BASIS OF PLANNING

King County is actively working on a number of projects to better manage, control, and reduce the number of overflow events within their system. This chapter describes the modeling efforts and control approaches considered in the development of the basis-of-planning requirements to manage CSOs from the North Beach Basin.

4.1 SYSTEM MODELING

The peak wet-weather flows and volumes in the North Beach Basin were modeled and calibrated based on historical flow monitoring data.

4.1.1 Background

The 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 permitted overflow points in the combined system to allow the excess, "combined sewer overflows", to be diverted to a receiving water body.

Figure 4.1 shows the extent of the North Beach Basin. As described in Chapter 3, the Basin is divided into five hydraulically separated sub-basins (NB01 through NB05). Sub-basin flows converge at the bottom of the Basin near the North Beach Pump Station.

4.1.2 Data

The North Beach 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.

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Figure 4.1
NORTH BEACH BASIN OVERVIEW

King County
Department of Natural Resources and Parks
Wastewater Treatment Division

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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.
- Lateral sewer drain entrances.
- Tax parcels within each basin, impervious and pervious connections noted.
- Impervious areas within the Parcels_name 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. 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 by the County in spreadsheet format. The data is based on the 2000 United States census and was assumed to be accurate since the North Beach Basin is built-out with very little development that would significantly impact population data. 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 pump station flows, 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.

The flow data used for model calibration came from a King County portable flow meter at the overflow manhole just upstream of the pump station and from five portable flow meters placed upstream in the basin.

ADS Environmental Services installed and monitored five flow meters to supplement county data and to provide data for the individual sub-basins. ADS monitored five flow meters in the North Beach Basin (see Figure 4.1) from December 2007 through June 2008. The details of the ADS flow monitoring program were summarized in the *Temporary Flow Monitoring Report* (ADS, July 2008).

4.1.2.3 Rainfall Records

The City of Seattle maintains rain gauges throughout the city. The rain data for the North Beach Basin was provided from Rain Gauge RG07 located at Whitman Middle School near the corner of 15th Avenue NW and NW 92nd Street (see Figure 4.1).

4.1.3 Model Description

The modeling software MIKE Urban was selected for developing the sub-basin models. 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 equations for estimating inflow. These parameters are not directly measurable; these must be estimated. RDI includes 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. An initial test calibration 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. 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 for this work 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 within +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 North Beach Calibration

The North Beach model was calibrated to the ADS flow data. A statistical analysis of the data, including correlation (expressed as R^2 values), 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 *North Beach Basin Calibration Round 1 Technical Memorandum* (Carollo Engineers, November 2008) in Appendix B.

4.1.4.3 Data Disaggregation

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.

King County concluded that the downstream meters for each basin, which they own, more accurately characterize the total basin flow 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. The disaggregation procedure is summarized in the *North Beach Flow Adjustment Technical Memorandum* (Carollo Engineers, January 2009) in Appendix B.

To complete the disaggregation process, three factors were developed for each meter and applied to the county data: 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 is water that enters the system from rainfall events. It is calculated as total flow minus BI and SF. The process to revise the flows was as follows:

- Step 1: County and ADS data were converted to a common time step of 15 minutes. For the North Beach Basin, the county meter was NBEACHINLET.
- Step 2: 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 *South Magnolia and North Beach 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) was calculated as total flow minus BI and SF. The WWF factor was based on the weighted-average WWF.
- Step 3: 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.
- Step 4: 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 Wet-Weather Calibration and Verification

The details of the North Beach wet-weather calibration process are summarized in the *North Beach Round 3 Calibration Technical Memorandum* (Carollo Engineers, July 2009) included in Appendix B. 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:

- Storage.

- Convey-and-Treat.
- 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, 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 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 here.

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 North Beach, the convey-and-treat approach involves increasing the capacity of the North Beach Pump Station and Force Main either by supplementing or replacing the existing infrastructure. In addition, treatment capacity at the Carkeek CSO Treatment Facility would need to be expanded.

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 North Beach, 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 to minimize impacts and costs (e.g., I/I improvements 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.

This project was initiated to address 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.”

Therefore, according to these regulatory requirements, CSOs must be controlled to an average of no more than one untreated discharge per year per outfall based on a long-term average.

King County calibrated the North Beach Basin Model using the County’s Runoff Model and approximately two years of data collected prior to 2007. Both the MIKE Urban and the Runoff/Transport calibrated models were used to simulate a 30-year record using the historical data from City of Seattle Rain Gauge RG07. A 30-year extended precipitation and evaporation time series (ETS) was input to the calibrated hydrologic models. 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 station.

Both calibrated models were run for a 30-year long-term simulation for the period from January 1, 1978 to June 30, 2008. 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).

After the Runoff/Transport model had been calibrated, it was discovered via a pump test that the meters used to calibrate the model were grossly overestimating flow to the North Beach Pump Station. The flows were adjusted prior to calibrating the MIKE Urban model. The MIKE Urban model results were used to size the CSO facility at North Beach.

All peak flows above the North Beach Pump Station capacity during the 30-year simulation were marked for analysis. Volumes of the events that exceeded the North Beach Pump Station capacity were ranked by storm event. For the 30-year simulation, the 30th CSO volume was selected for sizing the CSO storage facilities in the North Beach Basin.

The results of the three conditions were nearly the same. Both the long-term average storage volume and the storage volume from the maximum 20-year period in the record were the same. The average of 20-year averages was 0.01 MG smaller. The long-term average from the entire 30-year record was used for sizing the storage facility. This storage volume would have achieved the 1-year CSO discharge criteria in any 20-year period in the 30-year record. This work is summarized in the technical memorandum *Updated CSO Control Volumes for Puget Sound Beach CSOs* (King County, June 2010) in Appendix B.

The resulting design storage volume for North Beach Basin was approximately 0.19 million gallons (MG) based on a North Beach Pump Station capacity of 3.4 mgd. Subsequent to this memorandum, the capacity of the North Beach Pump Station was revised to 3 mgd based on the results of pump testing. The design storage volume and peak flow conveyance for North Beach was adjusted accordingly. Appendix B contains the final summary table of 1-year CSO control volumes for the three 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 0.23 MG and 9.6 mgd.

Table 4.1 summarizes the basis-of-planning for the North Beach Basin.

Table 4.1 North Beach Basis-of-Planning Requirements

Control Approach	Required Volume or Capacity
Convey-and-Treat	**6.6 mgd**[1]
Required Peak Convey-and-Treat Capacity	**9.6** mgd
Existing Convey-and-Treat Capacity	3.0 mgd
Storage	**0.23 MG**
End-of-Pipe Treatment	**6.6 mgd**[2]
Peak Flow Reduction (Demand Management)	
Storage Volume for 25% Impervious Disconnection[3]	0.12 MG
Storage Volume for 50% Impervious Disconnection[3]	0.06 MG
Storage Volume for 75% Impervious Disconnection[3]	0.02 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.