531 gallon capacity)
	175	-	Eastlake Ave E and E Garfield Street	Overflow weir

* Based on information from the SPU CSO Mapbook, SPU Maintenance Holes Shapefile and SPU Sewer/ Drainage Mainline Shapefile

Table T-12. Permitted CSO Outfalls in Study Area

Basin	NPDES Basin & Outfall No.	Outfall Location	Outfall Description
Ballard	150/151	To Salmon Bay from MH 011-184	**30-inch outfall**
	152	To Salmon Bay from MH 011-189 (152B) and MH 011-218 (152A)	**48-inch outfall**
Delridge	99	To West Waterway from MH 055-477	**96-inch outfall**
	168	To Longfellow Creek via detention tank outlet at MH069-408	**30-inch and 8-inch outlets from detention tank connect to 30-inch storm drain**
	169	To Longfellow Creek via detention tank outlet at MH 076-367	**30-inch outlet from detention tank connects to 24-inch storm drain**
	170	To Longfellow Creek from MH 069-144	**24-inch outfall**
Duwamish	107	To East Waterway from MH 056-097	**54-inch storm drain and outfall**
	111	To Duwamish River from: MH 056-195 (111A) MH 056-270 (111B) MH 056-365 (111C) MH 057-253 (111D) MH 057-065 (111E) MH 057-058 (111F) MH 057-513 (111G) MH 057-347 (111H)	**144-inch storm drain and outfall**
	116	To Duwamish River from MH 071-024	**30-inch outfall**
Fremont	147	To Lake Union from MH 022-187 and MH 022-160	**30-inch outfall**
	148	To Lake Union from MH 021-020	**12-inch outfall**
	174	To Lake Union from MH 021-052	**30-inch outfall**
Interbay	68A	To Elliot Bay from MH 028-431	**96-inch outfall**
Leschi	26	To Lake Washington from MH038-081	**8-inch outfall**
	27	To Lake Washington from MH042-269	**24-inch outfall**
	28	To Lake Washington from MH042-278	**15-inch outfall**
	29	To Lake Washington from MH042-303	**15-inch outfall**
	30	To Lake Washington from MH042-322	**24-inch storm drain**
	31	To Lake Washington from MH046-033	**8- inch outfall**
	32	To Lake Washington from MH046-078	**12-inch outfall**
	33	To Lake Washington from MH 046-171	**20-inch outfall**
	34	To Lake Washington from MH 046-054	**15-inch outfall**
	35	To Lake Washington from MH 046E-138	**16-inch outfall**
	36	To Lake Washington from MH 046E-150	**21-inch outfall**
Madison Park/ Union Bay	22	To Union Bay from MH 032-014	**24-inch storm drain**
	24	To Lake Washington from MH 038-143	**20-inch outfall**
	25	To Lake Washington from MH 038-149	**20-inch outfall**
Montlake	20	To Portage Bay from MH 031-382	**21-inch outfall**
	139	To Portage Bay from MH D031-078	**42-inch outfall**
	140	To Portage Bay from MH 031-001	**18-inch outfall**
North Union Bay	18	To Union Bay from MH025-380	**60-inch storm drain**
	19	To Union Bay from MH016-509 and MH 025-380	**42 inch outfall**
Portage Bay	127	To Lake Union from MH 036-140	**8-inch outfall**

Basin	NPDES Basin & Outfall No.	Outfall Location	Outfall Description
	130	To Lake Union from MH 030-410	**21-inch outfall**
	132	To Lake Union from MH 030-416	**18/24/30-inch outfall**
	135	To Lake Union from MH 023-208	**10-inch outfall**
	138	To Portage Bay from MH 023-192	**16-inch outfall**
	175	**To Lake Union from MH030-348 and MH038-028**	**54-inch outfall**

Based on information from the SPU CSO Mapbook, SPU Maintenance Holes Shapefile and SPU Sewer/ Drainage Mainline Shapefile

Table T-13. Pump Stations

Basin	NPDES Basin	Pump Station No.	Location*	Description*
Ballard	152	84	28th Ave NW and Ballard Terminal Drive	Lifts flow from shoreline to Basin 152 overflow structure
Fremont	148	54	NW 41st Street east of 8th Ave NW	Lifts flows to Basin 174
Leschi	34	2	West of Lakeside Ave S near S Charles Street	Lifts flows from Basin 34 to Basin 32
Madison Park/ Union Bay	22	50	Northern end of 39th Ave E	Lifts flow from Basin 22 to Basin 25
Madison Park/ Union Bay	24	7	East end of E Lee Street	Lifts flow from Basin 22, 24 and 25 to King County mainline
Montlake	20	13	Easement east of E Park Street and north of E Shelby Street	Lifts flows from Basin 20
Montlake	139	25	North of E Calhoun Street and east of 18th Ave E	Lifts flows from Basins 139 and 140 to King County mainline
Montlake	140	15	West Park Drive and E Shelby Street	Lifts flow from the detention tank in Basin 140 to the gravity system
North Union Bay	19	35	University of Washington campus. In parking lot between 27th Ave NE and NE University Village Street	Lifts flows from Basin 19 to King County mainline
North Union Bay	141	48	NE Boat Street near Brooklyn Ave NE	Lift flows from Basin 141 to King County mainline
North Union Bay	16	55	South end of Websterpoint Road NE	Lifts flow from Basin 16 to area tributary to King County system
Portage Bay	138	20	E Shelby Street near Fuhrman Ave E. West of Pump Station 67.	Lifts flows from Basin 138 to Basin 135
Portage Bay	124	61	Westlake Ave N north of Aloha Street	Lift flow from lakeside area in Basin 124 to Basin 123
Portage Bay	127	62	Fairview Ave W near intersection of Yale Ave N	Lifts flows from northwest portion of Basin 127 to trunk sewer in Basin 127
Portage Bay	129	63	E Blaine Street between Fairview Ave N and Eastlake Ave N	Lift flows from Basin 129 to Basin 128
Portage Bay	131	64	Fairview Ave N north of E Lynn Street	Lift flows from Basin 131 to Basin 129
Portage Bay	134	65	Fairview Ave N near E Allison Street	Lifts flow from Basin 134 to Basin 133
Portage Bay	136	66	Portage Bay Place north of E Allison Street	Lifts flow from Basin 136 to Basin 137
Portage Bay	138	67	E Shelby Street near Fuhrman Ave E. East of Pump Station 20	Lifts flows from Basin 137 to Basin 138, also receives overflows from Pump Station 20

* Based on information from the SPU Maintenance Holes Shapefile and SPU Sewer/ Drainage Mainline Shapefile

Table T-14. Hydrobrakes and Special Structures

Basin	NPDES Basin	Item*	Location*	Description*
Delridge	99	Hydrobrake and flap gate, low flow connection from the storm system to the sanitary system	SW Andover Street and 26th Ave SW	MH 055-478
	168	Control Chamber, Hydrobrake, flap gate and Gate Valve	Delridge Way SW and SW Orchard Street	MH 069-428
	169	Control Chamber, Hydrobrake, flap gate and Gate Valve and CSO facility bypass weir (leaping weir)	22nd Ave SW and SW Henderson Street	MH 076-367
	170	Hydrobrake	SW Webster Street and 24th Ave SW	MH 069-146
Duwamish	111	Hydrobrake	S Oregon Street and 10th Ave S	MH057-229
	111A	Flap gate	E Marginal Way S and S Oregon Street	MH056-195
	111B	Flap gate	Ohio Ave S and S Oregon Street	MH 056-270
	111D	Flap gate	1st Ave S and Diagonal Ave S	MH057-253
Fremont	147A	Flap gate	Stone Way N and N 34th Street	MH022-188
Interbay	68A	Hydrobrake	W Armour Street and 15th Ave NW	MH 028-422
	68B	Hydrobrake and flap gate	W Boston Street and 15th Ave W	MH 028-431
Leschi	29	Hydrobrake	Basin 29. Lake Washington Blvd and E James Street	MH 042-302
	30	Sluice Gate	Basin 30. Lake Washington Blvd and E Alder Street	MH 042-205
	32	Hydrobrake	Lakeside Ave S and S Lane Street	MH 046-156
	33	Hydrobrake	S Charles Street and Lakeside Ave S	MH 046-171
	34	Hydrobrake	Lakeside Ave S between S Charles Street and S Parkland Street, near Pump Station 2	MH 046-172
	35 (upper system)	Sluice Gate	Between 35th Ave S and 36th Ave S (next to I-90)	MH 046-188
	35 (lower system)	Hydrobrake	S Massachusetts Street	MH 046E-138
	36	Hydrobrake	East of Lake Washington Blvd S and S Plum Street	MH 046E-142
Montlake	140	Hydrobrake	NE of E Shelby Street and West Park Drive	MH 031-001
North Union Bay	18B	Hydrobrake	39th Ave NE and 40th Ave NE	MH 016-505
	18A	Hydrobrake and sluice gate	NE 41st Street and 36th Ave NE	MH 042-072
Portage Bay	138	Hydrobrake, flap gate and sluice gate	E Shelby Street and Boyer Ave E.	MH 023-434

* Based on information from the SPU CSO Mapbook, SPU Maintenance Holes Shapefile and SPU Sewer/ Drainage Mainline Shapefile

Table T-15. Site Inspections Summary (Monitoring Phase 3 Sites)

Area	Site ID	Model Basin	Status	Inspection Notes
Alaska Street	ALK_059-162A	059-164-a	Approved	
Alaska Street	ALK_059-165	059-445	Do Not Inspect	Alternate to ALK_059-162A
Alaska Street	ALK_059-168A	059-445	Rejected	Clay pipe with change in slope
Alaska Street	ALK_059-169A	059-445	Rejected	Clay pipe with change in slope
Alaska Street	ALK_059-170A	059-164-b	Rejected	Clay pipe with change in slope
Alaska Street	ALK_066-211A	059-164-b	Alternate	Alternate to ALK_059-162A
Ballard	BAL_012-112A	012-172	Rejected	Flow too rough
Ballard	BAL_012-127A	012-172	Approved	
Ballard	BAL_012-173A	012-172	Rejected	Not required
Ballard	BAL_012-373A	012-165	Approved	
Ballard	BAL_012-375A	012-165	Alternate	Alternate to BAL_012-373A
Ballard	BAL_012-380A	012-165	Alternate	Second alternative to BAL_012-373A
Ballard	BAL150_002-272A	011-248	Alternate	
Ballard	BAL150_002-272B	011-248	Rejected	Velocity too low, debris
Ballard	BAL150_002-329	011-248	Rejected	Dry pipe
Ballard	BAL150_002-332	011-248	Rejected	Dry pipe (only local houses connected)
Ballard	BAL150_002-368	012-172	Not Inspected	Not required
Ballard	BAL150_230-445	011-248	Rejected	Not required as flow does not enter CSO basin (flows to the north)
Ballard	BAL150_230-461	223-001S	Not Inspected	Not required
Ballard	BAL150_D011-032A	011-248	Rejected	Not required
Ballard	BAL150_D011-107A	011-248	Not Inspected	Not required
Ballard	BAL150_D012-079A	012-165	Approved	
Ballard	BAL150E_D012-079	012-165	Approved	
Ballard	BAL150E_D012-093	012-165	Not Inspected	Not required
Ballard	BAL150E_D012-094	012-165	Not Inspected	Not required
Ballard	BAL150E_D012-095	012-165	Not Inspected	Not required
Ballard	BAL150W_D011-029	011-248	Not Inspected	Not required
Ballard	BAL150W_D011-032	011-248	Not Inspected	Not required
Ballard	BAL150W_D011-049	011-248	Not Inspected	Not required
Ballard	BAL152_002-014A	011-248	Alternate	GSI
Ballard	BAL152_002-014B	011-248	Alternate	GSI
Ballard	BAL152_002-015A	011-248	Approved	GSI. West Pipe
Ballard	BAL152_002-015B	011-248	Rejected	GSI. Debris in Line. NW pipe
Ballard	BAL152_002-095A	011-248	Alternate	GSI. Alternate to BAL152_002-096A
Ballard	BAL152_002-096A	011-248	Approved	
Ballard	BAL152_011-152A	011-248	Rejected	Unsuitable hydraulics
Ballard	BAL152_011-160A	011-248	Approved	
Ballard	BAL152_D011-098A	011-248	Not Inspected	Not required
Ballard	BAL152_D011-101	011-248	Not Inspected	Not required
Ballard	BAL152_D011-106	011-248	Not Inspected	Not required
Ballard	BAL152_D011-107A	011-248	Hold	Approved but on hold
Broadview	BV_224-042A	223-001N	Alternate	Alternate to BV_224-104A
Broadview	BV_224-045A	223-001N	Alternate	
Broadview	BV_224-103A	223-001N	Rejected	Change in hydraulics
Broadview	BV_224-104A	223-001N	Approved	North pipe
Broadview	BV_224-104B	223-001N	Rejected	Significant change in pipe slope upstream
Broadview	BV_224-105A	223-001N	Alternate	
Broadview	BV_224-417	223-001N	Rejected	Bump in Channel
Broadview	BV_224-418A	223-001N	Rejected	Change in pipe slope upstream
Capitol Hill	CAP_036-342A	035-307	Rejected	Unsuitable hydraulics
Capitol Hill	CAP_036-343A	035-307	Alternate	Rough flow.
Capitol Hill	CAP_036-344A	035-307	Alternate	Rough flow and upstream tap

Area	Site ID	Model Basin	Status	Inspection Notes
Capitol Hill	CAP_036-345A	035-584	Rejected	Very rough flow
Capitol Hill	CAP_036-387A	035-584	Approved	
Capitol Hill	CAP_039-207A	035-584	Alternate	Alternative to CAP_036-387A
Commodore	COM_010-135	010-127	Not Inspected	Not required
Commodore	COM_010-136	010-127	Not Inspected	Not required
Commodore	COM_010-145	010-127	Not Inspected	Not required
Commodore	COM_010-165A	009-023N	Rejected	Roots and Bad Joints
Commodore	COM_020-072A	011-299	Alternate	Alternate to COM_032-073A
Commodore	COM_020-073A	011-299	Approved	
Commodore	COM_020-212A	020-170	Approved	
Commodore	COM_020-439A	020-170	Alternate	Alternate for COM_020-212A
Delridge	DEL_055-142A	055-136	Approved	
Delridge	DEL_D055-172A	055-136	Approved	
Delridge	DEL170_069-145A	055-136	Rejected	Outlet from hydrobrake is behind concrete which acts as a dam.
Delridge	DEL170_069-146A	055-136	Approved	
Delridge	DEL99_055-142A	055-136	Approved	
Delridge	DEL99_055-143A	055-136	Rejected	Tap
Delridge	DEL99_055-144A	055-136	Rejected	Tap
Delridge	DEL99_D055-014A	055-136	Alternate	Alternate to DEL99_D055-172A
Delridge	DEL99_D055-122A	055-136	Rejected	Bend
Delridge	DEL99_D055-172A	055-136	Approved	
Dexter	DEX_035-205A	021-406	Rejected	Located at end of siphon
Dexter	DEX_035-238A	035-205	Alternate	Alternate to DEX_035-241A
Dexter	DEX_035-241A	035-205	Approved	A pipe is 48inch SW
Dexter	DEX_035-241B	035-205	Approved	B pipe is 21inch W
Dexter	DEX_035-300A	035-205	Approved	
Dexter	DEX_035-365A	035-205	Alternate	Alternate to DEX_035-300A
Diagonal	DIAG_D057-001A	050-096	Rejected	Unsuitable Hydraulics
Diagonal	DIAG_D057-004A	050-096	Not Inspected	MH could not be located
Diagonal	DIAG_D057-008A	050-096	Not Inspected	MH could not be located
Diagonal	DIAG_D057-015A	050-096	Rejected	Too many large stones
Diagonal	DIAG_D057-015B	050-096	Approved	
Fremont	FRE147_022-187A	021-056	Approved	
Fremont	FRE147_D022-146A	021-056	Approved	
Fremont	FRE174_D021-058A	021-055	Alternate	Alternative to FRE174_D021-083A
Fremont	FRE174_D021-060A	021-055	Alternate	Alternative to FRE174_D021-083A
Fremont	FRE174_D021-083A	021-055	Approved	A is dry storm pipe
Fremont	FRE174_D021-084	021-055	Alternate	Alternative to FRE174_D021-083A
Genesee	GEN_059-442A	059-445	Approved	
Genesee	GEN_059-444A	059-445	Rejected	Sediment and upstream bend
Green Lake	GLK_004-120A	004-315	Rejected	Other sites are better alternatives
Green Lake	GLK_004-219A	004-315	Approved	
Green Lake	GLK_004-220A	004-315	Alternate	Alternate to GLK_004-219A
Green Lake	GLK_004-227A	004-315	Alternate	Alternate to GLK_004-219A
Green Lake	GLK_005-095A	024-017	Approved	
Green Lake	GLK_005-115A	024-017	Alternate	Alternate to GLK_005-117A
Green Lake	GLK_005-117A	024-017	Approved	
Green Lake	GLK_005-120A	024-017	Rejected	Clay pipe with joints
Green Lake	GLK_005-122A	024-017	Rejected	Clay pipe with joints
Green Lake	GLK_005-152A	005-116	Alternate	Alternative to GLK_005-157A
Green Lake	GLK_005-153A	005-116	Alternate	Alternative to GLK_005-157A
Green Lake	GLK_005-154A	005-116	Alternate	Alternative to GLK_005-157A
Green Lake	GLK_005-154B	005-116	Approved	Side line
Green Lake	GLK_005-157A	005-116	Approved	Mainline

Area	Site ID	Model Basin	Status	Inspection Notes
Green Lake	GLK_005-157B	005-116	Approved	Sideline
Green Lake	GLK_D005-077A	005-116	Rejected	Not required
Greenwood	GWD_231-430A	223-001S	Alternate	Alternate to GWD_231-434A
Greenwood	GWD_231-434A	223-001S	Approved	
Hanford	HAN_052-172A	052-087	Approved	
Hanford	HAN_052-173A	052-087	Rejected	Circular to oval transition
Hanford	HAN_052-174A	052-087	Rejected	Significant grease
Hanford	HAN_052-317A	052-109	Alternate	Alternate to HAN_052-318A
Hanford	HAN_052-318A	052-109	Approved	
Hanford	HAN_058-106A	058-104	Approved	
Hanford	HAN_D052-137A	052-087	Approved	
Hanford	HAN_D052-211A	052-087	Alternate	Alternate to HAN_D052-137A
Hanford	HAN_D052-212A	052-087	Rejected	Has flap gate
Henderson	HEN_306-242A	081-348-a	Approved	
Henderson	HEN_306-244A	081-348-a	Alternate	Alternate to HEN_306-242A
Holman Road	HRD_231-072A	223-001S	Alternate	Hydraulic wave upstream. Consider alternate locations
Holman Road	HRD_231-402A	223-001S	Alternate	Hydraulic wave upstream. Consider alternate locations
Interbay	INT_034-109A	027-503	Rejected	Not necessary
Interbay	INT68_027-181A	021-376	Rejected	Bend, cunette
Interbay	INT68_027-184A	021-376	Rejected	Turbulent Flow
Interbay	INT68_028-026A	021-376	Rejected	6" of silt
Interbay	INT68_028-027A	021-376	Rejected	Decided it was not necessary
Interbay	INT68_028-041A	021-376	Rejected	Turbulent Flow
Interbay	INT68_028-042A	021-376	Rejected	Rough Pipe
Interbay	INT68_028-043A	021-376	Approved	
Interbay	INT68_028-429A	021-376	Rejected	Slow flow and sediment
Interbay	INT68_028-430A	021-376	Approved	
Interbay	INT68_028-434A	021-376	Rejected	Cunette
Interbay	INT68_028-435A	021-376	Rejected	Debris caused by cunette downstream of 434A
KC North Interceptor	KCNI_022-185A	021-056	Approved	
KC North Interceptor	KCNI_022-466A	021-056	Alternate	Alternate to KCNI_022-185A
Leschi	LES33_046-120B	038-072	Approved	
Leschi	LES33_046-121A	038-072	Approved	
Leschi	LES33_046-121B	038-072	Rejected	Bend
Leschi	LES33_046-123A	038-072	Rejected	Tap
Leschi	LES33_046-129A	038-072	Approved	
Leschi	LES35_046E-031A	038-072	Approved	
Leschi	LES35_046E-033A	038-072	Rejected	Roots
Linden	LIN_225-094A	232-385	Rejected	Wave in upstream pipe
Linden	LIN_225-095A	232-385	Approved	
Linden	LIN_225-096A	232-385	Alternate	Alternate for LIN_225-095A
Linden	LIN_225-097A	232-385	Rejected	Upstream taps and grease
Lower Queen Anne	LQA_034-026A	055-389	Approved	
Lower Queen Anne	LQA_034-027A	055-389	Alternate	Alternate for LQA_034-026A
Lower Queen Anne	LQA_034-055A	055-389	Rejected	Rough flow in clay pipe
Lower Queen Anne	LQA_034-056A	055-136	Rejected	Clay pipe with transitions
Luna Park	LP_055-044A	034-293	Rejected	Very rough flow
Luna Park	LP_055-047A	034-293	Alternate	Alternate to LP_055-387A
Luna Park	LP_055-096A	034-293	Rejected	Very rough flow
Luna Park	LP_055-387A	034-293	Approved	
Madison Valley	MV_037-323A	NSA-Arboretum	Alternate	Alternative to MV_037-421A
Madison Valley	MV_037-324	NSA-Arboretum	Rejected	MH could not be located

