Chapter 3

Data Development

This chapter describes how the data that contributed to the benefit/cost analysis were developed and how they were used. It describes how information was obtained by characterizing local agency existing facilities, by monitoring flows and measuring rainfall, by simulating physical processes and system performance with hydrologic and hydraulic models, by constructing pilot projects, and by developing assumptions and alternatives for I/I reduction. Figure 3-1 shows the data development process.

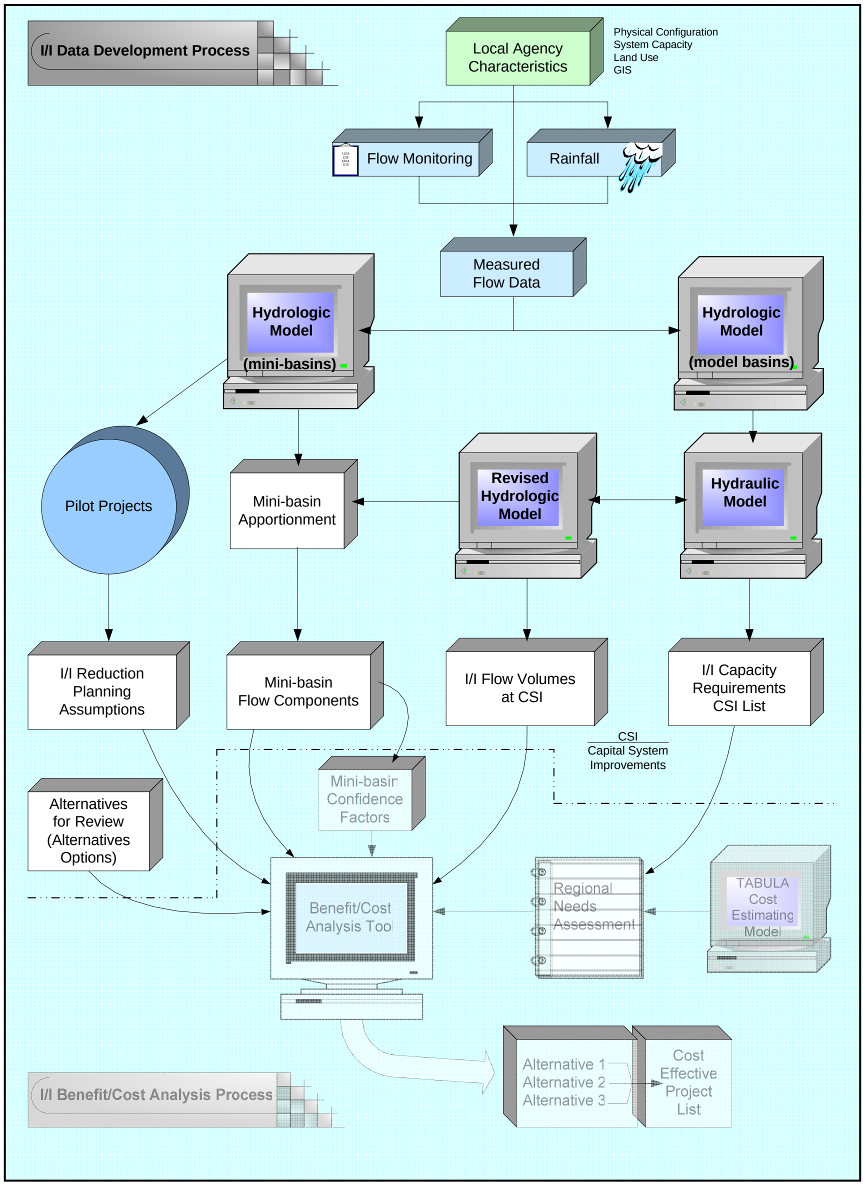


Figure 3-1. Data Development Process

In most cases, the information presented in this chapter is described in more detail in the separately published I/I reports that are referenced throughout this chapter. The reports are available online at http://dnr.metrokc.gov/wtd/i-i/library.htm.

