BASIS OF PLANNING

The following documentation describes the modeling efforts and control approaches considered in the development of the basis-of-planning requirements to manage CSOs from the South Magnolia Basin.

4.1 SYSTEM MODELING

The South Magnolia Basin was modeled and calibrated based on historical flow monitoring to determine peak wet-weather flows and volumes.

4.1.1 Background

King County (County) provides wastewater treatment for a number of municipalities in western Washington. The County owns and operates an extensive regional collection system to convey wastewater from the municipalities to the County's treatment plants. Portions of the system are up to 100 years old. The older sewer basins in the City of Seattle use combined sewers that convey both sanitary and stormwater flows in a common pipe.

The stormwater flow component entering the sewer during and following a rain event can be significant and exceed the system's conveyance capacity. The County has overflow points in the combined system to allow the excess flow, "combined sewer overflows", to be diverted to a receiving water body.

Figure 4.1 shows the extent of the South Magnolia Basin. The basin is divided into nine sub-basins (SM01 through SM09). Sub-basin flows converge at the bottom of the South Magnolia Basin near the County's CSO control structure (MAGCSO.)

4.1.2 Data

The South Magnolia Basin model was developed based on physical basin data, flow data, and rainfall records provided by the County.

4.1.2.1 Physical Basin Data

King County collected and provided all the necessary Geographical Information System (GIS) information for developing the models used in an electronic database format. The GIS data is from databases maintained by the County and the City of Seattle. Basin data falls into one of three general categories: geometric data, land use data, and population data.