Area	Site ID	Model Basin	Status	Inspection Notes
Madison Valley	MV_037-421A	NSA-Arboretum	Approved	Being transitioned to Stantec from Taylor
Madison Valley	MV_D037-160IN	031-062	Approved	Being transitioned to Stantec from Taylor
Madison Valley	MV_D037-160OUT	031-062	Approved	Being transitioned to Stantec from Taylor
Magnolia	MAG60_010-166A	Magnolia	Rejected	Clay pipe with transitions
Magnolia	MAG60_010-167A	Magnolia	Rejected	Clay pipe with transitions
Magnolia	MAG68_028-421B	Magnolia	Rejected	Clay pipe with transitions
Matthews Park	MTWPK_227-123A	228-243	Alternate	Alternate to MTWPK_227-185A
Matthews Park	MTWPK_227-184A	228-243	Alternate	Alternate to MTWPK_227-185A
Matthews Park	MTWPK_227-184B	228-243	Alternate	Alternate to MTWPK_227-185A
Matthews Park	MTWPK_227-185A	228-243	Approved	
Michigan	MICH_064-190A	071-395S	Rejected	Unsuitable Hydraulics
Michigan	MICH_064-191A	071-395S	Rejected	Unsuitable Hydraulics
Michigan	MICH_064-309A	071-395N	Rejected	Not required
Michigan	MICH_064-310A	071-395N	Rejected	Not required
Michigan	MICH_064-311A	071-395N	Rejected	Not required
Michigan	MICH_064-311B	071-395N	Rejected	Not required
Michigan	MICH_065-398A	064-188-a	Approved	
Michigan	MICH_065-399A	064-188-a	Rejected	Brick pipe with deposits
MLK Way	MLK_073-102A	073-125	Alternate	Not needed because of install at MLKKC_080-169A
MLK Way	MLK_073-103A	073-125	Alternate	Not needed because of install at MLKKC_080-169A
MLK Way KC	MLKKC_080-168A	305-021	Rejected	Rough flow and upstream taps
MLK Way KC	MLKKC_080-169A	305-021	Approved	
Montlake	MON139_D031-068A	031-132	Alternate	Not needed, can use level at MON139_031-313A
Mt Baker	MTB_052-254A	058-094	Approved	
Mt Baker	MTB_052-264A	058-094	Rejected	Slow flow
Norfolk	NOR_305-048A	305-023	Hold	Alternate to KC meter
Norfolk	NOR_305-048B	305-023	Hold	Alternate to KC meter
Norfolk	NOR_305-055A	305-023	Alternate	Alternate to KC meter
Norfolk	NOR_305-058A	305-023	Alternate	Alternate to KC meter
Norfolk	NOR_305-060A	305-023	Alternate	KC Meter at this site
North Queen Anne	NQA_021-245A	021-406	Approved	
North Queen Anne	NQA_021-270A	021-406	Rejected	Rough flow in clay pipe
North Queen Anne	NQA_021-409A	021-406	Alternate	Alternate to NQA_021-245
North Union Bay	NUB18_007-066A	015-077	Rejected	Not necessary
North Union Bay	NUB18_007-073A	015-077	Rejected	Not necessary
North Union Bay	NUB18_007-085A	015-077	Rejected	Not necessary
North Union Bay	NUB18_D016-050A	015-077	Alternate	Alternate to NUB_D016-009A.
North Union Bay	NUB18_D025-009A	015-077	Approved	
Rainer	RAN_045-185A	052-440	Alternate	Alternate to RAN_045-506A
Rainer	RAN_045-468A	052-440	Rejected	Unsuitable hydraulics
Rainer	RAN_045-469A	052-440	Approved	
Rainer	RAN_045-471A	052-440	Rejected	KC Meter at this site
Rainer	RAN_045-506A	052-440	Rejected	Use KC Meter
Rainer	RAN_052-417A	052-440	Approved	
Rainer	RAN_052-425A	052-440	Rejected	Some rough transitions
Rainer	RAN_052-432A	052-440	Rejected	Some rough transitions
Ravena	RAV_005-203A	024-017	Alternate	Alternate to RAV_014-126A
Ravena	RAV_014-126A	024-017	Approved	
Ravena	RAV_015-076A	015-272	Rejected	Upstream tap
Ravena	RAV_015-084A	015-272	Alternate	Alternate to RAV_015-085A
Ravena	RAV_015-085A	015-272	Hold	Rely on KC Model
Ravena	RAV_015-104A	015-272	Approved	
Seaview	SVW_010-007A	070-109-a	Hold	Not required (pump station data sufficient)
South Park	SPK_078-134A	010-126	Hold	Rely on KC Model
Wallingford	WAL_022-208A	021-056	Hold	Rely on KC Model
Wallingford	WAL_022-209A	021-056	Hold	Rely on KC Model
West Seattle	WS_053-020A	053-034	Hold	Rely on KC Model

Area	Site ID	Model Basin	Status	Inspection Notes
West Seattle	WS_053-021A	053-034	Hold	Rely on KC Model
West Seattle	WS_053-022A	053-034	Hold	Rely on KC Model
West Seattle	WS_068-144A	068-143-a	Hold	Rely on KC Model
South Park	SPK_078-134A	010-126	Hold	Rely on KC Model
Wallingford	WAL_022-208A	021-056	Hold	Rely on KC Model
Wallingford	WAL_022-209A	021-056	Hold	Rely on KC Model
West Seattle	WS_053-020A	053-034	Hold	Rely on KC Model
West Seattle	WS_053-021A	053-034	Hold	Rely on KC Model
West Seattle	WS_053-022A	053-034	Hold	Rely on KC Model
West Seattle	WS_068-144A	068-143-a	Hold	Rely on KC Model

Table T-16. Summary of Monitoring Locations in CSO Basins

Basin	NPDES Basin	Temporary Monitoring Locations (MH ID)*	Permanent Monitoring Locations (MH ID)*
Ballard	150	BAL150_002-273A; BAL150_002-274A; BAL150_002-349A BAL150_011-176A; BAL150_011-242A BAL150_D012-079A	NPDES150_MH011184
	152	BAL 152_006-015A BAL152_002-016A; BAL152_002-032A; BAL152_002-096A BAL152_002-123A; BAL152_002-232A; BAL152_011-090A; BAL152_001-160A; BAL152_011-187A; BAL152_011-213A BAL152_011-218A; BAL152_001-222A	NPDES152_MH011189
Delridge	99	DEL99_055-165A; DEL99_055-175A; DEL99_055-223A; DEL99_055-473A	NPDES099_MH055171
	168	DEL168_069-280A; DEL168_069-342A; DEL168_069-346A; DEL168_069-370A; DEL168_069-406A; DEL168_069-408A; DEL168_069-428A; DEL168_069-428B; SPU_076-217A;	NPDES168_MH069428
	169	DEL169_076-217A; DEL169_076-218A; DEL169_076-232A; DEL169_076-351A; DEL169_076-351B; DEL169_076-362A; DEL169_076-366A; DEL169_076-367A; DEL169_076-367B; DEL169_076-370A;	NPDES169_MH076367; NPDES169_O_MH076367;
	170	DEL170_069-146A	NPDES170_MH069144

Duwamish	111	DUW111_056-166A; DUW111_057-039A; DUW111_057-229A; DUW111_057-241A; DUW111_057-241B; DUW111_057-350	NPDES111A_MH056195; NPDES111B_MH056270; NPDES111C_MH056365; NPDES111D_MH057253; NPDES111E_MH057066; NPDES111F_MH057078; NPDES111G_MH057513; NPDES111H_MH057347
Fremont	147	FRE147_022-118A; FRE147_022-118B; FRE147_022-152A; FRE147_022-174A; FRE147_022-187[a]; FRE147_022-306A; FRE147_022-318A FRE147_D022-146A; FRE147_D021-083A; SPU_022-188A	NPDES147A_MH022187; NPDES147B_MH022160
	174	FRE174_013-115A; FRE174_021-044A; FRE174_021-045B; FRE174_021-050A; FRE174_021-066A; FRE174_022-039A FRE174_022-043A; FRE174_022-043A; FRE174_D021-083A; KC_021-056B	NPDES174_MH021052
Interbay	68A & 68B	INT68_028-422A; INT68_028-430A; INT68_028-043A	NPDES068A_028431; NPDES68B_028425
Leschi	26	LES26_042-270A	NPDES026_MH038081
	27	LES 27_042-273A	NPDES027_MH042269
	28	LES28_042-276A; LES28_042-282A	NPDES028_MH042275
	29	LES29_042-300A; LES29_042-302A; LES29_042-305A; LES29_042-305B LES29_042-306A	NPDES029_MH042303
	30	LES30_041-385A; LES30_041-386A; LES 30_042-008A; LES 30_042-202A; LES 30_046-015A; LES 30_042-206B; LES 30_042-205A	NPDES030_MH042322
	31	LES31_046-042A	NPDES031_MH046033

	32	LES32_046-084A; LES32_046-156A; LES32_046-163A	NPDES032A_MH046157; NPDES032B_MH046078
	33	LES33_046-050A; LES33_046-120A; LES33_046-120B; LES33_046-121A; LES33_046-129A; LES34_046-174A	NPDES033_MH046171
	34	LES34_046-061A;	NPDES034_MH046054
	35	LE35_046-139A; LE35_046-188A; LE35_046-188B; LE35_046E-017A; LE35_046E-026A; LES35_046E-031A; LES35_046E-138A	NPDES035_MH046E138
	36	LES36_046E-044A; LES36_046E-113A; LES36_046E-113B; LES36_ 046E-141A; LES36_046E-142A; LES36_046E-149B	NPDES036_MH046E149
	-	SPU_038-353A; SPU_042-231A	-
Madison Park/ Union Bay	22	-	NPDES022_MH032014
	24	UB24_032-097A; UB24_038-141A; UB24_038-283A	NPDES024_PS7
	25	UB25_032-044A; UB25_032-078A; UB25_032-187A; UB25_032-188A; UB25_032-193A; UB25_032-202A; UB25_038-149A; UB25_038-153A; UB25_038-285A	NPDES025_MH038149
Montlake	20	MON20_031-037A; MON20_031-381A; MON20_031-027A	NPDES020_MH031382
	139	MON139_031-310A; MON139_031-313A	NPDES139_MH031313
	140	MON140_031-002A MON140_031-001A	NPDES140_MH031001

	Gravity Basin	SPU_031-143A; SPU_031-227A; SPU_031-231A	
North Union Bay	18	NUB18_007-061A; NUB18_007-094A; NUB18_007-183A; NUB18_007-436A; NUB18_007-438A; NUB18_016-021A; NUB18_016-021B; NUB18_016-076A; NUB18_016-078A; NUB18_016-078B; NUB18_016-078C; NUB18_016-083A; NUB18_016-197A; NUB18_016-505A; NUB18_016-508A; NUB18_016-508B; NUB18_016-510A; NUB18_016-518A; NUB18_016-525A NUB18_024-059A; NUB18_024-059B; NUB18_024-072A; NUB18_001A; NUB18_025-018A; NUB18_025-025A; NUB18_D025-009A	NPDES18A_MH025-380; NPDES18B_MH016-509
	19	-	NPDES19_MH015-237
Portage Bay	127	-	NPDES127_MH036146
	130	PB130_030-133A	NPDES130_MH030410
	132	PB132_030-178A; PB132_030-179A; PB132_030-194A; PB132_030-426A	NPDES132_MH030416
	135	PB135_023-239A	NPDES135_MH023208
	138	PB138_023-188B; PB138_023-188C; PB138_023-191A; PB138_023-434A; PB138_023-438A; PB138_030-352A	NPDES138_MH023192
	175	**PB175_030-072A; PB175_030-074A; PB175_030-074B; PB175_030-096A; PB175_036-046A; PB175_036-046B; PB175_036-581A; PB175_036-585A; PB175_036-585B; SPU_030-080A; SPU_030-358A**	**NPDES175_MH030348**

* Based on information from ZFM2 (2009)

^ Based on information from ADS Intelliserve (2009)

Note – Table include meters which have been removed during the study

Table T-17. Permanent Monitoring Locations Summary

Basin	NPDES Basin	MH No.	Monitoring System Sensor Installation Requirements*	Manhole Location*	Upstream Pipe Length (ft)^	Rain Gage*
Ballard	150	011-184	Velocity/pressure sensors installed in MH inlet pipe	NW Market Street & 24th Ave NW	63,513	08
	152	011-189	Velocity/pressure sensors installed in MH inlet pipe	28th Ave NW & NW Market Street	112,889	08
Delridge	99	055-171	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	26th Ave SW & SW Andover Street	9,735	15
	168	069-428	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	Delridge Way SW & SW Orchard Street	51,335	17
	169	076-367	Pressure only sensor mounted on MH side wall	22nd Ave SW & Henderson Street	31,213	17
	169_0	076-094	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe (overflows only)	22nd Ave SW & Henderson Street	-	17
	170	069-144	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	27th SW & SW Webster Street	6,034	17
Duwamish	107	056-097	Velocity/pressure sensors installed in MH inlet pipe	S Spokane Street & E Marginal Way S	385	15
	111A	056-195	Velocity/pressure sensors installed in MH inlet pipe	E Marginal Way south of S Idaho Street	3,906	15
	111B	056-270	Velocity/pressure sensors installed in MH inlet pipe	Intersection of Oregon Street S, Diagonal Ave S &	2,415	15
	111C	056-365	Velocity/pressure sensors installed in MH inlet pipe	S Oregon Street and Colorado Ave S	4,143	15
	111D	057-253	Velocity/pressure sensors installed in MH inlet pipe and ultra/ pressure sensor installed at floor level on overflow side of weir	1st Ave. S & Diagonal Ave. S. (S of Daniel Smith)	2,201	15
	111E	057-066	Ultra/ pressure/ velocity sensors installed in MH inlet pipe	6th Ave S & S Industrial Way	12,313	15
	111F	057-078	Ultra/ pressure/ velocity sensors installed in MH outlet pipe (reverse installation) and ultra sensor location on surcharge mount on MH wall above invert of outlet	6th Ave S & S Snoqualmie Street	8,352	15
	111G	057-513	Velocity/pressure sensors installed in MH inlet pipe and in MH outlet pipe (standard installation) plus velocity/ pressure sensors located in overflow pipe (reverse installation)	Airport Way S. & S. Snoqualmie Street	5,743	15
	111H	057-347	Ultra/ pressure/ velocity sensors installed in MH inlet pipe	10th Ave S & S Oregon Street	12,889	15
	116	071-024	Ultra/ pressure/ velocity sensors installed in MH inlet pipe	E Marginal Way S & S Brighton Street	3,519	15

Basin	NPDES Basin	MH No.	Monitoring System Sensor Installation Requirements*	Manhole Location*	Upstream Pipe Length (ft)^	Rain Gage*
Fremont	147A	022-187	Velocity/pressure sensors installed in MH inlet pipe (regular installation) and in MH overflow pipe (reverse installation)	3400 Stone Way N at N 34th Street	35,508	09
	147B	022-160	Velocity/pressure sensors installed in MH inlet pipe (regular installation) and in MH overflow pipe (reverse installation)	N 34th St & Woodland Park Ave N	18,571	09
	174	021-052	Velocity/pressure sensors installed in MH inlet pipe and in MH overflow pipe (both regular installation)	NW 36th St & 2nd Ave NW	66,956	09
Interbay	68A	028-431	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	W Boston Street and 15th Ave W	21,703	12
	68B	028-425	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	15th Ave West north of intersection with W Armour Street	34,005	12
Leschi	26	038-081	Velocity/pressure sensors installed in MH inlet pipe with ultrasonic sensor installed outside of and above the inlet pipe to read level over the weir (Surcharge mount).	4000 E Denny Blaine Place	1,186	20
	27	042-269	Velocity/ pressure sensors installed in MH inlet pipe with MP2 sensor installed in MH overflow pipe	1522 Lake Washington Blvd	75,294	20
	28	042-275	Velocity/pressure sensors installed in MH inlet pipe with ultrasonic sensor installed outside of and above the inlet pipe to read level over the weir (Surcharge mount).	1501 Lake Washington Blvd	4,900	20
	29	042-303	Velocity/pressure sensors installed in MH inlet pipe	519 Lake Washington Blvd	5,719	20
	30	042-322	Velocity/pressure sensors installed in MH inlet pipe	219 Lake Washington Blvd	16,177	20
	31	046-033	Velocity/ pressure sensors installed in MH inlet pipe and in MH overflow pipe	300 Lakeside Ave S	1,372	20
	32A	046-157	Velocity/ pressure sensors installed in MH inlet pipe	714 Lakeside Ave S	4,243	20
	32B	046-078	Velocity/pressure sensors installed in MH inlet pipe	35th Ave S and Lakeside Ave S	118	20
	33	046-171	Velocity/pressure sensors installed in MH inlet pipe	900 Lakeside Ave S	12,428	20
	34	046-054	Velocity/pressure sensors installed in MH inlet pipe	900 Lakeside Ave S	18,640	20
	35	046E-138	Velocity/pressure sensors installed in MH inlet pipe	1700 Lakeside Ave S	8,404	20
	36	046E-149	Velocity/pressure sensors installed in MH inlet pipe	2318 Lake Park Drive S	2,928	20

Basin	NPDES Basin	MH No.	Monitoring System Sensor Installation Requirements*	Manhole Location*	Upstream Pipe Length (ft)^	Rain Gage*
Madison Park/ Union Bay	22	032-014	Velocity/pressure/ultrasonic sensors installed in MH outlet pipe (reverse installation).	39th Ave E & E McGilvra Street	6,795	03
	24	PS 7	Ultra/ pressure sensor with ultra on surcharge mount	E Lee Street &42nd Ave E	3,114	20
	25	038-149	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	E Lee Street & 42nd Ave E	39,429	20
Montlake	20	031-382	Velocity/pressure/ultrasonic sensors installed in MH outlet pipe (reverse installation).	2159 E Shelby St	13,416	03
	139	031-313	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	16th Ave E & E Calhoun Street	6,289	03
	140	031-001	Velocity/pressure sensors installed in MH inlet pipe with ultrasonic sensor installed on surcharge mount above inlet pipe	E Shelby Street & W Park Drive E	2,622	03
North Union Bay	18A	025-380	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	3718 NE 41st Street	17,634	03
	18B	016-509	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	40th Ave NE near intersection with 39th Ave NE	133,198	02
	19	015-237	Velocity/pressure/ultrasonic sensors installed in MH outlet pipe (reverse install/ surcharge mount)	2746 NE 45th Street	1,405	03
Portage Bay	127	036-146	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	1109 Fairview Ave N	1,810	03
	130	030-140	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	Minor Ave E and E Roanoke Street	42,220	03
	132	030-381	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe and velocity/ pressure/ ultrasonic sensors installed in MH overflow line (reverse mount)	Minor Ave E and E Roanoke Street	40,943	03
	135	023-208	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	Fuhman Ave E and Eastlake Ave E	15,228	03
	138	023-192	Velocity/pressure/ultrasonic sensors installed in MH outlet pipe (reverse install for dry weather flows)	Dead-end of E Shelby Street and Furham Ave	11,053	03
	175	030-348	Velocity/pressure/ultrasonic sensors installed in MH inlet pipe	Eastlake Ave E and Garfield Street E	61,236	20

* Based on information from ADS Intelliserve (2009)

^ Based on information from SPU Maintenance Hole Shapefile and SPU Sewer/ Drainage Mainlines Shapefile