3.1 Data Required for the Benefit/Cost Analysis

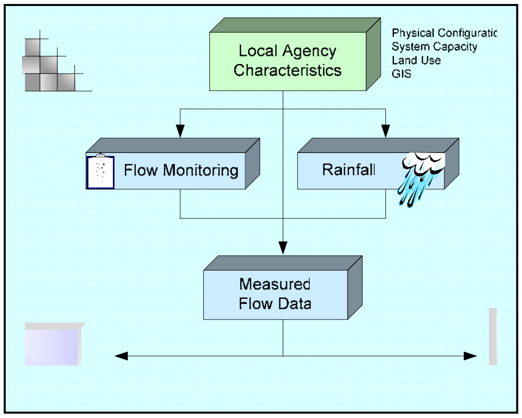
To conduct the benefit/cost analysis, specific data were needed that could be used to address:

- The anticipated effort and cost necessary to reach target levels of I/I reduction
- The capacity and cost-saving effects of proposed I/I reduction on the regional conveyance system
- The cost effectiveness of implementing I/I reduction projects compared with the costs of regional conveyance system improvements

Information about existing and future local agency wastewater facilities and land uses was used to help estimate present and future capacity needs. Rainfall data and wastewater flow monitoring provided the basis for locating and measuring wastewater flows within local agency wastewater collection systems. Once collected, this information was used in commercially available hydrologic and hydraulic models to simulate existing and future wastewater system performance, to evaluate flow data accuracy, and to establish baseline costs for evaluating the cost effectiveness of removing I/I. Cost and performance data collected from the County and local agencies and from ten I/I reduction pilot projects were used to develop I/I reduction planning assumptions for the benefit/cost analysis. A collaborative County/local agency process guided the use of the collected and developed data.

3.2 Data Sources

3.2.1 Characterizing Local Agency Facilities



To identify the physical configuration and capacity of the local agency collection system, and to define the limits of the existing and future wastewater service areas, data were needed to characterize local agency wastewater collection facilities, geography, and land use.

Information about the physical configuration of local agency facilities was accessed through the King County Geographic Information System (GIS). Data showing the physical layout of collection system pipes and existing land use were provided by local agencies and were imported into the County's GIS database. Information about local agency geography, property parcel lines, and the location of future service areas was provided by the County and verified with the local agencies. These data were used to establish:

- The boundaries of specific geographic areas used for defining mini-basins and model basins (see Section 3.2.3 for a description of mini-basins and model basins)
- Points of connection by the local agency wastewater collection system to the regional conveyance system (used to establish flow conditions)
- Lengths of sewer lines and numbers of manholes available for rehabilitation (used as the basis for the cost of possible I/I reduction projects)
- Acreage served (used to calculate the I/I flows in gallons per acre per day [gpad])
- Existing land use and zoning within the defined mini-basins and model basins (used to identify existing and future sewer service areas)
- Parcel count (used to estimate the number of existing and future side sewers)

To gather information about pipe sizes, pipe elevations, pump station capacities, etc., the County made use of conveyance system specifications from the County's GIS database or from local agencies. The specification information was a key input into the hydraulic model (see Section 3.2.4.2 for a description of the hydraulic model).

To obtain land use information for the service area, the County gathered population data, parcel numbers, aerial photos, and zoning information. Land use information was important for defining "sewered"[1] and "sewerable"[2] areas. Defining sewered areas was necessary to accurately calculate existing I/I flows (in contrast, large open spaces like parks are "unsewered" and do not contribute to I/I flows in the sewer system).[3] Defining sewerable area was necessary to calculate the estimated future I/I flows from areas that are not currently sewered. These land use data were valuable for calibrating the hydrologic and hydraulic models[4] (see Sections 3.2.4.2 and 3.2.4.4 for descriptions of the hydrologic and hydraulic models) and for applying growth assumptions.