This page intentionally left blank

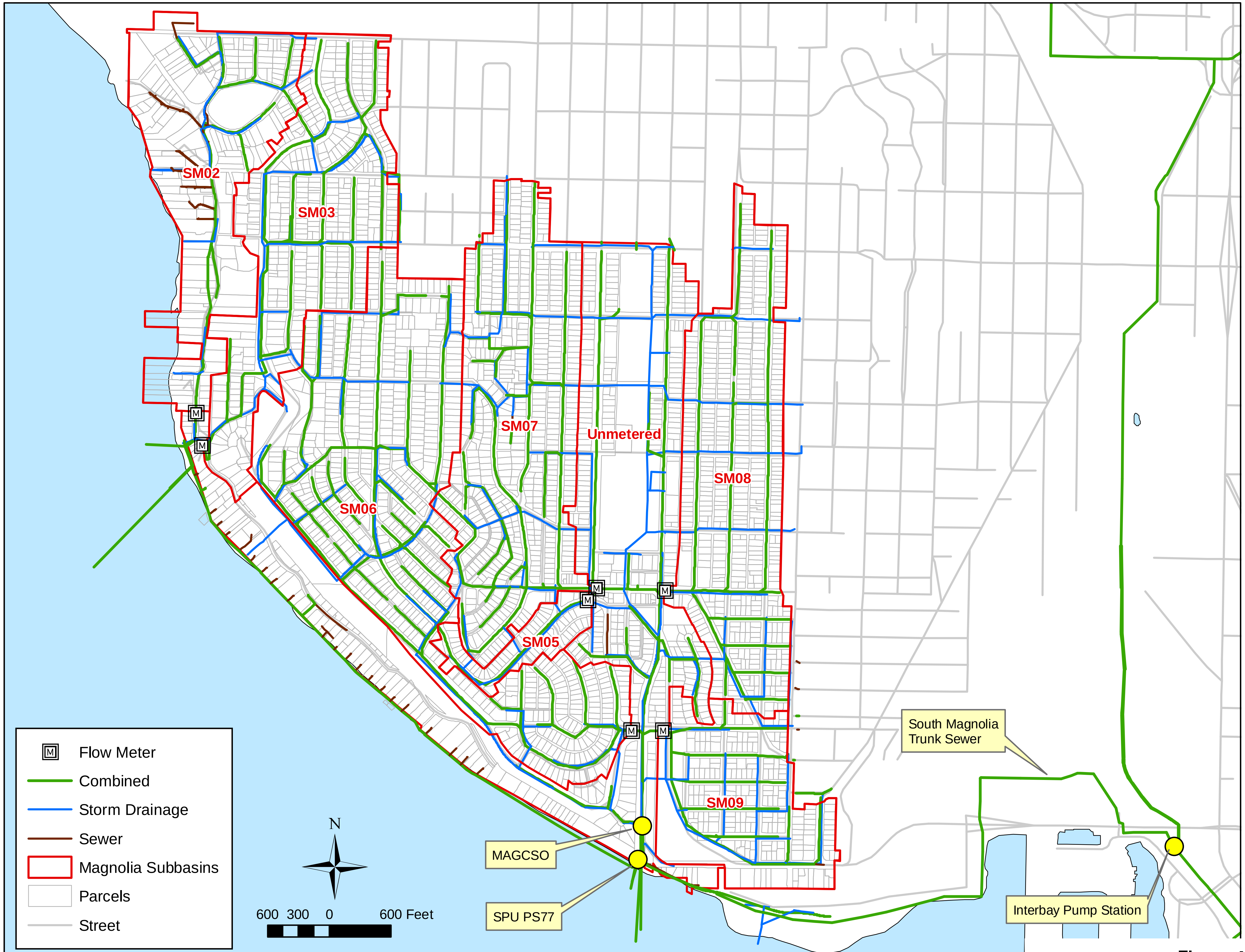

Figure 4.1
SOUTH MAGNOLIA TRUNK SEWER SYSTEM

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

FIGURE 4-1.ai

DRAFT – December 2010

This page intentionally left blank

4.1.2.1.1 Geometric Data

The GIS database contains the majority of the physical data including the following layers:

- Basin boundary.
- Building footprints.
- Points where ditches drain into the combined sewer.
- Elevation contours with 2-foot intervals.
- Combined sewer piping, including pipe diameter, length, and the upstream and downstream manholes.
- Numbered sub-basins delineated by King County.
- Surface run-off channel.
- Known lateral sewer and drain line locations.
- Known lateral sewer drain entrances.
- Tax parcels within each basin, impervious and pervious connections noted.
- Impervious areas within the Parcels layer.
- Rights-of-way within the basin divided into sub areas by run-off destination.
- Road labels broken down by block.

4.1.2.1.2 Land Use Data

Land use data is contained in a separate GIS database table. Data is coded by parcel identification number and contains all of the zoning information.

4.1.2.1.3 Population Data

The population data for the basin was provided in spreadsheet format by the County. The population is divided into residential, commercial, and industrial populations on a County-designated basin level.

4.1.2.2 Flow Data

Flow data for model setup and calibration came from several sources, including King County and ADS Environmental Services. King County monitors sewer flows, levels, and overflows at select points within the system. The flow data is sampled every 10 to 15 minutes and is measured with a portable flow meter. In the South Magnolia basin, the county's long term portable flow meter is located just upstream of its CSO control manhole, and it is named "MAGCSO." It records flow from most of the basin; additional data is obtained from two long term portalable meters in sub basins SM02 and SM03 upstream of the City of Seattle pump station 77.

The flow data used for model calibration came from a King County portable flow meter at the CSO control structure as well as the two upstream moters. Initial modeling by the county to determine peak flows and volumes was based on long term data from these three sources. These sources capture most flow in the basin, the exception being flow directly tributary to pump station 77 and downstream of the two sub basins that are monitored.

In December, 2007, ADS Environmental Services installed and monitored five additional flow meters (SM05, SM06, SM07, SM08, and SM09 and at the City of Seattle pump station 77) to supplement county data and to provide data for the individual sub-basins through June 2008. The details of the ADS flow monitoring program were summarized in the *Temporary Flow Monitoring Report* (ADS, July 2008). These data were used in conjunction with county data for initial input and calibration of flow models developed for this project.

4.1.2.3 Rainfall Records

The City of Seattle maintains a number of rain gages throughout the city. The rain data for the South Magnolia Basin was provided from Rain Gage RG12 located at Catherine Blaine Middle School, 2550 34th Avenue W. during flow monitoring in 2007/2008.

4.1.3 Model Description

The modeling software, MIKE Urban, was selected for developing the sub-basin models for this project. The county has typically used its Runoff/Transport Model for these purposes. The MIKE Urban software models and details can be found in the *MIKE Urban Collection Systems Users Guide* (Danish Hydraulic Institute, 2005), as well as the *MIKE Urban Model Manager Users Guide* (Danish Hydraulic Institute, 2007).

4.1.3.1 Hydrology

MIKE Urban has several modules to estimate wet weather flow from a sub-basin. In consultation with King County, the catchment modules consisting of MOUSE Kinematic Wave -B (MOUSE-B) and RDI were chosen to model inflow and infiltration, respectively. MOUSE- B includes measurable parameters that can be extracted from GIS databases including catchment slope, length (analogous to time of concentration), and five parameters describing percent impervious/pervious area. MOUSE-B also includes 26 Kinematic Wave parameters, including values for Horton’s and Manning’s equation for estimating inflow. These parameters are not directly measurable; these must be estimated. RDI module 19 parameters for infiltration (near surface and groundwater) that are also not directly measurable and so must be estimated.