Table T-18. NPDES Basin Temporary Monitoring Locations Summary

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Ballard	150	BAL150_002-273A	002-272_ 002-273	Measure level and velocity; calculate flow from north west portion of Basin 150, characterize hydrology	25	Missing data*	11,079	8
Ballard	150	BAL150_002-274A	002-310_ 002-274	Measure level and velocity' calculate flow in the north-central portion of Basin 150, characterize hydrology	28	Missing data*	25,435	8
Ballard	150	BAL150_002-349A	002-350_ 002-349	Measure level and velocity; calculate flow in the north east portion of Basin 150, characterize hydrology. Meter removed 3/31/09 as sufficient data collected	18	2.14	5,615	8
Ballard	150	BAL150_011-176A	011-168_ 011-176	Measure level and velocity; calculate flow from Basin 150, characterize hydrology	34	2.6	59,084	8
Ballard	150	BAL150_011-242A	011-241_ 011-242	Measure level and velocity; calculate flow in the interceptor/lakeline downstream from the basin 150 overflow weir, characterize hydrology.	42	0.1	187,814	8
Ballard	150	BAL150_D012-079A	D012-091 D012-079	Measure level and velocity; calculate flow in storm drainage system. New Install Phase 3.	66	0.62	36,638	8
Ballard	152	BAL152_002-015A	002-014_ 002-015	Collect data for Ballard GSI study. New Install Phase 3.	21	0.91	8,269	8
Ballard	152	BAL152_002-016A	002-015_ 002-016	Measure level and velocity; calculate flow in the north-west portion of basin 152, characterize hydrology.	21	1.08	16,338	8
Ballard	152	BAL152_002-032A	002-031_ 002-032	Measure level and velocity; calculate flow in the west -central portion of basin 152, characterize hydrology.	28	4.09	20,498	8
Ballard	152	BAL152_002-096A	002-095_ 002-096	Collect data for Ballard GSI study. New Install Phase 3.	21	0.47	7,656	8
Ballard	152	BAL152_002-123A	002-122_ 002-123	Measure level and velocity; calculate flow in the north-east portion of basin 152, characterize hydrology.	36	1.92	38,192	8
Ballard	152	BAL152_002-232A	002-231_ 002-232	Measure level and velocity; calculate flow in eastern most part of Basin 152. Meter removed 10/19/09.	15	1.92	5,277	8
Ballard	152	BAL152_011-090A	011-091_ 011-090	Measure level and velocity; calculate flow from branch in south east of Basin 152, characterize hydrology. Meter removed 10/19/09.	12	0.57	1,936	8
Ballard	152	BAL152_011-160A	011-152_ 011-160	Measure level and velocity; calculate flow in Basin 152, characterize hydrology. New install Phase 3.	43	1.5	108,967	8
Ballard	152	BAL152_011-187A	011-188_ 011-187	Measure level and velocity; calculate flow exiting basin 152, downstream of overflow weir, characterize hydrology.	36	0.084	122,269	8

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Ballard	152	BAL152_011-213A	011-210_ 011-213	Measure level and velocity; calculate flow from southwest portion of Basin 152 upstream of Pump Station 84. Meter removed 2/3/09 as sufficient data collected	10	0.49	2,285	8
Ballard	152	BAL152_011-218A	011-218_ 011-220	Measure level and velocity; calculate flow from northern and eastern portions of Basin 152, immediately upstream of Pump Station 84. Meter removed 3/31/09 as sufficient data collected	10	1.18	4,991	8
Ballard	152	BAL152_011-222A	011-222_ 011-218	Alternative to Meter BAL152_011-218A. Meter removed 3/31/09 as sufficient data collected	10	0.39	1,958	8
Delridge	168	DEL168_069-280A	069-280 _ 069-279	Measure level and velocity; calculate flow from southern portion of basin upstream of DEL168_069-278A	21	4.49	18,600	17
Delridge	168	DEL168_069-342A	069-364_ 069-342	Alternative to DEL168_069-346A. Meter removed 11/25/2008 as sufficient data collected	30	1.01	27,410	17
Delridge	168	DEL168_069-346A	069-345_ 069-346	Measure level and velocity; calculate flow from northern portion of basin upstream of DEL168_069-278A	24	4.29	31,540	17
Delridge	168	DEL168_069-370A	069-370_ 069-369	Measure level and velocity; calculate flow to CSO facility from basin 168	18	1.00	11,452	17
Delridge	168	DEL168_069-406A	069-406_ 069-405	Measure level and velocity; calculate flow downstream of hydrobrake and storage facility	16	0.64	51,602	17
Delridge	168	DEL168_069-408A	Detention tank	Measure level in storage tank	NA	NA	51,008	17
Delridge	168	DEL168_069-428A	Control chamber	Measure level in control chamber	NA	NA	51,008	17
Delridge	168	DEL168_069-428B	Control chamber	Measure level in control chamber	NA	NA	51,008	17
Delridge	169	DEL169_076-217A	076-218_ 076-217	Measure level and velocity; calculate flow through leaping weir to the DWF side	8	4.52	30,744	17
Delridge	169	DEL169_076-218A	076-232_ 076-218	Measure level in chamber with leaping weir	8x13	0.87	30,511	17
Delridge	169	DEL169_076-232A	076-250 _ 076-232	Measure level and velocity; calculate flow from basin before leaping weir diversion	30	1.22	29,643	17
Delridge	169	DEL169_076-351A	076-351_ 301-155	Measure level and velocity; calculate mainline CSO system flows from NPDES Basin 169, upstream of the leaping weir diversion to the King County system. Installed as an alternative to DEL169_301-155 Meter removed 7/17/09 as sufficient data collected	30	0.35	14,571	17
Delridge	169	DEL169_076-351B	076-351_ 076-352	Measure level and velocity; calculate storm flow into basin, potential alternative to DEL169_301-155A Meter removed 7/17/09 as sufficient data collected	12	8.87	1,790	17

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Delridge	169	DEL169_076-362A	076-363 _ 076-362	Measure level and velocity; calculate flow downstream of hydrobrake flow control and storage facility	12	0.91	31,711	17
Delridge	169	DEL169_076-366A	Storage chamber	Measure level in storage tank	NA	NA	NA (offline)	17
Delridge	169	DEL169_076-367A	Control chamber	Measure level in control chamber	NA	NA	31,710	17
Delridge	169	DEL169_076-367B	Control chamber	Measure level in control chamber	NA	NA	31,710	17
Delridge	169	DEL169_076-370A	076-371_ 076-370	Measure level and velocity; calculate wet weather flow to CSO facility from basin	30	1.34	30,745	17
Delridge	170	DEL170_069-146A	069-144_ 069-146	Measure depth in the hydrobrake chamber. New install Phase 3.	NA	NA	6,346	15
Delridge	99	DEL99_055-165A	055-166_ 055-165	Measure level and velocity; calculate flow downstream of CSO facility & hydrobrake	29.3x23	0.1	32,415	15
Delridge	99	DEL99_055-175A	055-176_ 055-175	Measure level and velocity; calculate flow from western part of Basin 99, characterize hydrology. Meter removed 7/27/09 as the influence of the downstream hydrobrake prevented meter capturing representative flows in larger events	22.8x22	0.83	7,831	15
Delridge	99	DEL99_055-223A	055-224_ 055-223	Measure level and velocity; calculate flow from eastern portion of Basin 99	12	1.6	13,396	15
Delridge	99	DEL99_055-473A	055-499_ 055-473	Measure level in storage pipe	84	NA	NA (offline)	15
Delridge	-	SPU_069-198A	069-199_ 069-198	Measure level and velocity; calculate flow from Basin 170 and upstream basins to King County mainline, characterize hydrology	15	1.37	87,648	17
Delridge	-	SPU_069-242A	069-403_ 069-242	Measure level and velocity; calculate flow from Basin 168, characterize hydrology	15	3.18	79,687	17
Delridge	-	SPU_076-217A	076-218_ 076-217	Measure level and velocity; calculate flow from Basin 169, characterize hydrology	8	4.52	30,744	17
Duwamish	111	DUW111_056-166A	057-550_ 056-166	Measure level and velocity; calculate flow to the King County pump station from the northern part of Basin 111, characterize hydrology	36	0.61	45,462	15
Duwamish	111	DUW111_057-039A	057-040_ 057-039	Measure level and velocity; calculate flow entering Basin 111 from upstream area to northeast, characterize hydrology	20	0.4	21,129	15
Duwamish	111	DUW111_057-229A	057-365_ 057-229	Measure level and velocity; calculate flow downstream of the hydrobrake, characterize hydrobrake	18	2.5	14,418	15
Duwamish	111	DUW111_057-241A	057-165_ 057-241	Measure level and velocity; calculate flow from eastern portion of Basin 111, upstream of all the overflow weirs	12	5.84	5,507	15
Duwamish	111	DUW111_057-241B	057-242_ 057-241	Measure level and velocity; calculate flow from eastern portion of Basin 111, upstream of all the overflow weirs	12	2.65	2,720	15

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Duwamish	111	DUW111_057-247A	057-240_ 057-247	Measure level and velocity; calculate overflow from NPDES 111H to Michigan St basin. Site removed on 3/30/2009, because it was not necessary for basin characterization	8	3.7	8,397	15
Duwamish	111	DUW111_057-350A	057-215_ 057-350	Measure level upstream of hydrobrake, characterize hydrobrake	NA	NA	13,971	15
Fremont	147	FRE147_022-118A	022-117_ 022-118	Measure level and velocity; calculate flow from western portion of Basin 147 (west pipe), characterize hydrology.	12	3.76	6,619	9
Fremont	147	FRE147_022-118B	022-119_ 022-118	Measure level and velocity; calculate flow from western portion of Basin 147 (northwest pipe), characterize hydrology.	12	4.55	4,033	9
Fremont	147	FRE147_022-152A	022-151_ 022-152	Measure level and velocity; calculate flow from western portion of Basin 147 (east pipe), characterize hydrology.	15	4.00	5,679	9
Fremont	147	FRE147_022-174A	022-173_ 022-174	Measure level and velocity; calculate flow entering the King County Interceptor from west/south-west Basin 147, characterize hydrology.	24	0.22	22,158	9
Fremont	147	FRE147_022-187A	022-271_ 022-187	Characterize hydraulics at Basin 147A overflow.	30	1.49	35,508	9
Fremont	147	FRE147_022-306A	022-309_ 022-306	Measure level and velocity; calculate flow in the north portion of Basin 147, characterize hydrology.	18	3.49	13,026	9
Fremont	147	FRE147_022-318A	022-319_ 022-318	Measure level and velocity; calculate flow in the east portion of Basin 147, characterize hydrology	15	4.67	10,931	9
Fremont	147	FRE147_D022-146A	D022-140_ D022-146	Measure level and velocity; calculate flow in storm drainage system.	42	3.518	35,431	9
Fremont	174	FRE174_013-115A	013-083_ 013-115	Measure level and velocity; calculate flow entering the basin from Woodland Park Zoo, characterize hydrology.	18	1.51	413	9
Fremont	174	FRE174_021-044A	021-043_ 021-044	Alternative to 021-045A.	21	0.28	12,318	9
Fremont	174	FRE174_021-045B	021-083_ 021-045	Measure level and velocity; calculate flow from the western portion of Basin 174 and all of Basin 148, characterize hydrology.	24	0.39	13,872	9
Fremont	174	FRE174_021-050A	021-049_ 021-050	Measure level and velocity; calculate flow from Basin 148 and west/central Basin 174 upstream of the King County Interceptor, characterize hydrology.	36	0.15	27,612	9
Fremont	174	FRE174_021-066A	021-067_ 021-066	Measure level and velocity; calculate flow from northeast Basin 174 upstream of the King County Interceptor, characterize hydrology.	36	1.60	39,308	9
Fremont	174	FRE174_022-039A	022-038_ 022-039	Measure level and velocity; calculate flow further downstream on line from zoo, characterize hydrology.	15	6.89	11,555	9

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Fremont	174	FRE174_022-043A	022-044_ 022-043	Measure level and velocity; calculate flow in the middle-eastern portion of Basin 174, characterize hydrology.	12	12.3	7,194	9
Fremont	174	FRE174_D021-083A	D021-059_ D021-083	Measure level and velocity; calculate flow in storm drainage system	36	8.98	22,073	9
Fremont	-	KC_021-056B	021-413_ 021-056	Level only site to determine the impact of the King County Interceptor levels on Basin 174 overflows.	108	0.03	NA	9
Fremont	-	SPU_022-188A	022-187_ 022-188	Level only site located downstream of non-return valve near NPDES 147A that prevents back flow from the King County Interceptor. Measures level to characterize the non-return valve losses and impact of KC interceptor level.	12	3.33	35,547	9
Interbay	68	INT68_028-043A	028-047_ 028-043	Measure level and velocity; calculate flow in southern part of Basin 68, characterize hydrology. New Install Phase 3	19	18.67	16.464	12
Interbay	68	INT68_028-422A	028-425_ 028-422	Level only site to measure depth upstream of hydrobrake. New Install Phase 3.	24	7.7	2,622	12
Interbay	68	INT68_028-430A	028-431_ 028-430	Measure level and velocity; calculate flow in southern part of Basin 68, characterize hydrology. New Install Phase 3	18	-0.311	21,735	12
Leschi	26	LES26_042-270A	042-266_ 042-270	Measure level and velocity; calculate flow from Basin 26, characterize hydrology. Meter removed 7/30/09 as data quality was affected by bump in channel during dry weather and sufficient wet weather data collected	12	0.64	3,092	20
Leschi	27	LES27_042-273A	042-273_ 042-226	Measure level and velocity; calculate flow from Basin 28, characterize hydrology Meter removed 9/17/09	24	0.1	74,248	20
Leschi	28	LES28_042-276A	042-251_ 042-276	Measure level and velocity; calculate flow entering Basin 27 from north Basin 28 upstream from CSO 28 weir, characterize hydrology. Meter removed 9/17/09	10	3.59	666	20
Leschi	28	LES28_042-282A	042-283_ 042-282	Measure level and velocity; calculate flow entering Basin 27 from south Basin 28 upstream from weir, characterize hydrology.	12	1.55	3,807	20
Leschi	29	LES29_042-300A	042-298_ 042-300	Measure level and velocity; calculate flow collected in north basin 29. Characterize hydrology.	12	0.62	2,614	20
Leschi	29	LES29_042-302A	042-325_ 042-302	Level only site. Primary metering goal is to measure level at the hydrobrake.	18	0.99	2,044	20
Leschi	29	LES29_042-305A	042-303_ 042-305	Measure level and velocity; calculate flow entering the lakeline from basin 29. Located downstream of CSO 29, characterize hydrology.	8	3.46	5,751	20

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Leschi	29	LES29_042-305B	042-308_ 042-305	Measure level and velocity; calculate flow in the lakeline upstream of the outfall from basin 29	21	0.12	60,553	20
Leschi	29	LES29_042-306A	042-307_ 042-306	Measure level and velocity; calculate flow in south basin 29. characterize hydrology.	12	0.63	1,737	20
Leschi	30	LES30_041-385A	041-387_ 014-385	Measure level and velocity; calculate flow from west Basin 30 upstream from orifice weir west of the CSO weir, characterize hydrology. Meter removed 04/08/09 as sufficient data collected	10	5.91	3,769	20
Leschi	30	LES30_041-386A	041-384_ 041-386	Measure level and velocity; calculate the sum of flows from Basins 33, 34, 35, and 36 after PS 34. Characterize flows from PS 34. Meter removed 04/08/09 as sufficient data collected	10	6.67	5,120	20
Leschi	30	LES30_042-008A	042-008_ 042-007	Measure level and velocity; calculate flow in the manhole to characterize flow exiting the orifice weir. Primary goal is to capture level data. Meter removed 9/24/09.	10	0.75	520	20
Leschi	30	LES30_042-202A	042-119_ 042-202	Measure level and velocity; calculate flow from north and west Basin 30 upstream of the CSO weir, characterize hydrology.	18	3.14	11,097	20
Leschi	30	LES30_042-205A	CSO Facility	Measure level at the sluice gate	42	0.90	4,530	20
Leschi	30	LES30_042-206B	042-322_ 042-206	Measure level downstream of sluice gate at CSO facility	10	1.18	16,189	20
Leschi	30	LES30_046-015A	046-017_ 046-015	Measure level and velocity; calculate flow from south Basin 30 (incoming SW line) upstream of the CSO weir, characterize hydrology. Meter removed 9/24/09	10	5.22	2,690	20
Leschi	31	LES31_046-042A	046-043_ 046-042	Measure level and velocity; calculate flow in lakeline, upstream from the outfall from basin 31. Characterize hydrology.	18	0.14	40,320	20
Leschi	32	LES32_046-084A	046-085_ 046-084	Measure level and velocity; calculate flow from Basin 32 upstream of the CSO weir and storage facility, characterize hydrology.	12	12.58	2,671	20
Leschi	32	LES32_046-156A	046-157_ 046-156	Measure level in the storage pipe to track overflows.	8	0.59	4,378	20
Leschi	32	LES32_046-163A	046-156_ 046-163	Measure level and velocity; calculate flow in the lake-line to detect backflows into the storage pipe.	8	0.1	4,392	20
Leschi	33	LES33_046-050A	046-171_ 046-050	Measures level of flow relative to the overflow weir. Meter removed 04/08/09 as sufficient data collected	10	0.92	12,482	20
Leschi	33	LES33_046-120A	046-119_ 046-120	Measures flow from the majority of Basin 33 upstream of the overflow weir, characterize hydrology. Installed in the north-most line.	15	8.65	9,432	20

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Leschi	33	LES33_046-120B	046-119_ 046-120	Measure level and velocity; calculate flows and characterize hydrology for Basin 33 (New Install Phase 3)	15	8.65	9,380	20
Leschi	33	LES33_046-121A	046-123_ 046-121	Measure level and velocity; calculate flows and characterize hydrology for Basin 33 (New Install Phase 3)	8	7.26	1,159	20
Leschi	33	LES33_046-129A	046-130_ 046-129	Measure level and velocity; calculate flows and characterize hydrology for Basin 33 (New Install Phase 3)	8	8.41	418	20
Leschi	33	LES33_046-174A	046-177_ 046-074	Measure level in the storage tank at Pump Station 2. Meter removed 04/08/09 as sufficient data collected	54	2.00	12,399	20
Leschi	34	LES34_046-061A	046-061_ 046-060	Measure level and velocity; calculate flows and characterize hydrology for Basin 34. Meter removed 4/2/09 as sufficient data collected	12	0.15	1,470	20
Leschi	35	LES35_046-139A	046-180_ 046-139	Measure level and velocity; calculate flows downstream of sluice gate in CSO Facility	12	4.44	5,560	20
Leschi	35	LES35_046-188A	046-166 _046-180	Measure level upstream of the sluice gate.	12	6.6	5,482	20
Leschi	35	LES35_046-188B	046-166_ 046-180	Measure level in storage tank CSO	NA	NA	5,482	20
Leschi	35	LES35_046E-017A	046E-016_ 046E-017	Measure level and velocity; calculate flow from part of Basin 35, characterize hydrology	15	3.82	5,003	20
Leschi	35	LES35_046E-026A	046E-139_ 046E-026	Measure level and velocity; calculate flow from Basin 35 downstream from the overflow weir; also includes flow from basin 36. Characterize hydrology and basin 035 hydrobrake.	15	0.48	15,217	20
Leschi	35	LES35_046E-031A	046E-033_ 046E-031	Measure level and velocity; calculate flow and characterize hydrology for Basin 35 (New Install Phase 3)	21	0.25	8,870	20
Leschi	35	LES35_046E-138A	Hydrobrake chamber	Measures level just upstream of the hydrobrake since the permanent meter in the same manhole is not at the same level as the hydrobrake.	NA	NA	8,404	20
Leschi	36	LES36_046E-044A	046E-166_ 046E-044	Measure level and velocity; calculate flow entering the lakeline from west of basin 36 and level relative to weir height (south line), downstream from the CSO weir. Meter removed 9/30/09	8	7.00	932	20
Leschi	36	LES36_046E-113A	046E-119_ 046E-113	Measure level and velocity; calculate flow from the majority of basin 36, located upstream from the overflow weir. Characterize hydrology. Meter removed 1/8/09 as site hydraulics not conducive to collecting good data. Moved downstream to 149B	8	0.86	1,032	20

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Leschi	36	LES36_046E-113B	046E-114_ 046E-113	Measure level and velocity; calculate flow from the majority of basin 36, located upstream from the overflow weir. Characterize hydrology. Meter removed 1/8/09 as site hydraulics not conducive to collecting good data. Moved downstream to 149B	8	11.4	936	20
Leschi	36	LES36_046E-141A	046E-142_ 046E-141	Measure level and velocity; calculate flow downstream of the hydrobrake in NPDES 36.	16	0.3	5,864	20
Leschi	36	LES36_046E-142A	046E-143_ 046E-142	Measures primarily level upstream of the hydrobrake in NPDES 36. Velocity data will be reviewed to see if it is usable.	16	0.25	5,664	20
Leschi	36	LES36_046E-149B	046E-108_ 046E-149	Measure level and velocity; calculate flow from basin 36. Meter removed 4/2/09 as site hydraulics were not conducive to collecting data (steep slope)	8	30	2,928	20
Leschi	-	SPU_038-353A	038-098_ 038-353	Measure level and velocity; calculate flow outside of the Leschi basin into the King County line that enters into the Montlake basin	12	5.5	4,961	20
Leschi	-	SPU_042-231A	042-227_ 042-231	Measure level and velocity; calculate flow from basin to the West of Leschi that joins flows from the E. Pine street pump station and flows to the Montlake regulator.	36	0.3	48,716	20
Montlake	139	MON139_031-310A	030-309_ 030-310	Measure level and velocity; calculate flows from Basin 139 upstream of overflow weir, characterize hydrology	18	5.27	4,915	3
Montlake	139	MON139_031-313A	031-313_ D031-075	Level only, confirm whether overflows occur and identify storm drain influence on overflow	MH	NA	6,289	3
Montlake	140	MON140_031-001A	031-015_ 031-001	Level only, confirm whether overflows occur and identify lake level influence on overflow	18	2.45	2,622	3
Montlake	140	MON140_031-002A	031-001_ 031-002	Measure level and velocity; calculate flow downstream of hydrobrake CSO, characterize hydrobrake	8	0.51	2,739	3
Montlake	20	MON20_031-027A	031-430_ 031-027	Measure level and velocity; calculate flows from PS #13 in order to develop pump curves. Meter removed 2/6/09 as sufficient data collected	8	0.3	14,472	3
Montlake	20	MON20_031-037A	031-038_ 031-037	Measure level and velocity; calculate flow from most of Basin 20, characterize hydrology	21	0.53	10,024	3
Montlake	20	MON20_031-381A	031-384_ 031-381	Measure level and velocity; calculate flows from Basin 20 upstream of overflow weir and pumping station, characterize hydrology. Meter removed 10/23/2009 as sufficient data collected	24	11.58	13,395	3

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Montlake	Montlake Gravity	SPU_031-143A	031-358_ 031-143	Measure level and velocity; calculate flow from Basin 139 and the gravity portion of the Montlake basin tributary to the King County trunk main, characterize hydrology	66	0.24	83,839	3
Montlake	Montlake Gravity	SPU_031-227A	031-222_ 031-227	Measure level and velocity; calculate flow from area to southwest in the Montlake gravity basin, characterize hydrology. Meter removed 8/20/09 as sufficient data collected	24 x 36	2.55	34,929	3
Montlake	Montlake Gravity	SPU_031-231A	031-232_ 031-231	Measure level and velocity; calculate flow from area to southeast in the Montlake gravity basin, characterize hydrology. Meter removed 8/20/09 as sufficient data collected	27	0.72	22,288	3
North Union Bay	-	KC_025-050A	025-361_ 025-050	Measure level and velocity; calculate flow to Belvoir Pump Station and characterize the pump station	48	NA	163,456	2
North Union Bay	18	NUB18_007-061A	007-055_ 007-061	Measure level and velocity; calculate flow in the northwest portion of basin 18B, characterize hydrology. Meter removed 10/14/09	27	4.88	40,110	2
North Union Bay	18	NUB18_007-094A	007-095_ 007-094	Measure level and velocity; calculate flow in north-central portion of basin 18B, characterize hydrology. Meter removed 7/22/2009	18	4.85	12,769	2
North Union Bay	18	NUB18_007-183A	007-193_ 007-183	Measure level and velocity; calculate flow in the eastern portion of basin 18B, characterize hydrology. Meter removed 12/1/09 as sufficient data collected.	21	1.31	13,514	2
North Union Bay	18	NUB18_007-436A	007-093_ 007-436	Measure level and velocity; calculate combined flows from meters 007-183 and 007-095, characterize hydrology. Meter removed 10/14/2009	24	4.92	32,965	2
North Union Bay	18	NUB18_007-438A	007-065_ 007-438	Measure level and velocity; calculate flow in the western portion of basin 18B, characterize hydrology. Meter removed 2/11/09 as site hydraulics not conducive to collecting good data. Rely on 016-078	27	4.77	51,195	2
North Union Bay	18	NUB18_016-021A	016-011_ 016-021	Measure level and velocity; calculate flow in western portion of Basin 18B, characterize hydrology (two sensor pair). Meter removed 4/6/09	12	6.34	5,743	2
North Union Bay	18	NUB18_016-021B	016-022_ 016-021	Measure level and velocity; calculate flow in western portion of Basin 18B, characterize hydrology (two sensor pair). Meter removed 4/6/09	12	0.67	2,608	2

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
North Union Bay	18	NUB18_016-076A	016-041_ 016-076	Measure level and velocity; calculate flow in western portion of Basin 18B, upstream of junction with flows from northern and eastern part, characterize hydrology. Meter removed 10/14/09.	21	2.57	14,278	2
North Union Bay	18	NUB18_016-078A	016-077_ 016-078	Measure level upstream of weir. Meter removed 1/12/09 as accuracy of data uncertain. Replaced with 016-078C	24	6.43	130,222	2
North Union Bay	18	NUB18_016-078B	016-077_ 016-078	Measure level upstream of weir. Meter removed 1/12/09 as accuracy of data uncertain. Replaced with 016-078C	24	6.43	130,222	2
North Union Bay	18	NUB18_016-078C	016-077_ 016-078	Measure level upstream of weir. Meter removed 10/14/2009	24	6.43	130,222	2
North Union Bay	18	NUB18_016-083A	016-084_ 016-083	Measure level and velocity; calculate flow from southeast portion of Basin 18B, characterize hydrology. Meter removed 10/14/2009	24	1.09	18,856	2
North Union Bay	18	NUB18_016-197A	016-197_ 016-198	Measure level and velocity; calculate total flows from Basin 18B, upstream of King County trunk main	26	0.35	143,726	3
North Union Bay	18	NUB18_016-505A	016-524_ 016-505	Measure level in storage facility, characterize hydrobrake	Level Only	NA	135,864	3
North Union Bay	18	NUB18_016-508A	016-507_ 016-508	Measure level and velocity; calculate flow downstream of two overflow weirs and upstream of storage facility and overflow weir at CSO 18B	54	0.3	165,031	2
North Union Bay	18	NUB18_016-508B	016-507_ 016-508	Measure level and velocity; calculate flow downstream of two overflow weirs and upstream of storage facility and overflow weir at CSO 18B	54	0.3	165,644	2
North Union Bay	18	NUB18_016-510A	016-077_ 016-510	Measure level and velocity; calculate flow upstream of storage facility and hydrobrake (not in overflow lines)	24	0.31	135,490	2
North Union Bay	18	NUB18_016-518A	016-532_ 016-518	Measure level and velocity; calculate flow downstream of the hydrobrake, characterize hydrobrake	24	5.06	137,050	3
North Union Bay	18	NUB18_016-525A	016-508_ 016-525	Measure level and velocity; calculate flow entering storage facility 24. Meter removed 2/4/09, replaced by meters at 508A/B to obtain better hydrology data	54	5.24	133,152	2
North Union Bay	18	NUB18_024-059A	025-022_ 024-059	Measure level and velocity; calculate flow from Basin 18A in the 30-inch pipe, upstream of King County trunk main	30	-0.22	165,665	3
North Union Bay	18	NUB18_024-059B	024-072_ 024-059	Measure level and velocity; calculate flow from Basin 18A in the 18-inch pipe downstream of hydrobrake and upstream of junction with 30-inch pipe (see above), characterize hydrobrake	30	0.48	165,644	3

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
North Union Bay	18	NUB18_024-072A	025-378_ 024-072	Measure level in storage facility, characterize hydrobrake	72	0.2	165,644	3
North Union Bay	18	NUB18_025-001A	016-197_ 025-001	Measure level and velocity; calculate flow entering Basin 18A from 18B over the weir, model flows over weir. Meter removed 7/29/09, not required as weir will be removed	15	10.24	143,785	2
North Union Bay	18	NUB18_025-018A	025-011_ 025-018	Measure level and velocity; calculate sum of flows entering Basin 18A from 18B over the weir and flows from western portion of Basin 18A	21	1.99	146,352	2
North Union Bay	18	NUB18_025-025A	025-026_ 025-025	Measure level and velocity; calculate flow from eastern portion of basin 18A, characterize hydrology	30	0.24	17,353	2
North Union Bay	18	NUB18_D025-009A	D025-152_ D052-009	Measure level and velocity; calculate flow in storm drainage system. New Install Phase 3.	72	NA	206,400	2
Portage Bay	130	PB130_030-133A	030-134_ 030-133	Measure level and velocity; calculate flow from basin 130, characterize hydrology	18	1.05	5,265	2
Portage Bay	132	PB132_030-178A	030-177_ 030-178	Measure level and velocity; calculate combined flows from southwest and eastern portions of basin 132, characterize hydrology	15	4.55	3,661	3
Portage Bay	132	PB132_030-179A	030-180_ 030-179	Measure level and velocity; calculate flow from southwest portion of basin 132, characterize hydrology	8	2.65	1,223	3
Portage Bay	132	PB132_030-194A	030-195_ 030-194	Measure level and velocity; calculate flow from eastern portion of basin 133, characterize hydrology	15	7.61	7,103	3
Portage Bay	132	PB132_030-426A	030-425_ 030-426	Measure level and velocity; calculate total flows from Basin 133 and upstream basins entering Basin 132	30	0.43	32,911	3
Portage Bay	135	PB135_023-239A	023-238_ 023-239	Measure level and velocity; calculate flow from Basin 135 and 138 upstream of overflow weir	12	0.56	13,973	3
Portage Bay	138	PB138_023-188B	023-221_ 023-188	Measure level and velocity; calculate flow from northern part of Basin 138, characterize hydrology (two sensor pair)	15	9.13	1,393	3
Portage Bay	138	PB138_023-188C	023-187_ 023-188	Measure level and velocity; calculate flow from northern part of Basin 138, characterize hydrology (two sensor pair)	10	5.36	2,619	3
Portage Bay	138	PB138_023-191A	023-434_ 023-191	Measure level and velocity; calculate flow downstream of hydrobrake, characterize hydrobrake	18	0.5	8,065	3
Portage Bay	138	PB138_023-434A	023-418_ 023-434	Measure level and velocity; calculate flow upstream of the hydrobrake	18	0.9	7,850	3
Portage Bay	138	PB138_023-438A	023-437_ 023-438	Measure level in the storage pipes	132	0.52	Offline	3

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Portage Bay	138	PB138_030-352A	030-235_ 030-352	Measure level and velocity; calculate flow from southern part of Basin 138, characterize hydrology	18	0.18	3,658	3
Portage Bay	175	PB175_030-072A	030-074_ 030-072	Measure level and velocity; calculate flow in Basin 175, characterize hydrology. Meter was removed 11/25/2008 as site hydraulics were not conducive to collecting good data. Replaced by 036-074A and 030-096A	15	0.14	8,574	3
Portage Bay	175	PB175_030-074A	030-081_ 030-074	Measure level and velocity; calculate flow from part of Basin 175, characterize hydrology	15	3.01	3,409	3
Portage Bay	175	PB175_030-074B	030-075_ 030-074	Measure level and velocity; calculate flow from part of Basin 175, characterize hydrology	12	26.87	5,102	3
Portage Bay	175	PB175_030-096A	030-101_ 030-096	Measure level and velocity; calculate flow from part Basin 175, characterize hydrology. Meter removed 12/5/08	15	0.92	3,971	3
Portage Bay	175	PB175_036-046A	036-059_ 036-046	Measure level and velocity; calculate flows from eastern part of Basin 175, characterize hydrology (two sensor pair). Meter removed 10/16/09	12	1.95	5,691	3
Portage Bay	175	PB175_036-046B	036-047_ 036-046	Measure level and velocity; calculate flow from eastern part of Basin 175, characterize hydrology (two sensor pair). Meter removed 10/16/09	10	3.75	2,806	20
Portage Bay	175	PB175_036-581A	036-587_ 036-581	Measure level and velocity; calculate flow in the 30-inch pipe entering Basin 175 from Basin 128	30	0.71	13,074	20
Portage Bay	175	PB175_036-585A	036-584_ 036-585	Measure level and velocity; calculate flow from majority of Basin 175, characterize hydrology. Meter removed 11/17/2008 as site hydraulics were not conducive to collecting good data (rely on downstream meter at 038-561	24	0.81	12,174	3
Portage Bay	175	PB175_036-585B	036-586_ 036-585	Measure level and velocity; calculate flow from small portion of Basin 175, characterize hydrology. Meter removed 11/17/2008 as site hydraulics were not conducive to collecting good data (rely on downstream meter at 038-561)	12	13.48	559	3
Portage Bay	-	SPU_030-080A	030-070_ 030-080	Measure level and velocity; calculate flow from part of Basin 175, characterize hydrology	21	0.14	10,522	3
Portage Bay	-	SPU_030-358A	030-420_ 030-358	Measure level and velocity; calculate flows in Basin 175, characterize hydrology	48	0.15	71,839	3
Union Bay	-	KC_031-053A	031-054_ 031-053	Measure level and velocity; calculate flow in the King County system from Leschi and Union Bay	60	0.6	217,554	3

Basin	NPDES Basin	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage**
Union Bay	24	UB24_032-097A	032-096_ 032-097	Measure level and velocity; calculate flow entering trunk main from west part of Basin 25 between 032-078 and 032-187, characterize hydrology. Meter removed 4/6/09 as sufficient data collected	15	0.15	2,029	20
Union Bay	24	UB24_038-141A	038-140 _ 038-141	Measure level and velocity; calculate flow from southern part of Basin 24 upstream of Pump Station 7, characterize hydrology. Meter removed 9/19/09 as sufficient data collected	18	0.1	4,365	20
Union Bay	24	UB24_038-283A	038-143_ 038-283	Meter downstream of CSO overflow weir to document influence of lake level on overflow	21	1.79	47,084	20
Union Bay	25	UB25_032-044A	032-016_ 032-044	Measure level and velocity; calculate flow from Basin 22 and northeast part of Basin 25, characterize hydrology. Site removed 9/19/09 as sufficient data collected	8	0.41	14,800	3
Union Bay	25	UB25_032-078A	032-077_ 032-078	Measure level and velocity; calculate flow in Basin 25, characterize hydrology in upper basin. Meter removed 9/30/09 as sufficient data collected	24	0.1	20,189	3
Union Bay	25	UB25_032-187A	032-188_ 032-187	Measure level and velocity; calculate flow upstream of storage in Basin 25, characterize hydrology. Meter removed 4/15/09 as site hydraulics not conducive to collecting good data, moved upstream to 188A	36	0.1	31,903	20
Union Bay	25	UB25_032-188A	032-189_ 032-188	Measure level and velocity; calculate flow upstream of storage in Basin 25, characterize hydrology	36	0.5	31,865	20
Union Bay	25	UB25_032-193A	032-108_ 032-193	Measure level and velocity; calculate flow from part of Basin 25, characterize hydrology. Meter removed 4/6/09 as sufficient data collected	12	1.90	2,009	3
Union Bay	25	UB25_032-202A	032-204_ 032-202	Measure level and velocity; calculate flow from part of Basin 25, characterize hydrology. Meter removed 4/6/09 as sufficient data collected	18	0.79	4,654	3
Union Bay	25	UB25_038-149A	MH 038-149	Measure level downstream of CSO overflow weir to confirm data from permanent meter (previously called UB25_038-280A)	NA	NA	NA	20
Union Bay	25	UB25_038-153A	038-154_ 038-153	Measure level and velocity; calculate flow from part Basin 25, characterize hydrology. Meter removed 04/08/09 as sufficient data collected	10	0.58	1,606	3
Union Bay	25	UB25_038-285A	038-157_ 038-285	Measure level and velocity; calculate flows from western part of Basin 25, characterize hydrology	21	4.92	5,172	20

^ Pipe ID consists of Upstream MH ID-Downstream MH ID

** In some cases the GIS data was incomplete and the pipe slope could not be calculated*

***Rain gage assigned for data review - some basins may be covered by multiple gages*

Data in this table based on information from ZFM2 (2009), SPU Maintenance Holes Shapefile and SPU Sewer/ Drainage Mainlines Shapefile

Table T-19. System Wide Temporary Monitoring Locations Summary

Area	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage
Alaska Street	ALK_059-162A	059-163_059-162	Characterize hydrology for system wide model (Basin 059-445)	60	0.308	108,021	18
Ballard	BAL_012-127A	012-112_012-127	Characterize hydrology for system wide model (Basin 012-172)	44	0.376	99,967	8
Ballard	BAL_012-373A	012-380_012-373	Characterize hydrology for system wide model (Basin 012-165)	42	2.4	556,282	8
Capitol Hill	CAP_036-387A	036-342_036-387	Characterize hydrology for system wide model (Basin 035-584)	32 x 42	2.36	94,975	20
Commodore	COM_020-073A	020-073_020-073	Characterize hydrology for system wide model (Basin 011-299)	24	2.69	43,752	8
Commodore	COM_020-212A	020-213_020-212	Characterize hydrology for system wide model (Basin 020-170)	30 X 45	0.41	56,016	8
Dexter	DEX_035-241A	035-239_035-241	Characterize hydrology for system wide model (Basin 035-205)	48	0.26	35,152	11
Dexter	DEX_035-241B	035-238_035-241	Characterize hydrology for system wide model (Basin 035-205)	21	1.76	14,323	11
Dexter	DEX_035-300A	035-365_035-300	Characterize hydrology for system wide model (Basin 035-205)	60	0.7	143,374	11
Genesee	GEN_059-442A	056-443_059-442	Characterize hydrology for system wide model (Basin 059-4450	42	0.09	121,001	30
Green Lake	GLK_004-219A	004-220_004-219	Characterize hydrology for system wide model (Basin 004-315)	54	0.138	56,829	9
Green Lake	GLK_005-095A	005-433_005-095	Characterize hydrology for system wide model (Basin 024-017)	90		366,652	9
Green Lake	GLK_005-117A	005-118_005-117	Characterize hydrology for system wide model (Basin 024-017)	36	2.06	6,197	9
Green Lake	GLK_005-154B	005-155_005-154	Measure level and velocity to calculate inflows to combined system from Green Lake	36	2.94	NA	9
Green Lake	GLK_005-157A	005-436_005-157	Characterize hydrology for system wide model (Basin 005-116)	54	1.79	59,015	9
Green Lake	GLK_005-157B	005-158_005-157	Measure level and velocity to calculate inflows to combined system from Green Lake	24	1.89	NA	9
Hanford	HAN_052-172A	052-174_052-172	Characterize hydrology for system wide model (Basin 052-087)	36 x 54	1.794	81,943	15
Hanford	HAN_052-318A	052-319_052-318	Characterize hydrology for system wide model (Basin 052-109)	18	12.55	22,181	15
Hanford	HAN_058-106A	058-405_058-106	Characterize hydrology for system wide model (Basin 058-104)	30	0.808	23,507	15
Hanford	HAN_D052-137A	D052-138_D052-137	Measure level and velocity and calculate flows in storm drainage system	36	1.455	36,027	15
Henderson	HEN_306-242A	306-244_306-242	Characterize hydrology for system wide model (Basin 081-348a)	18	NA	436,462	30
KC North Interceptor	KCNI_022-185A	022-191_022-185	Characterize hydrology for system wide model (Basin 021-056)	108	0.089	2,671,902	9
Linden	LIN_225-095A	225-094_225-095	Characterize hydrology for system wide model (Basin 232-385)	21	0.806	118,791	1
Luna Park	LP_055-387A	055-044_055-387	Characterize hydrology for system wide model (Basin 055-136)	30	3.39	64,730	14
Lower Queen Anne	LQA_034-026A	034-027_034-026	Characterize hydrology for system wide model (Basin 034-283)	42	0.922	41,437	11
Michigan	MICH_065-398A	065-394_063-398	Characterize hydrology for system wide model (Basin 064-188A)	30	5.17	49,385	16
MLK Way KC	MLKKC_080-169A	080-521_080-169	Characterize hydrology for system wide model (Basin 305-021)	60	NA	169,719	18

Area	Site ID	Upstream Pipe ID^	Purpose	Pipe Dia (in)	Pipe slope (%)	Upstream Pipe Length (ft)	Rain Gage
Mt Baker	MTB_052-254A	052-476_052-254	Characterize hydrology for system wide model (Basin 058-094)	30 x 45	NA	30,811	18
Madison Valley	MV_037-421A	037-146_037-421	Characterize hydrology for system wide model (Basin NSA-Arboretum)	60	NA	170,652	20
North Queen Anne	NQA_021-245A	021-270_021-245	Characterize hydrology for system wide model (Basin 021-406)	30	2.54	22,095	9
North Union Bay	NUB18_D025-009A	D025-152_D025-009	Measure level and velocity and calculate flows in storm drainage system	72	NA	206,449	2
Rainer	RAN_045-469A	045-468_046-469	Characterize hydrology for system wide model (Basin 052-440)	18	1.97	20,348	20
Rainer	RAN_052-417A	052-407_052-417	Characterize hydrology for system wide model (Basin 052-440)	15	10.07	10,132	15
Ravena	RAV_014-126A	005-203_014-126	Characterize hydrology for system wide model (024-017)	48	0.75	71,908	4
Ravena	RAV_015-104A	015-105_015-104	Characterize hydrology for system wide model (015-272)	21	7.42	21,823	4

Table T-20. Monitoring Hydrobrake and Sluice Gate Performance

Basin	NPDES Basin	Hydrobrake or Sluice Gate MH ID	Supporting Upstream Monitoring Location (MH ID)	Supporting Downstream Monitoring Location (MH ID)
Delridge	99	056-478	055-477	055-165
	168	069-428	069-428A	069-406
	169	076-367	076-367A	076-362
	170	069-146	NPDES170_069-144	-
Duwamish	111	057-229	057-350	057-229
Leschi	29	042-302	042-302A	NPDES029_042-303; 042-305A
	30	042-205 (sluice gate)	042-205A	-
	32A	046-156	046-156A	046-163A
	33	046-171	046-171	046-050A
	33/34*	046-172	Not monitored	Not monitored
	35	046-188 (sluice gate)	046E-188A	046-0139A
	35	046E-138 (hydrobrake)	NPDES035_046E-138	046E-026 minus 046E-141
	36	046E-142	046E-142	046E-141
Montlake	140	031-001	NPDES140_031-001	031-002
North Union Bay	18B	016-505	016-505	016-518
	18A	042-072	024-072	025-059B
Portage Bay	138	023-434	023-438	023-191

* The hydrobrake in Basin 33 is downstream of a weir that diverts excess flows to the storage tank in Basin 34.