4.1.3.2 Hydraulics

The collection system hydraulic module CS Pipeflow was used to model pipes and junctions. This module solves the complete St. Venant (dynamic wave) equations throughout the drainage network, which allows for modeling of backwater effects, flow reversal, surcharging in manholes, alternating free-surface and pressurized flow, tidal outfalls, storage basins, pumps, weirs, orifices, etc. The pipe flow model can also perform long term simulation (LTS) and automatic dynamic pipe design.

4.1.4 Model Setup, Calibration, and Verification

The details of model construction for the basin are described in the *MIKE Urban Modeling Approach Technical Memorandum* (Carollo Engineers, October 2008) included in Appendix B-1. An initial test calibration that addressed calibration of the model for all basins was conducted for the North Beach Sub-basin NB05, which is also summarized in the *MIKE Urban Calibration Test Technical Memorandum* (Carollo Engineers, November 2008) included in Appendix B-1. The results are summarized here.

4.1.4.1 Calibration Standards

Proper calibration requires an assessment of the precision and accuracy of the modeled variables in predicting the measured variables. In this case, flows are the primary variables used for calibration. The goal of calibration depends on the specific use of the model. The model needed to be accurately calibrated to flow volume, peaks, and hydrograph shape because both conveyance as well as equalization facilities were analyzed.

The wet weather calibration focused on meeting the recommendations on model verification contained in the *Code of Practice for the Hydraulic Modeling of Sewer Systems*, Version 3.001, (Wastewater Planning Users Group (WWPUG) December 2002), a section of the Chartered Institution of Water and Environmental Management. By these conventions the comparison period between observed and modeled events should last until flow has substantially returned to dry weather flows (DWF). Observed and modeled hydrographs should meet the criteria for two out of three events. The accuracy of the predicted peak flow should be in the range +25% to -10%. The accuracy of the predicted volume of flow should be in the range of +20% to -10%.

4.1.4.2 Initial South Magnolia Calibration

The South Magnolia model was calibrated to the ADS flow data. A statistical analysis of the data including correlation (R^2), total volume, peak flows, and time to centroid was performed for each sub-basin. In general, the data correlation was average (R^2 = 0.60 to 0.79; Volume/Peak/Timing Error = 10 to 20%) to good ($R^2 \geq$ 0.80; Volume/Peak/Timing Error ≤ 10%). Detailed results of this calibration are provided in the *South Magnolia Basin Calibration Round 2 Technical Memorandum* (Carollo Engineers, March 2009) in Appendix B-2.

4.1.4.3 Data Disaggregation Procedure

Following initial modeling, there were questions on the dry weather flow since the sum of the ADS meters was greater than the downstream county meters. A decision was made to adjust the ADS meter DWF to match the county meters as this would result in the model predicting less DWF and a more conservative estimate of inflow/infiltration. Details of the data disaggregation procedure are summarized in the *South Magnolia and North Beach Basins Population/Land Use Analysis Technical Memorandum* (Carollo Engineers, January 2008) in Appendix B-3.

King County concluded that the downstream meter owned by the County represented more accurate flows for the basin in total, than the sum of the observed ADS meters. Therefore, the individual sub-basin flows used in the model were disaggregated county flows based on observed ADS meters. Meters in sub basins SM02 and SM03 are tributary to the City of Seattle pump station PS77 and so flows were not disaggregated; these basins discharge through a force main to the county's CSO control structure downstream of the county's flow meter at the CSO control structure.

The disaggregation procedure is summarized in the *North Beach Flow Adjustment Technical Memorandum* (Carollo Engineers, January 2009) in Appendix B-4; it is applicable to all basins.

To revise all of the flows, three factors were developed for each meter and applied to the county data. These factors include: base infiltration (BI), sanitary flow (SF), and wet weather flow (WWF). Base infiltration is calculated using the Stevens-Schutzbach equation and, along with the sanitary flow, makes up the average dry weather flow. Sanitary flow is flow generated only by customers. It is calculated as the average dry weather flow minus BI. Wet weather flow (WWF) is water that enters the system from rainfall events. It is calculated as total flow minus BI minus SF. The process to revise the flows was as follows:

- <u>Step 1</u>: County data and ADS data were converted to common time step of 15 minutes. For the South Magnolia Basin, the county meter was MAGCSO.
- <u>Step 2</u>: County flow data was disaggregated for each sub-basin by applying the three component factors (BI, SF, and WWF). The BI and SF values are presented in the *North Beach and South Magnolia Basins Population/Land Use Analysis Technical Memorandum* (Carollo Engineers, January 2008). BI and SF were based on the dry weather flow period from May 4, 2008 to May 11, 2008. This period observed no rainfall with light to dry antecedent conditions. WWF for each meter, ADS, and county were calculated as total flow minus BI and SF. The WWF factor was based on the weighted-average WWF.
- <u>Step 3</u>: Each disaggregated county hydrograph was plotted against the observed ADS data. The three factors were adjusted until a good fit was found for peak flows and volumes.
- <u>Step 4</u>: All disaggregated county hydrographs were added together and checked against the total county basin hydrograph. When the individual disaggregated county hydrographs matched well to the observed ADS meter flow, and added up these equaled the downstream county hydrograph, the process was considered complete.

Based on this process, the factors in the *North Beach Flow Adjustment Technical Memorandum* (Carollo Engineers, January 2009) were generated to produce an adequate fit to each sub-basin. The sum of the disaggregated county hydrographs added up to the county downstream flows.

4.1.4.4 <u>Wet Weather Calibration and Verification</u>

The details of the South Magnolia wet weather calibration are summarized in the *South Magnolia Round 3 Calibration Technical Memorandum* (Carollo Engineers, June 2009) included in Appendix B-5. The model calibrated well (see Section 4.1.4.1 for calibration standards) to all wet weather storms, and was acceptable for conducting long-term simulations.

The final basis-of-planning requirements are presented in Section 4.3.

4.2 CSO CONTROL APPROACHES

During the planning process, four CSO control approaches were considered partially effective at controlling overflows to the required level. These approaches were:

- Convey-and-Treat.
- Storage.
- End-of-Pipe Treatment.
- Peak-Flow Reduction (Demand Management).

In addition, a combination of these approaches was considered wherever feasible.

The process of developing CSO control approaches was initiated in 2007 based on existing county documentation, flow monitoring records, modeling data, and basin-specific field work. Preliminary evaluations of potential approaches, including constraints and opportunities in each basin, were prepared.

During this effort it was recognized that additional information relating to how peak flows were distributed within each sub-basin was needed to fully evaluate the range of potential approaches. Therefore, a flow monitoring and modeling program was initiated in late 2007 using a contractor, ADS Environmental. The contractor installed five additional portable flow meters at selected points in the collection system, as well as a flow meter in the City of Seattle pump station 77. These meters were was used to obtain data for smaller areas within each basin. This information helped determine the feasibility of the distributed control approaches and/or approaches away from the bottom of the basin considered in this work.

4.2.1 Convey-and-Treat Approach

The convey-and-treat control approach involves transporting peak flows out of the basin to existing facilities for treatment prior to discharge. This approach requires an increase in pumping and/or conveyance capacity as well as an increase in treatment and/or outfall capacity at existing facilities.

In South Magnolia, the convey-and-treat approach involves increasing the capacity of the South Magnolia Trunk Sewer by supplementing or replacing the existing infrastructure. Downstream capacity of the Interbay Pump Station may be a limiting factor in feasibility of this approach.

4.2.2 Storage Approach

The storage-control approach involves capturing peak flows in excess of the existing conveyance capacity during precipitation events for storage. Stored flow is pumped back to the existing combined system for conveyance/treatment at existing facilities following the event. This approach would require new storage facilities in the basin. Rectangular storage on private property and pipeline storage within the public right of way were considered.

4.2.3 End-of-Pipe Treatment Approach

The end-of-pipe treatment control approach involves capturing peak flows in excess of the existing conveyance capacity during precipitation events for treatment and discharge. This approach would require new treatment, including solids capture and disinfection, at or near the existing CSO location.

In South Magnolia, end-of-pipe treatment would involve construction of a high-rate clarification and disinfection treatment facility within the basin. Discharge is assumed to be through the existing CSO outfall as the peak rate of discharge would be identical to the existing system.

4.2.4 Peak-Flow Reduction Approach

Peak-flow reduction entails reducing the basin-wide flow to the combined system infrastructure during precipitation events to a level that provides adequate CSO control. This could be achieved through one or more of the following techniques.

4.2.4.1 Green Stormwater Infrastructure (GSI)

Stormwater is separated from the combined sewer system and re-routed to GSI (e.g., rain barrels, rain gardens, bioswales, etc.) facilities. Stormwater generated during precipitation events can also be reduced through implementing other GSI techniques (e.g., permeable pavement).