Based on information from ZFM2 (2009), ADS Intelliserve (2009), SPU CSO Mapbook and SPU Basin Schematics

Table T-21. Monitoring Storage Facility Performance

Basin	NPDES Basin	Storage Facility Location	Diameter (inch)	Length (ft)	Endpoint MH IDs	Supporting Monitors	Related Hydrobrake
Delridge	99	26th Ave SW and SW Andover Street	84	565	055-472; 055-473	055-473; 055-477	056-478
	168	Delridge Way SW and SW Orchard Street	1.6 million gallon storage tank		069-408	069-408; 069-428a	069-428
	169	22nd Ave SW and SW Henderson Street	1.6 million gallon storage tank		076-366	076-366; 076-367A	076-367
	170	24th Ave SW between SW Webster St and SW Holden St	96		069-149: 069-146	069-146A	069-146
Leschi	29	East side of Lake Washington Blvd at E James Street	18	307	042-306; 042-325	042-300; 042-302; 042-306	042-302
	30	East side of Lake Washington Blvd at E Alder Street	42	251	042-205; 046-161	042-205; NDPES030 042-322	042-205
	32	Lakeside Ave S between S Lane Street and S Dearborn Street	30	164	046-158; 046-156	046-156; NPDES032A 046-157	046-156
	35	Upper system between 35th Ave S and 36th Ave S (next to I-90), Lower system S Massachusetts Street	72	55	046-179; 146-180	046-180	046E-138; 046-188
	36	Lake Washington Blvd S near Lake Park Drive S	16	1205	046E-142; 046E-150	046E-142	046E-142
Magnolia	62, 63	Magnolia Blvd W and W Armour Street	72	227	026-422; 026-420	026-422A	MH 026-422
Montlake	20	Easement east of E Park Drive and north of E Shelby Street	72	273	031-375; 031-380	031-381; NPDES020 031-382	None
			72	277	031-388; 031-380		
	140	West Park Drive and E Shelby Street	54	25	031-417; 031-416	031-002; NPDES140 031-001	031-001
			120	36	031-416; 031-415		
North Union Bay	18B	39th Ave NE and 40th Ave NE	144	1000	016-525; 016-505	016-505	016-505
North Union Bay	18	NE 41st Street and 36th Ave NE	72	740	025-380; 024-072	024-072	02472
Portage Bay	138	E Shelby Street and Boyer Ave E.	132	89	023-437; 023-438	023-438	023-434
			132	89	023-436; 023-435		

Information sourced from CSO Mapbook, SPU Basin Schematics and SPU Maintenance Holes Shapefile and SPU Sewer/ Drainage Mainline Shapefile

Note that this table does not include storage facility that are not being monitored as part of the Long Term Control Plan

Table T-22. Rainfall Monitoring Locations

Gage Number	Location	Description	NPDES Basins
01	Haller Lk Shop, N 138th St and Ashworth Ave	Tipping Bucket	-
02	Warren G Magnusson Park, Sand Point Way	Tipping Bucket	18 (part)
03	University of Washington (UW Harris Hydraulics Club), NE Pacific Street and 15th Ave NE	Tipping Bucket	139, 140, 20, 22, 18 (part), 19, 130, 132, 135,138,175,24 (part),25 (part)
04	Maple Leaf Reservoir (Roosevelt Ave N and NE 86th Street)	Tipping Bucket	-
05	Fauntleroy Ferry Terminal (W Seattle Ferries Building)	Tipping Bucket	-
07	Whitman Junior High (15h Ave NW & NW 95th Street)	Tipping Bucket	-
08	Hiram M Chittenden Locks, 3015 NW 54th Street	Tipping Bucket	150,152
09	Woodland Park Zoo (Rain Forest Food Pavilion), 5000 Phinney Ave NE	Tipping Bucket	147, 148, 174
11	Metro-KC Denny Regulator (Myrtle Edwards Park)	Tipping Bucket	-
12	Catherine Blaine Middle School, 2550 34th Ave W	Tipping Bucket	68 (part)
14	West Seattle High School (Walnut Ave S and SW Winthrop Street)	Tipping Bucket	-
15	4401 E Marginal Way (parking lot of State Liquor Board)	Tipping Bucket	99, 107, 111
16	Metro-KC E Marginal Pump Station (E Marginal Way S and 13th Ave S)	Tipping Bucket	-
17	West Seattle Reservoir, 8th Ave SW and Cloverdale Street	Tipping Bucket	168, 169, 170
18	Aki Kurose Middle School, S Graham Street	Tipping Bucket	-
20	TT Minor Elementary School, 1700 E Union Street	Tipping Bucket	28,29,30,31,32, 33,34, 35,36,175, 24 (part),25 (part)
30	9125 Rainer Ave S, Seattle Public Library Rainer Beach	Tipping Bucket	-

Based on information from ADS Intelliserve (2009) and SPU Theisson polygon shapefile

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Glossary

Accuracy - Accuracy is defined as the degree of agreement of a measurement to an accepted reference or true value.

Hydrologic data generally have no "true" results for comparison. For hydrologic data, accuracy will be assessed by comparison of results to repeat measurements (e.g. repeated velocity measurements at the same or similar depth – the scatter graph), use of another instrument, engineering calculations, or to manufacturer specifications.

Velocity data – The independently measured value may be determined by manually measuring velocity in the cross-section using a portable meter (e.g., Marsh-McBirney Flo-Mate).

Discharge data – Discharge is computed as the product of measured velocity and cross-sectional area of the flow in accordance with standard procedures (PSEP 1997), and is thus subject to the accuracy of those parameters. An independently measured value could be determined by dye-dilution tests.

Water depth data - The independently measured value will be derived by measuring the water depth at the flow monitor using a staff gauge or ruler.

Precipitation depth - The independently measured value is the theoretical accuracy as specified by the manufacturer. The rain gauge's actual readings will be determined by measuring the volume of water required to initiate one tip of the associated bucket by adding incremental drops of water with a pipette.

Comparability - Comparability is the confidence with which one data set can be compared to another. Comparability can be related to accuracy and precision, as these quantities are measures of data reliability. Data are comparable if sample collection techniques, measurement procedures, analytical methods and reporting are equivalent for samples within a sample set.

With flow data, comparability will be assessed with the scatter plot of velocity plotted against depth of flow. If at a given depth, measured velocity is expected to fall within a specific range dependent on the measurement site and the measurement technology.

Completeness – Completeness ensures that a sufficient amount of data and information (relative to the prescribed DQOs) are present. For flow monitoring, completeness, completeness refers to the number of monitoring stations established in the service area and is related to Representativeness.

Compliance - An element of the data verification process. The extent that adherence to SOPs, QAPP, and/or contractual requirements were followed, achieved, and/or completed successfully, and that conditions under which the data were recorded also met the requirements. Compliance ensures that the data pass numerical quality control tests, including criteria on precision and accuracy, based on parameters or specified limits specified in relevant SOPs and or QAPP.

Consistency - An element of the data verification process. The extent to which data collection procedures were done in a similar manner across different sites (if applicable) and data reporting was done in a similar manner in multiple places. Consistency (also known as comparability) ensures that the reported values are the same when used throughout the study.

Correctness - An element of the data verification process. A mechanical, objective check that data collection plans and protocols have been followed and that basic operations and calculations were performed using properly documented and properly-applied algorithms. Correctness ensures that the reported values are based on properly documented algorithms.

Precision Objectives - Precision is the degree of agreement between a set of replicate measurements. For flow monitoring it will be measured by observation of the scatter plot of velocity vs. depth. The repeatability of measurements at a given depth is a measure of precision.

Representativeness - Representativeness is the degree to which data accurately and precisely represent a characteristic of a population. Representativeness is a function of sample site selection (as sites provide a representative measure of the different characteristics of the service area), sampling methods, and analytical techniques. The rationale for sample site selection and sampling methodology is provided in Section 6.2.3.

Drawings

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Drawing 1. Study Area Maps

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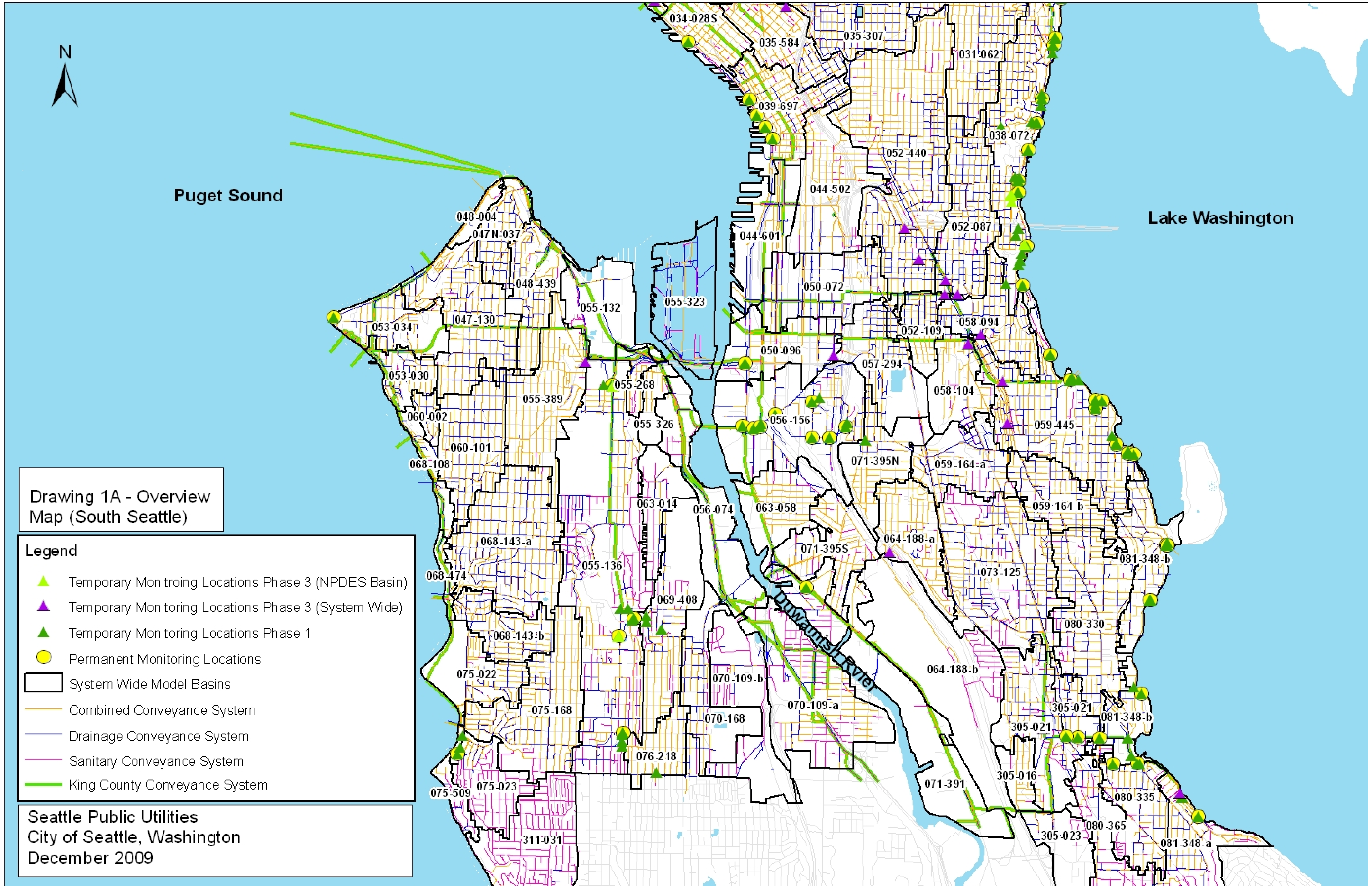

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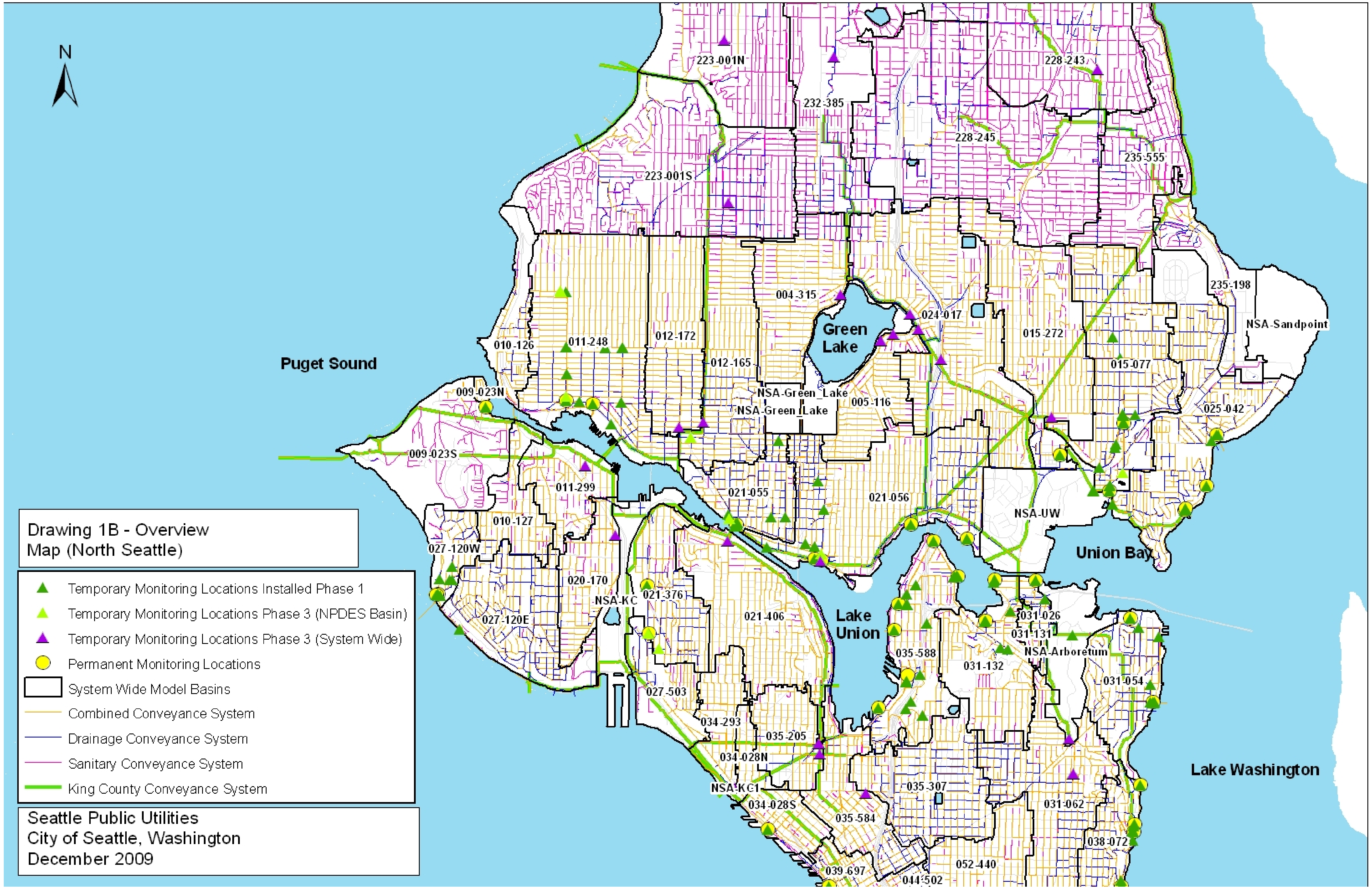
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Lake Union
Union Bay
Lake Washington
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235-198
NSA-Sandpoint
004-315
024-017
015-272
015-077
010-126
011-248
012-172
012-165
NSA-Green_Lake
005-116
025-042
009-023N
009-023S
011-299
021-055
021-056
NSA-UW
010-127
027-120W
020-170
NSA-KC
021-376
021-406
027-120E
035-588
031-026
031-131
NSA-Arboretum
031-132
031-054
027-503
034-293
035-205
034-028N
NSA-KC1
034-028S
035-307
035-584
031-062
038-072
039-697
052-440
044-502
Drawing 1B - Overview Map (North Seattle)
Temporary Monitoring Locations Installed Phase 1
Temporary Monitoring Locations Phase 3 (NPDES Basin)
Temporary Monitoring Locations Phase 3 (System Wide)
Permanent Monitoring Locations
System Wide Model Basins
Combined Conveyance System
Drainage Conveyance System
Sanitary Conveyance System
King County Conveyance System
Seattle Public Utilities
City of Seattle, Washington
December 2009

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Drawing 2. SPU Rain Gages and Theisson Polygons

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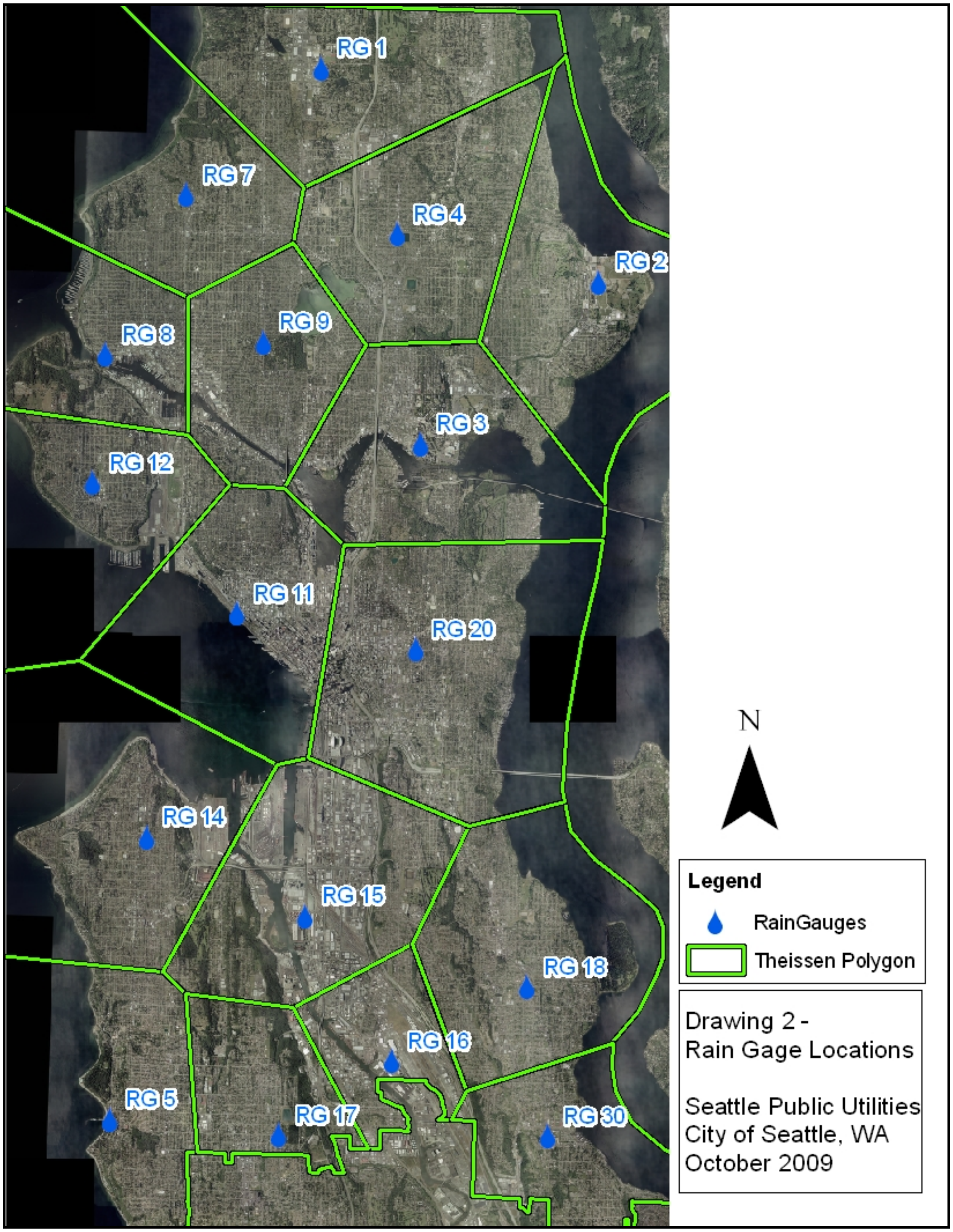
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Drawing 2 -
Rain Gage Locations
Seattle Public Utilities
City of Seattle, WA
October 2009

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Appendix A
Basin Schematics

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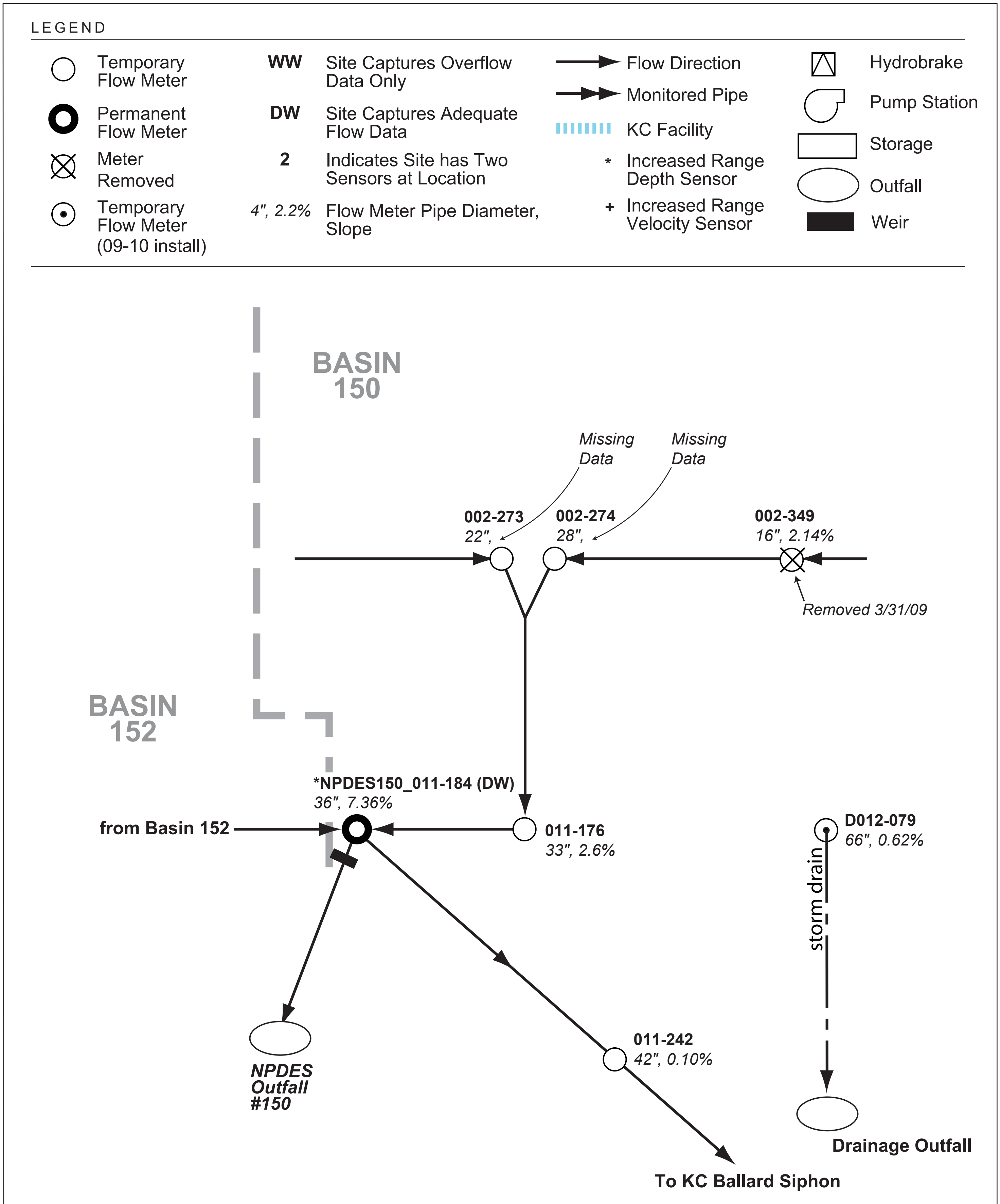


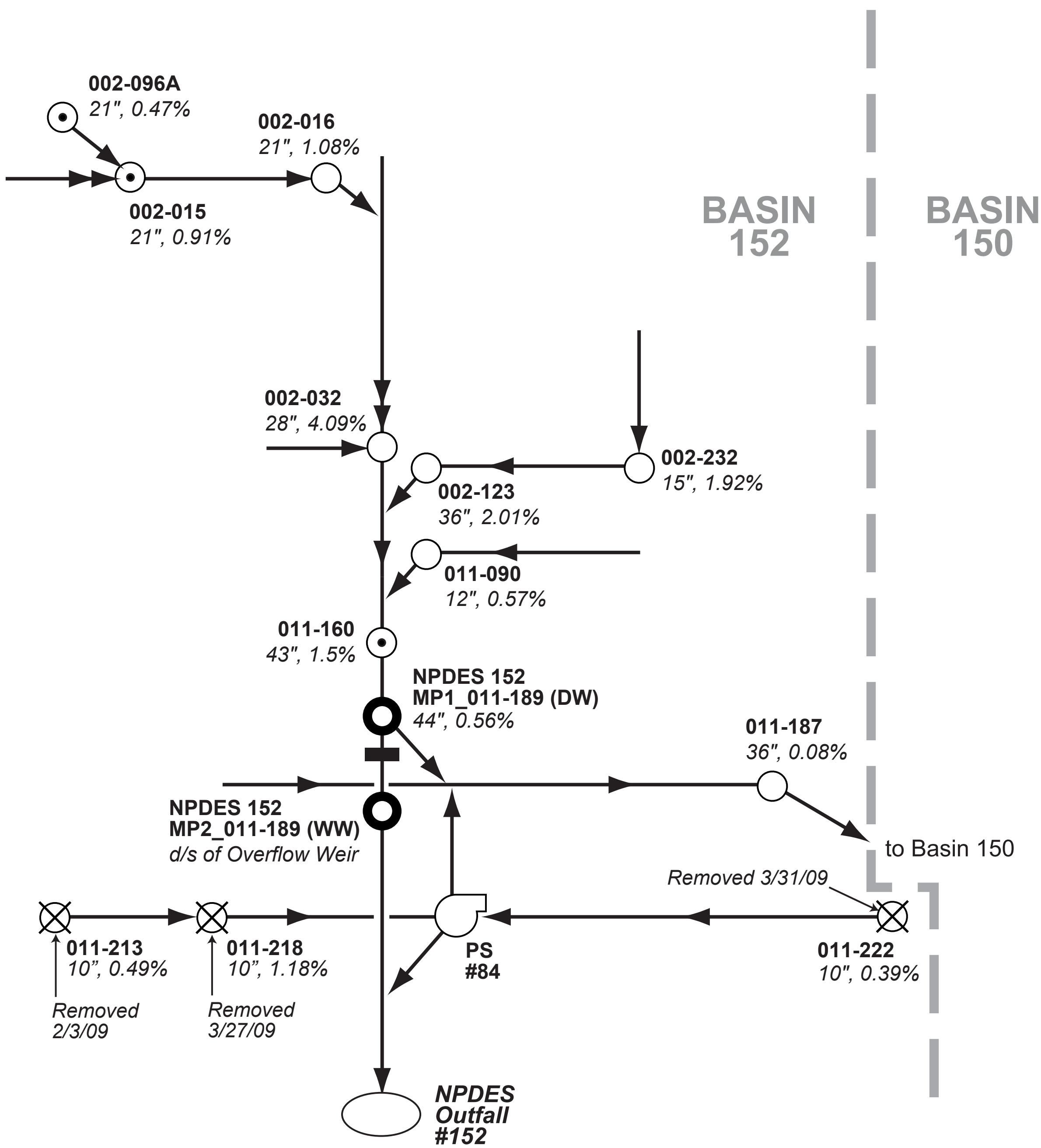
DRAWING NOT TO SCALE

382138.01.06.03_SPU ppt_WB112008002SEA . Ballard_150.ai . 7/9/09 . dk

Seattle Public Utilities **BALLARD: Basin 150**	METER SCHEMATIC DIAGRAM November 2009

LEGEND

Temporary Flow Meter	WW Site Captures Overflow Data Only	Flow Direction	Hydrobrake
Permanent Flow Meter	DW Site Captures Adequate Flow Data	Monitored Pipe	Pump Station
Meter Removed	2 Indicates Site has Two Sensors at Location	KC Facility	Storage
Temporary Flow Meter (09-10 install)	*4", 2.2%* Flow Meter Pipe Diameter, Slope	* Increased Range Depth Sensor	Outfall
		+ Increased Range Velocity Sensor	Weir



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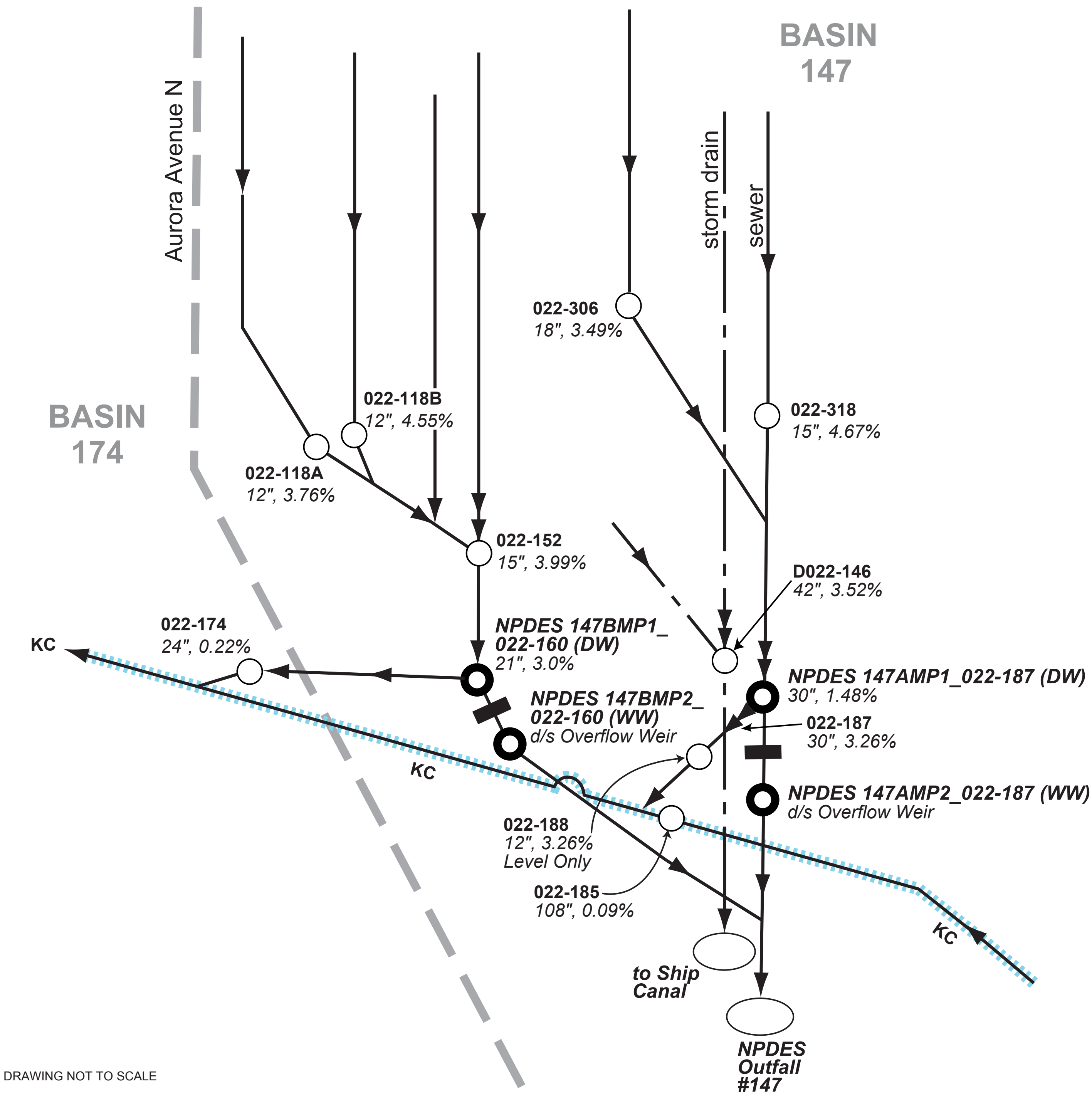
382138.01.06.03_SPU ppt_WB112008002SEA . Ballard_152.ai . 7/8/09 . dk

Seattle Public Utilities **BALLARD: Basin 152**	METER SCHEMATIC DIAGRAM November 2009

LEGEND

○	Temporary Flow Meter	WW	Site Captures Overflow Data Only
◉	Permanent Flow Meter	DW	Site Captures Adequate Flow Data
✕	Meter Removed	2	Indicates Site has Two Sensors at Location
⊙	Temporary Flow Meter (09-10 install)	*4", 2.2%*	Flow Meter Pipe Diameter, Slope
→	Flow Direction		Hydrobrake
→→	Monitored Pipe		Pump Station
	KC Facility		Storage
*	Increased Range Depth Sensor		Outfall
+	Increased Range Velocity Sensor		Weir



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382138.01.06.03_SPU ppt_WB112008002SEA . Fremon_147.ai . 7/8/09 . dk

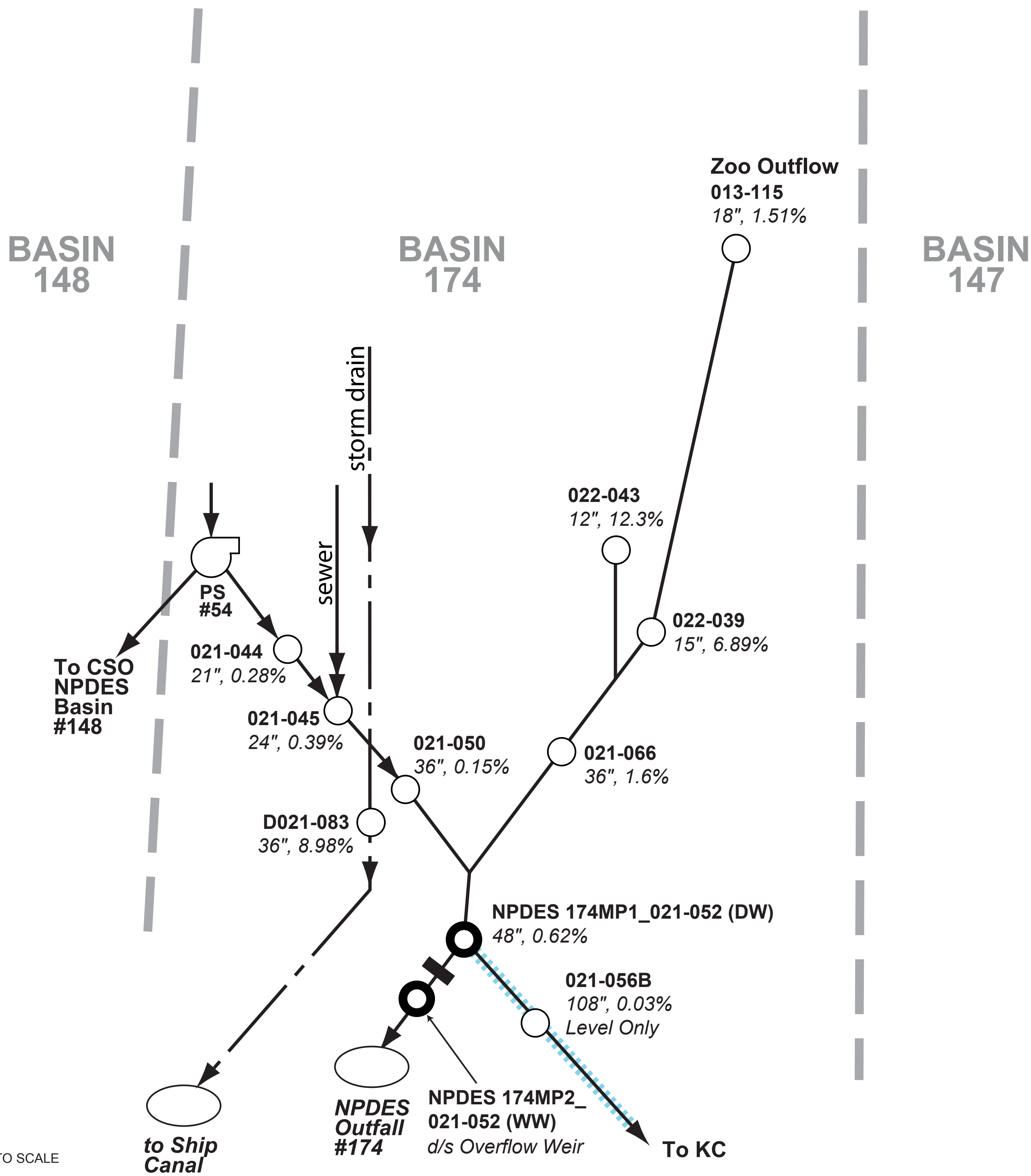
Seattle Public Utilities
FREMONT: Basin 147

METER SCHEMATIC DIAGRAM
November 2009

LEGEND

Temporary Flow Meter	WW	Site Captures Overflow Data Only
Permanent Flow Meter	DW	Site Captures Adequate Flow Data
Meter Removed	2	Indicates Site has Two Sensors at Location
Temporary Flow Meter (09-10 install)	*4", 2.2%*	Flow Meter Pipe Diameter, Slope

Flow Direction
Monitored Pipe
KC Facility
* Increased Range Depth Sensor
+ Increased Range Velocity Sensor
Hydrobrake
Pump Station
Storage
Outfall
Weir



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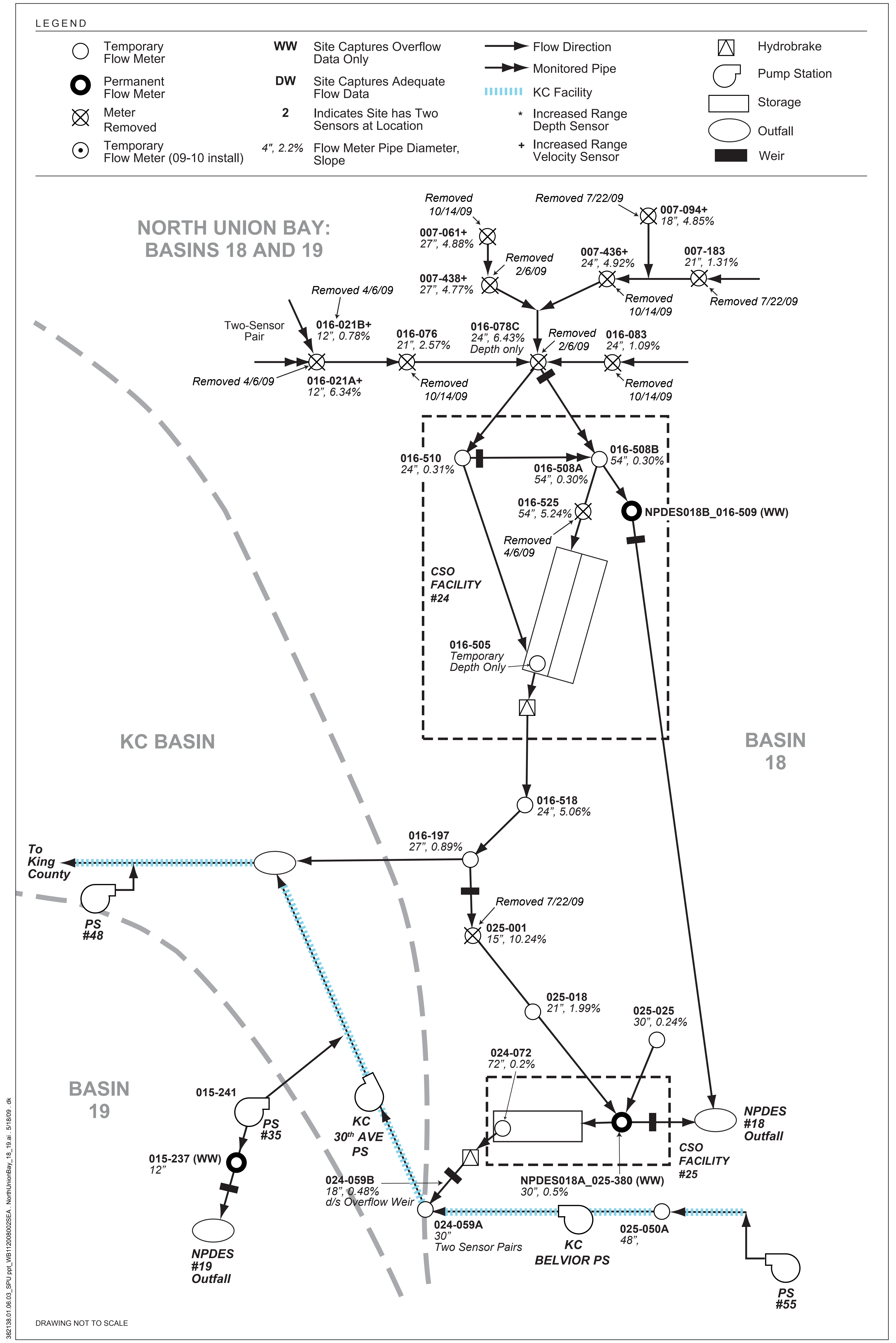
382138.01.06.03_SPU ppt_WB112008002SEA . Fremont_174.ai . 7/9/09 . dk