4.2.4.2 Inflow and Infiltration (I/I) Improvements

Inflow improvements involve taking stormwater from impervious areas (e.g., rooftops, roadways, driveways, etc.) that currently goes to the combined sewer system and re-routing the flow to new or existing storm sewer pipes and outfalls. Infiltration improvements involve rehabilitation of sewer laterals and mains to eliminate stormwater/groundwater infiltration to the sewer system.

4.2.5 Combined Approach

A combined approach involves using any of the above CSO control approaches together (where feasible) to minimize impacts and costs (e.g., rooftop disconnections to reduce the storage volume at the bottom of the basin).

4.3 BASIS OF PLANNING REQUIREMENTS

The following planning requirements were developed based on regulatory requirements for control of CSOs, system modeling and viable control approaches.

Regulatory requirements require CSOs to be limited to an average of no more than one untreated discharge per year per outfall on a long-term average, according to the following:

- **Revised Code of Washington (RCW) 90.48.480**: This law requires “the greatest reasonable reduction of combined sewer overflows.”
- **Washington Administrative Code (WAC) 173-245-020 (22)**: “The greatest reasonable reduction’ means control of each CSO in such a way that an average of one untreated discharge may occur per year.”

King County calibrated the South Magnolia Basin Model using the County’s Runoff Model and approximately two years of data collected prior to 2007. In order to compare MIKE Urban model results with previous county Runoff/Transport model results, both the MIKE Urban and the county’s Runoff/Transport calibrated models were used to simulate a 30-year record using the historical data from City of Seattle Rain Gauge RG07 as a comparison of two model approaches. Both calibrated models were run for a 30-year long-term simulation for the period from January 1, 1978 to June 30, 2008. An assumed capacity of 4.3 mgd was used for the South Magnolia Trunk. All peak flows above 4.3 mgd during the 30-year simulation were marked for analysis. Volumes of the events that exceeded the 4.3 mgd were ranked by storm event. A list of the resulting overflow volumes and peak flow rates are shown in Appendix B-7. For the 30-year simulation, the 30th CSO volume was selected for sizing the CSO storage facilities in the South Magnolia basin. The 30-year simulation produces a time series of flows at the basin outlet. The output from these model runs represent the base wastewater flow plus the rainfall-dependent inflow and infiltration that is conveyed to the pump stations.

A comparison of overflow events and overflow durations was made between each of the model results and the historical data. A judgment was made that the Runoff/Transport model had a closer match to the number and duration of overflow events. Therefore, it was used for sizing the South Magnolia CSO facility (see Appendix B).

Based on the modeling data, the required storage volume and peak flow rate were determined for the following conditions:

1. The long-term average from the entire rainfall record.
2. The average of 20-year averages (e.g., the 1-year control volume is computed for each 20-year period in the 30-year record; then the 11 1-year control volumes are averaged).
3. The maximum 20-year rainfall period in the entire rainfall record. (The rainfall record is not repeated for this calculation.)

This work is summarized in the technical memorandum *Updated CSO Control Volumes for Puget Sound Beach CSOs* (King County, June 2010) in Appendix B-6.

The resulting design storage volume for South Magnolia was approximately 1.8 million gallons (MG) based on a South Magnolia Trunk Sewer capacity of 4.3 mgd. The peak flow conveyance was 20 mgd total. Appendix B contains the final summary table of 1-year CSO control volumes for the 3 conditions evaluated and 1-year peak flow rate. The supporting data files for this table (also in Appendix B) rank the storms by overflow volume and peak flow rate to yield the basis-of-planning requirements of 1.8 MG and 15.7 mgd. Table 4.1 summarizes the basis of planning for the South Magnolia Basin.

Table 4.1 South Magnolia Basis-of-Planning Requirements

Control Approach	Required Volume or Capacity
Convey and Treat	**20 mgd**[1]
Required Peak Convey-and-Treat Capacity	**15.7** mgd
Existing Convey-and-Treat Capacity	4.3 mgd
Storage	**1.8 MG**
End-of-Pipe Treatment	**15.7 mgd**[2]
Peak Flow Reduction (Demand Management)	
Storage Volume for 25% Impervious Disconnection[3]	1.11 MG
Storage Volume for 50% Impervious Disconnection[3]	0.49 MG
Storage Volume for 75% Impervious Disconnection[3]	0.13 MG

Notes:
1. Convey-and-treat capacity is the difference between "required peak convey-and-treat capacity" and "existing convey-and-treat capacity".
2. End-of-pipe treatment capacity is the difference between "required peak convey-and-treat capacity" and "existing convey-and-treat capacity".
3. Represents the percentage of impervious surface currently connected to the combined sewer system that must be disconnected to reduce the required storage volume.