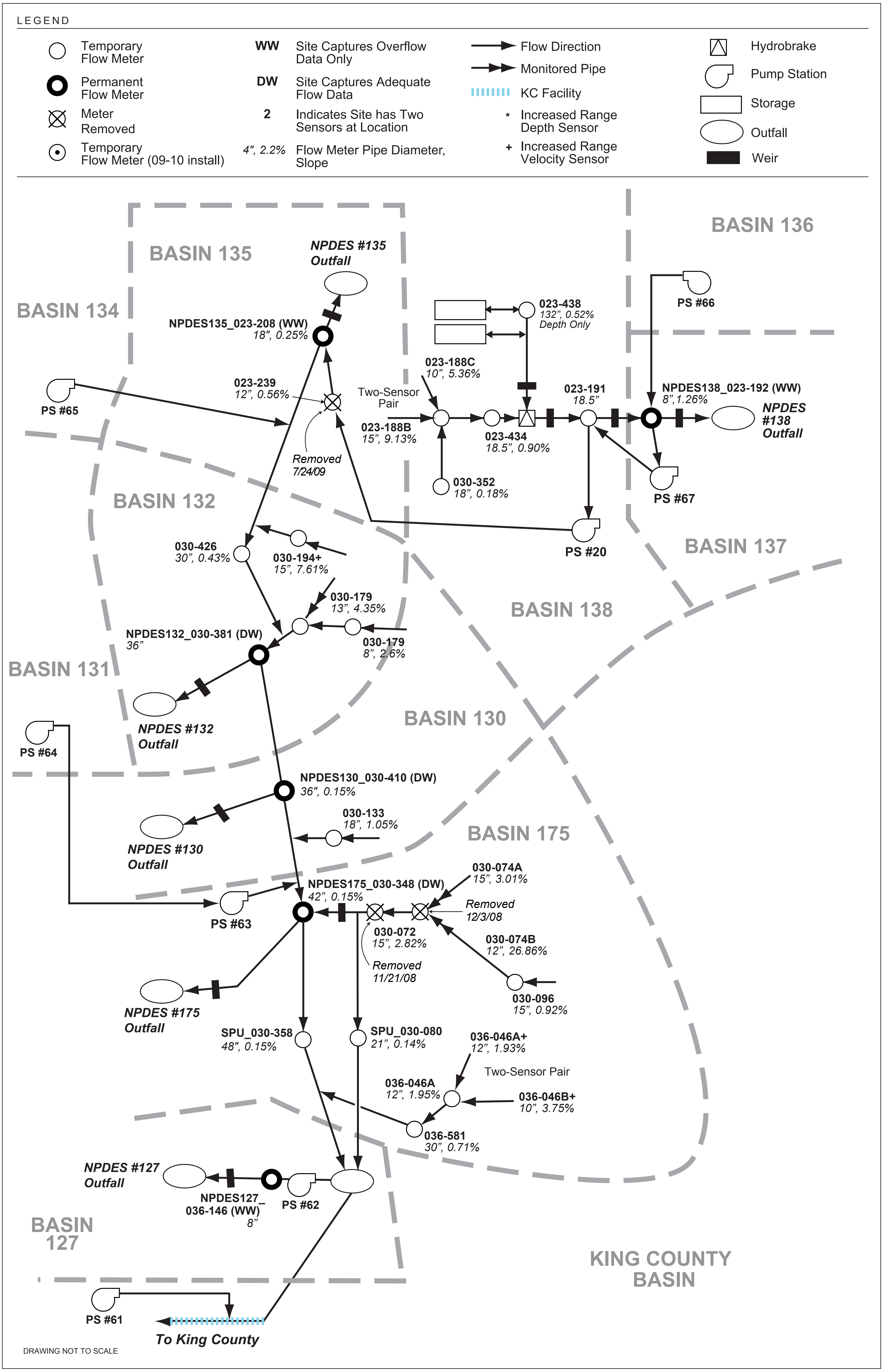
Seattle Public Utilities **FREMONT: Basin 174**	METER SCHEMATIC DIAGRAM November 2009



Seattle Public Utilities
NORTH UNION BAY: Basins 18, 19

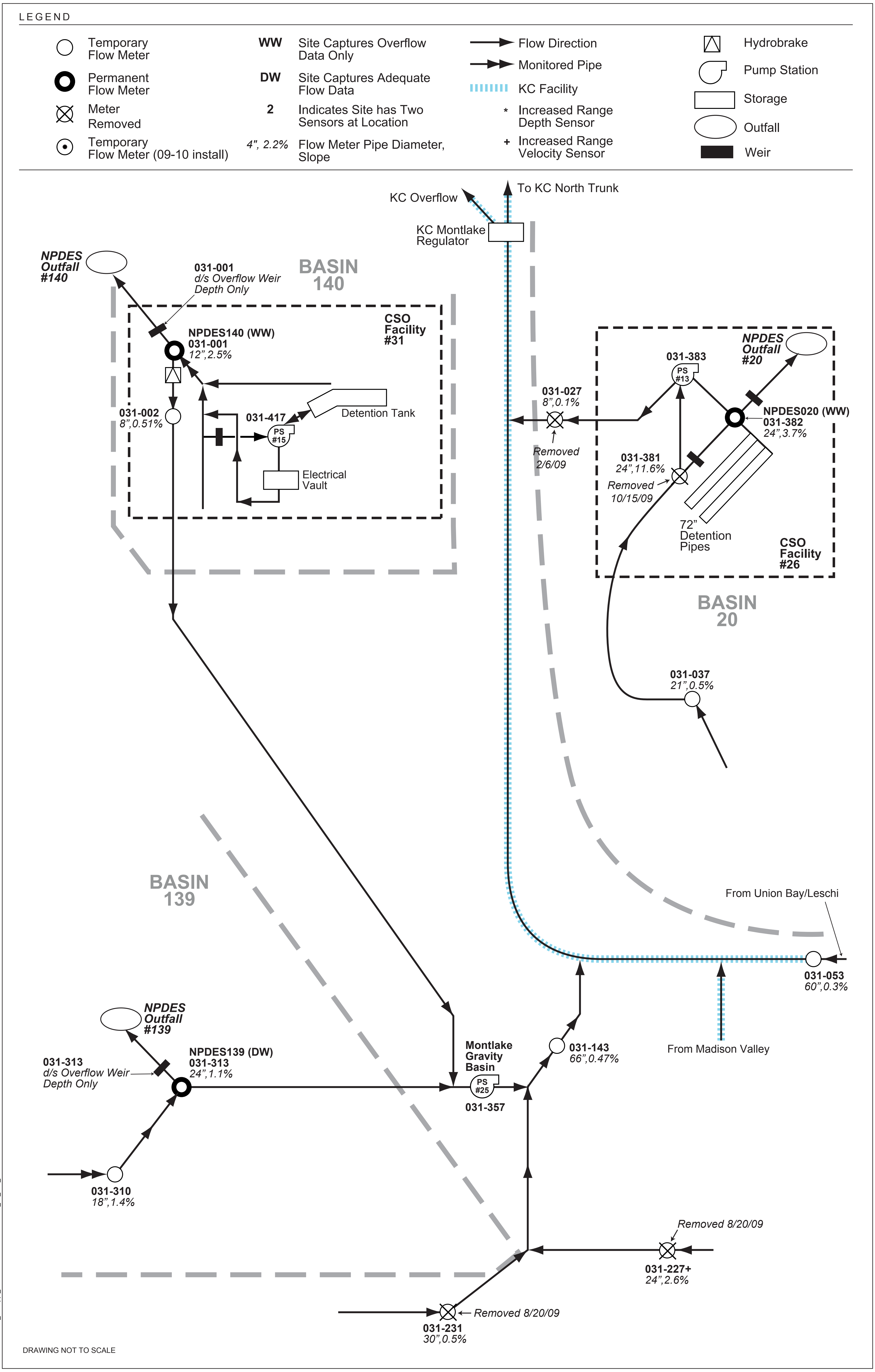
METER SCHEMATIC DIAGRAM

November 2009



382138.01.06.03_SPU ppt_WB11200802SEA . PortageBay_127_130_132_135_138_175.ai . 5/18/09 . dk

Seattle Public Utilities **PORTAGE BAY: Basins 127, 130, 132, 135, 138, 175**	METER SCHEMATIC DIAGRAM November 2009

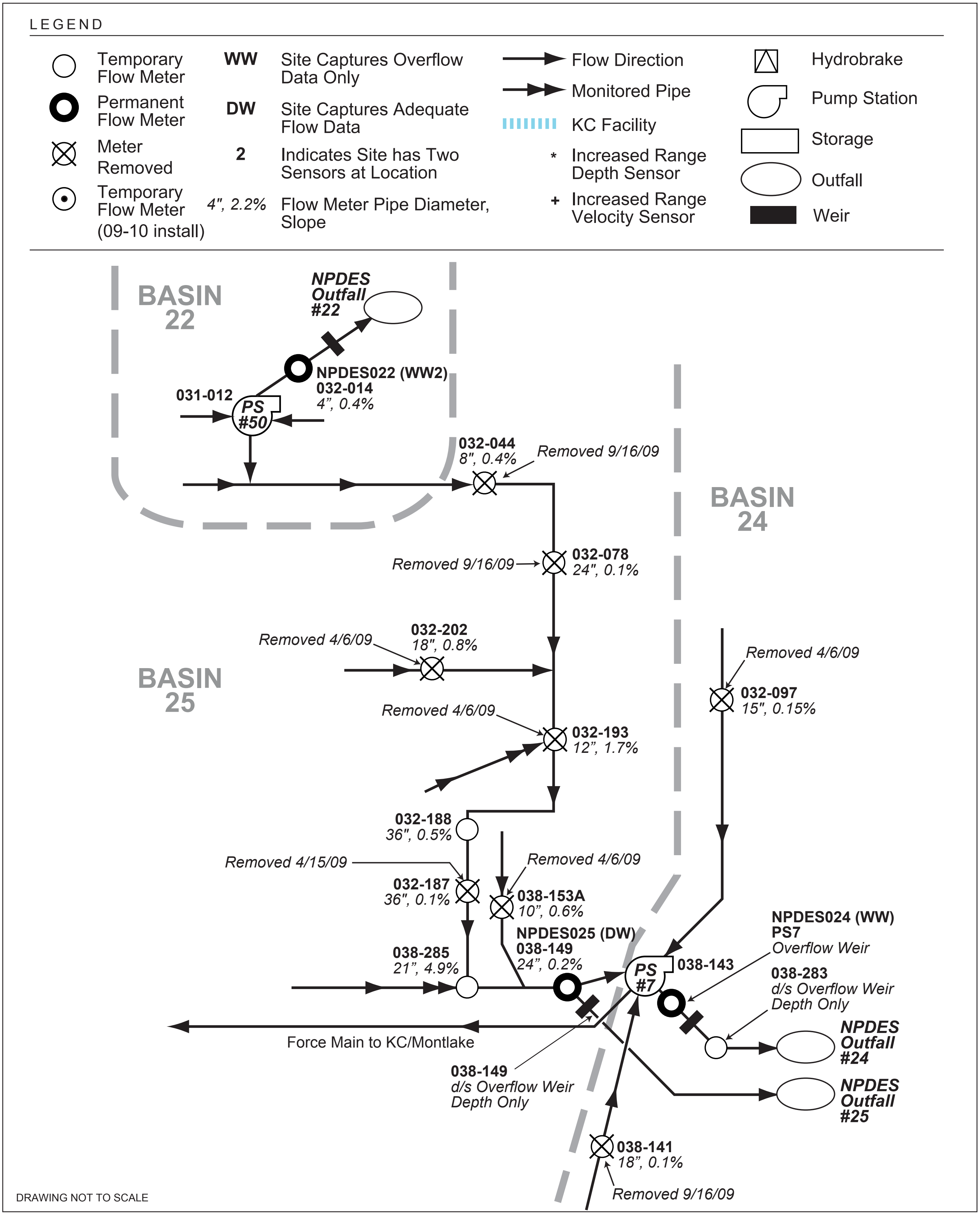


382138.01.06.03_SPU ppt_WB112008002SEA . Montlake_20_139_140.ai . 7/9/09 . dk

Seattle Public Utilities
MONTLAKE: Basins 20, 139, 140

METER SCHEMATIC DIAGRAM

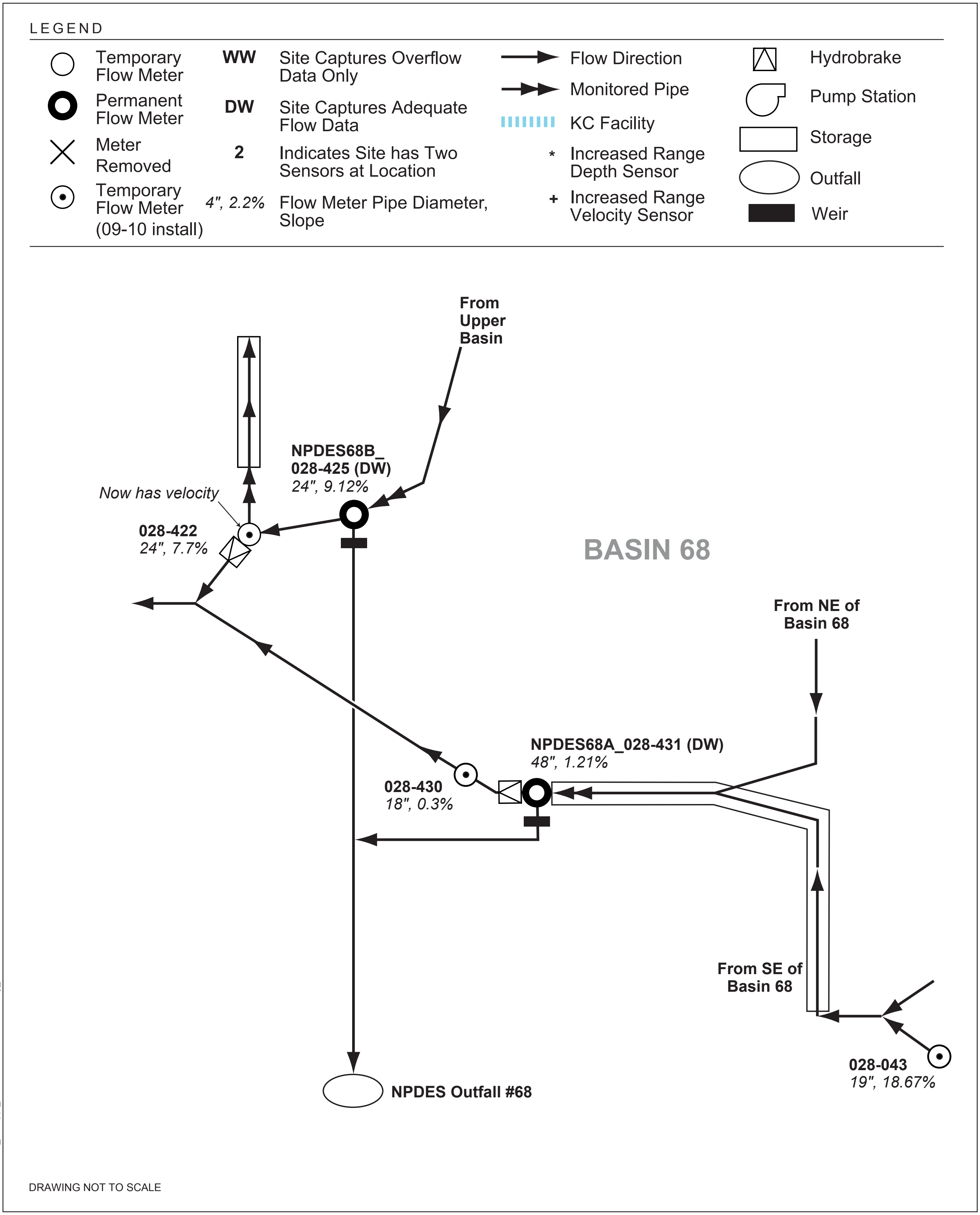
November 2009



382138.01.06.03_SPU ppt_WB112008002SEA . MadisonPark_UnionBay_22_24_25.ai . 5/18/09 . dk

Seattle Public Utilities
MADISON PARK/UNION BAY: Basins 22, 24, 25

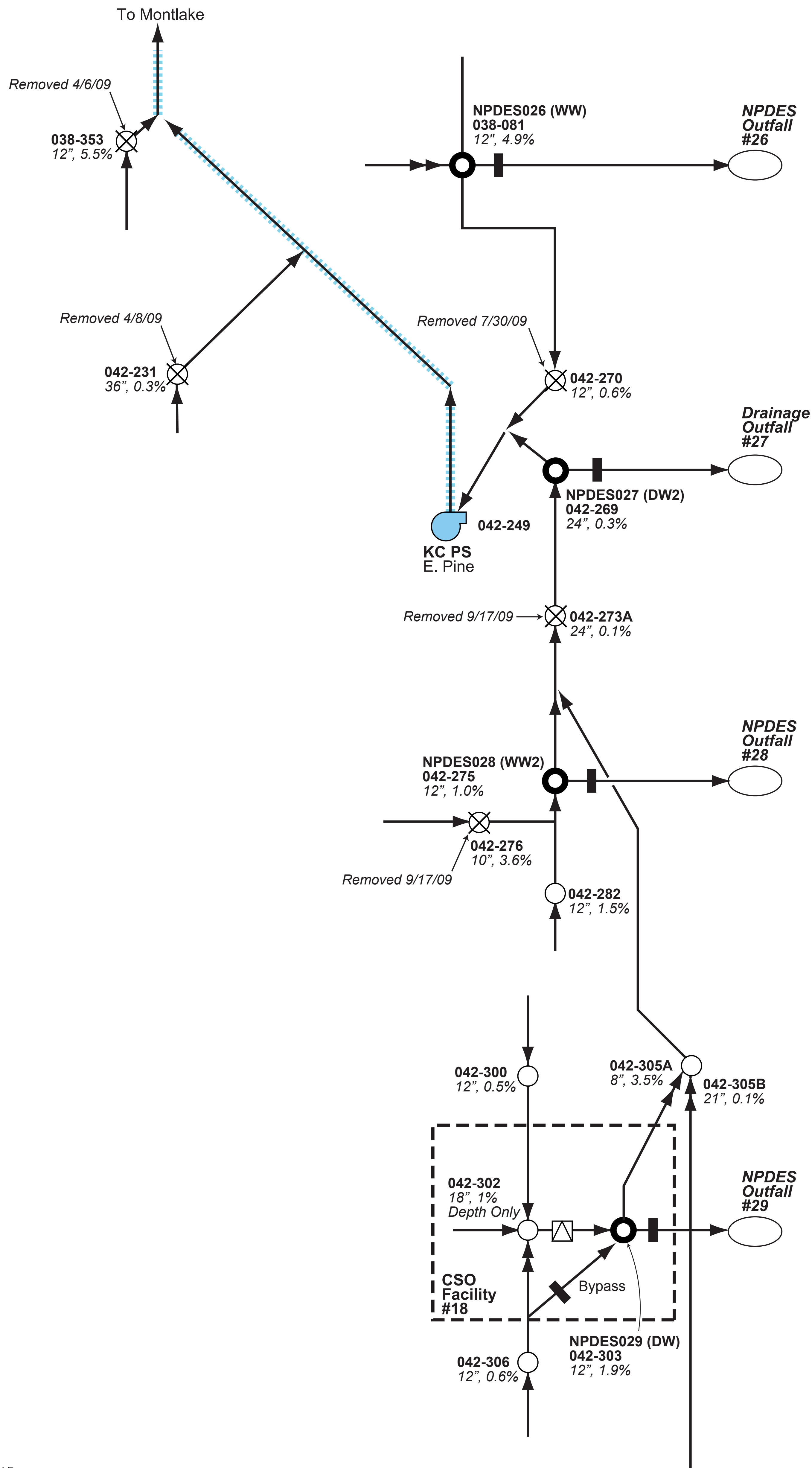
METER SCHEMATIC DIAGRAM
November 2009



Seattle Public Utilities **INTERBAY: Basin 68**	METER SCHEMATIC DIAGRAM November 2009

LEGEND

Temporary Flow Meter	WW Site Captures Overflow Data Only	Flow Direction	Hydrobrake
Permanent Flow Meter	DW Site Captures Adequate Flow Data	Monitored Pipe	Pump Station
Meter Removed	2 Indicates Site has Two Sensors at Location	KC Facility	Storage
Temporary Flow Meter (09-10 install)	*4", 2.2%* Flow Meter Pipe Diameter, Slope	* Increased Range Depth Sensor	Outfall
		+ Increased Range Velocity Sensor	Weir



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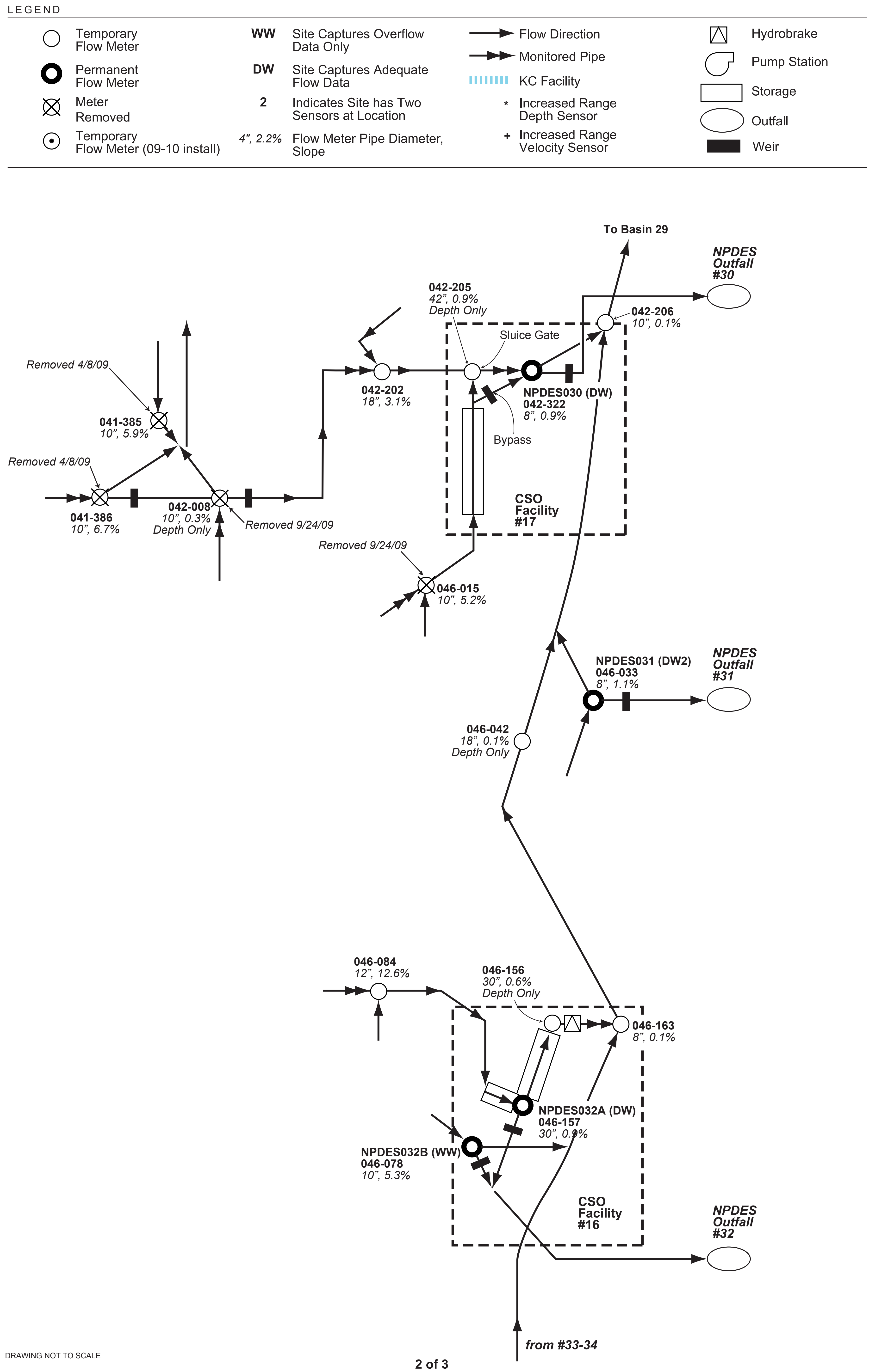
Seattle Public Utilities **LESCHI: Basins 26, 27, 28, 29**	METER SCHEMATIC DIAGRAM November 2009



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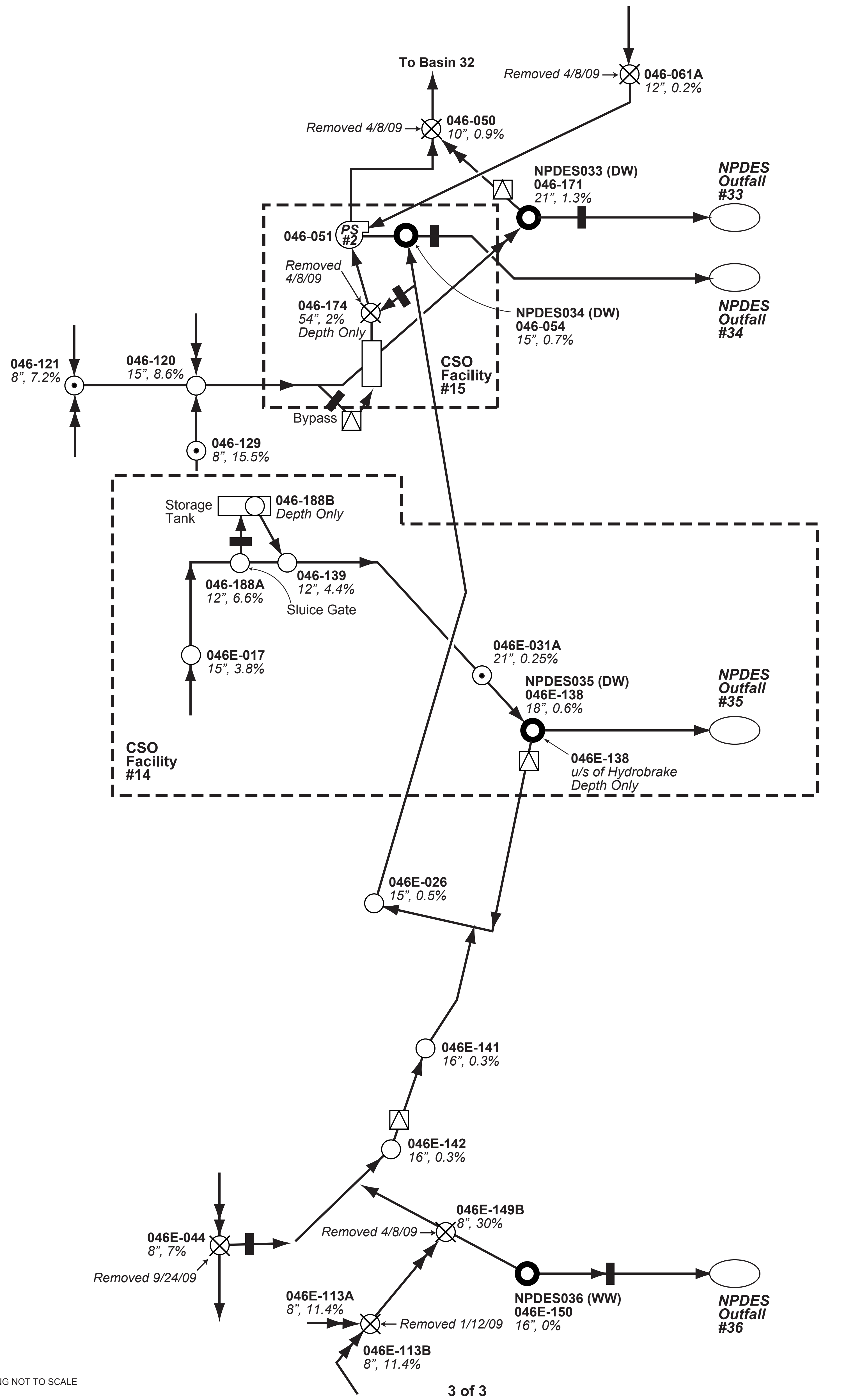
382138.01.06.03_SPU ppt_WB11200800025EA . Leshi_2of3_30_31_32.ai . 7/9/09 . dk

Seattle Public Utilities **LESCHI: Basins 30, 31, 32**	METER SCHEMATIC DIAGRAM November 2009

LEGEND

- Temporary Flow Meter
- Permanent Flow Meter
- Meter Removed
- Temporary Flow Meter (09-10 install)
- **WW** Site Captures Overflow Data Only
- **DW** Site Captures Adequate Flow Data
- **2** Indicates Site has Two Sensors at Location
- *4", 2.2%* Flow Meter Pipe Diameter, Slope
- Flow Direction
- Monitored Pipe
- KC Facility
- * Increased Range Depth Sensor
- \+ Increased Range Velocity Sensor
- Hydrobrake
- Pump Station
- Storage
- Outfall
- Weir



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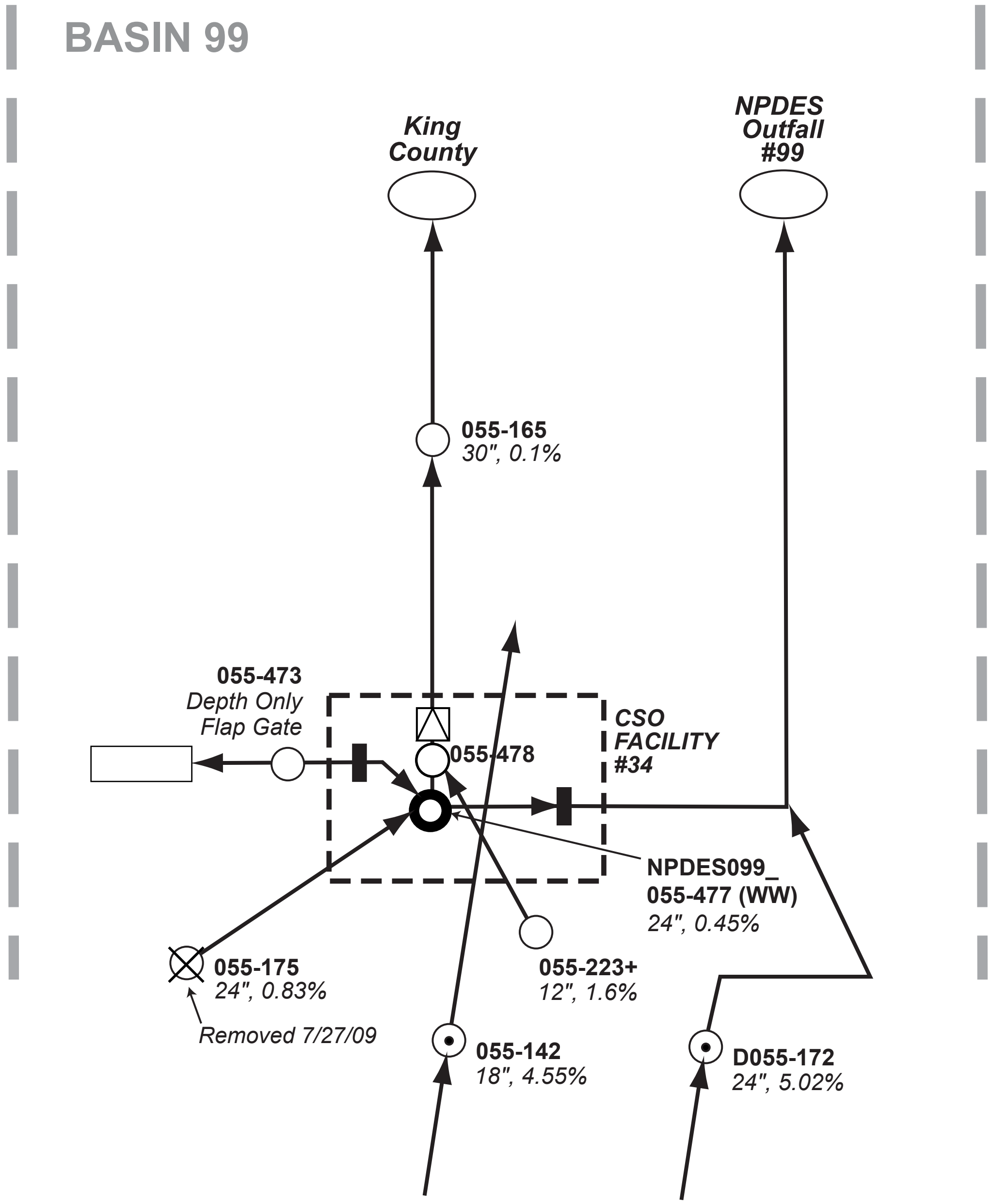
Seattle Public Utilities
LESCHI: Basins 33, 34, 35, 36

METER SCHEMATIC DIAGRAM
November 2009

LEGEND

Temporary Flow Meter	WW — Site Captures Overflow Data Only	Flow Direction	Hydrobrake
Permanent Flow Meter	DW — Site Captures Adequate Flow Data	Monitored Pipe	Pump Station
Meter Removed	2 — Indicates Site has Two Sensors at Location	KC Facility	Storage
Temporary Flow Meter (09-10 install)	*4", 2.2%* — Flow Meter Pipe Diameter, Slope	* Increased Range Depth Sensor	Outfall
		+ Increased Range Velocity Sensor	Weir



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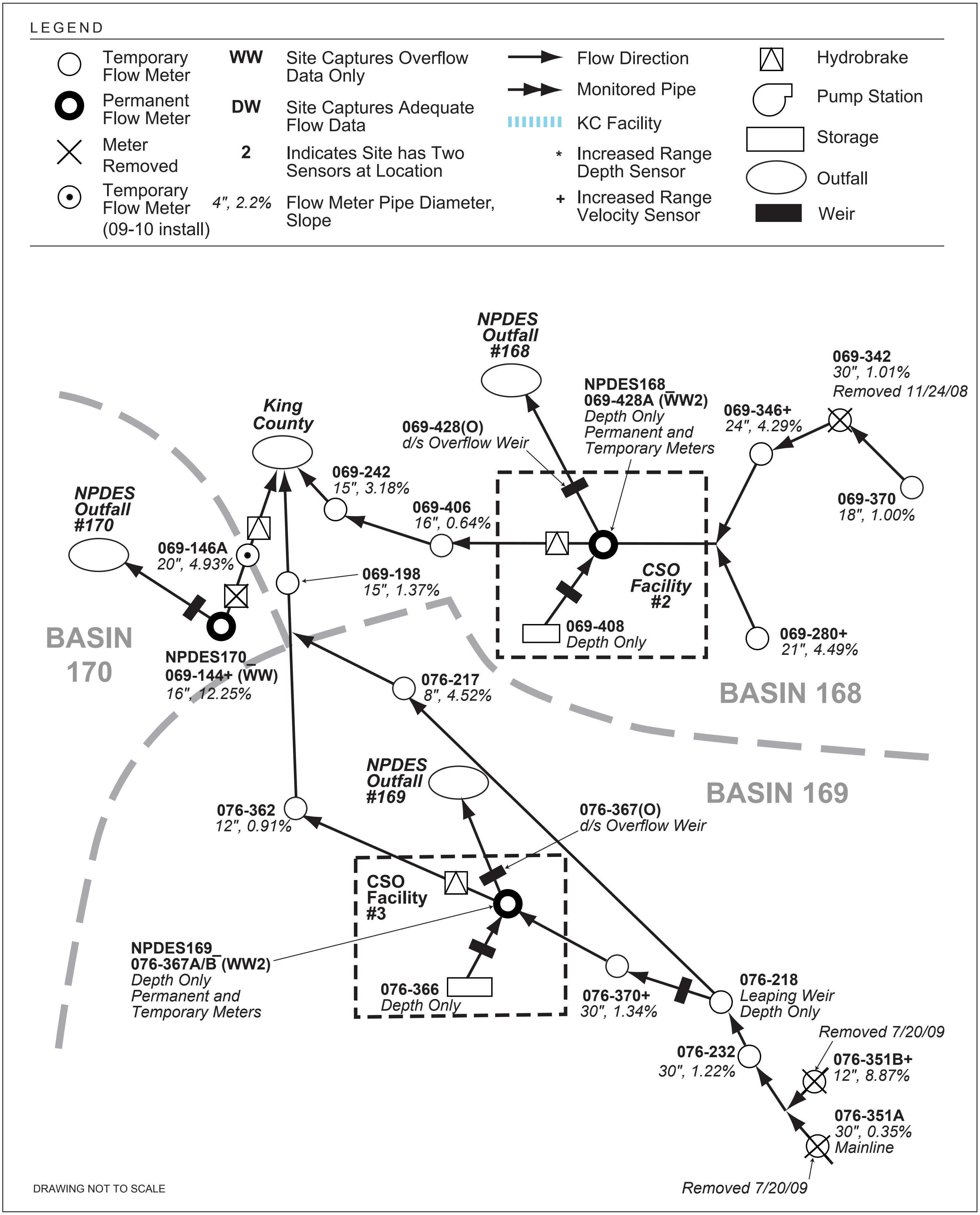
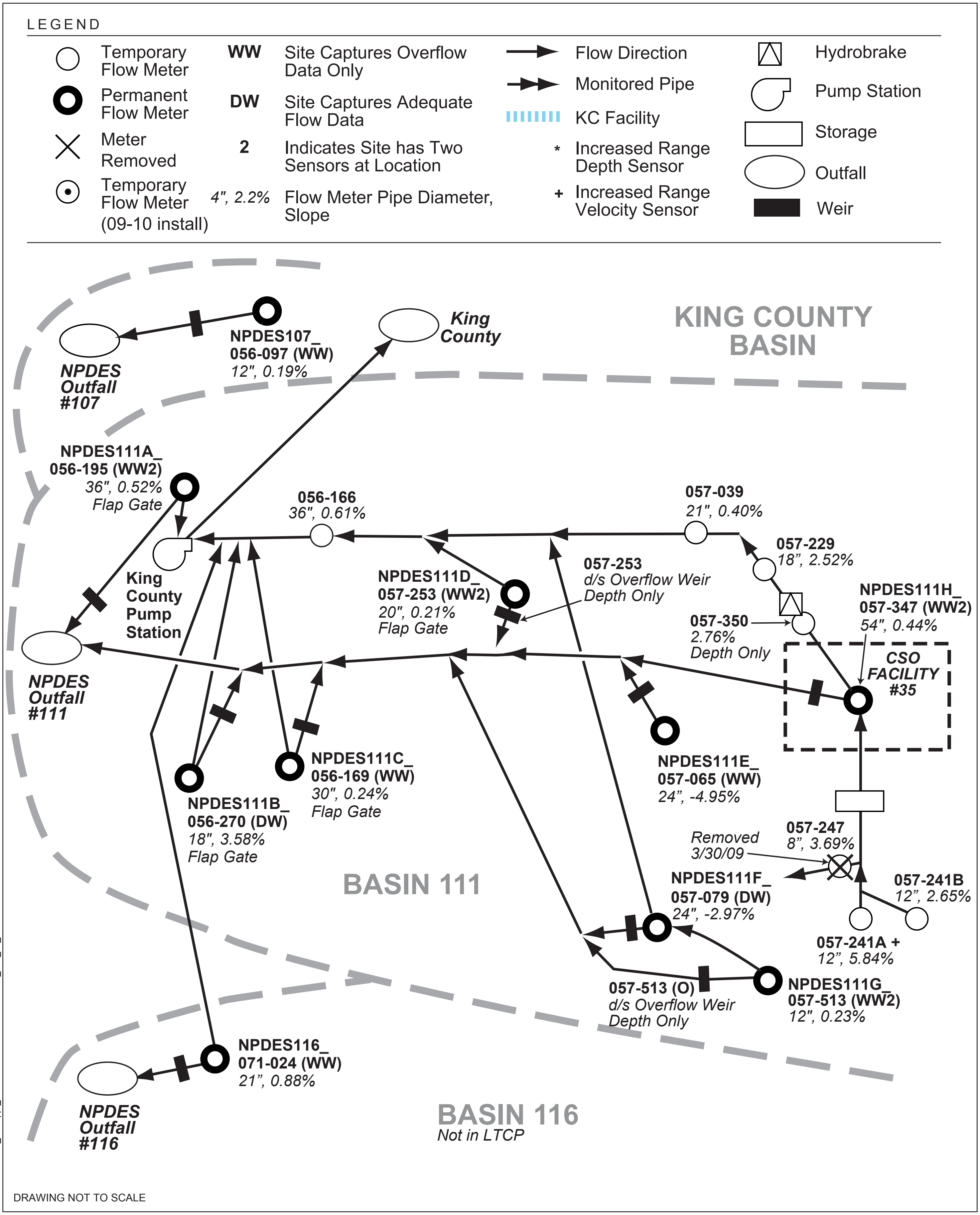
382138.01.06.03_SPU ppt_WB112008002SEA . Delridge_99.ai . 5/18/09 . dk

Seattle Public Utilities **DELRIDGE: Basin 99**	METER SCHEMATIC DIAGRAM November 2009



Seattle Public Utilities **DELRIDGE: Basins 168, 169 and 170**	METER SCHEMATIC DIAGRAM November 2009



382138.01.06.03_SPU ppt_WB112008002SEA . Duwamish_107_11_116.ai . 5/18/09 . dk

Seattle Public Utilities **DUWAMISH: Basins 107, 111 and 116**	METER SCHEMATIC DIAGRAM November 2009

Appendix B through H
(included in electronic format on enclosed CD)