3.2.2 Rainfall

Rainfall data were needed to help understand: (a) the I/I patterns that cause peak flows during storm events, and (b) the relationship between a given area's measured rainfall and wastewater flows. Rainfall data also provided input for calibrating the hydrologic model.

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[1] Sewered areas are served by a sanitary sewer collection system and contribute to the I/I flows in the sewer system.
[2] Sewerable areas are part of a future service area that will be served by a sanitary sewer collection system.
[3] For more information about classifying sewered and unsewered areas, see Appendix A3 of the *Regional Needs Assessment Report* (March 2005).
[4] Calibrating the hydrologic and hydraulic models involved comparing the model results to actual measured flow data and adjusting the parameters as necessary so that model outputs matched up with measured flow data.

The County maintains a system of 72 rainfall gauges throughout the service area to provide data for ongoing programs. However, the level of measurement accuracy needed for the I/I program would have required adding a significant number of new gauges, and the cost was prohibitive. Instead, the County utilized CALAMAR (*calcul de lames d'eau a l'aide du radar*, which translates from French as "calculating rain with the aid of radar"), a technology that uses radar images from the National Weather Service NEXRAD radar and the County's network of rain gauges[5]. Figure 3-2 shows the County's service area and the location of the NEXRAD radar.

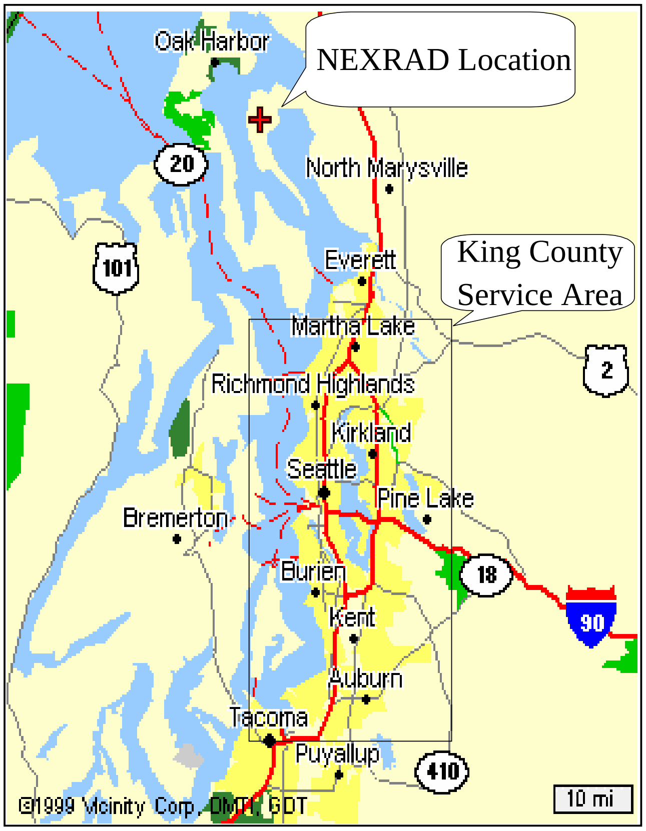

Figure 3-2. NEXRAD and King County Service Area

CALAMAR was used to calculate rainfall intensities during all storm events corresponding to two flow monitoring periods (see Section 3.2.3 for a description of flow monitoring). CALAMAR compares rain gauge values to radar reflectivity at multiple locations and statistically calibrates the radar reflectivity over a calibration zone[6]. The CALAMAR process allows a finer resolution in geographic coverage than would be obtainable with rain gauges alone.

[5] For more information about how CALAMAR was used, see pages 37 through 50 of the *2000/2001 Wet Weather Flow Monitoring Technical Memorandum* (May 2001) and Appendix E of the October 2004 *Pilot Project Report*.
[6] The service area was divided into eight calibration zones of 200 to 500 square kilometers each to ensure that only rainfall within each zone was used to calibrate that zone. For more information about the calibration zones, see page 42 of the *2000/2001 Wet Weather Flow Monitoring Technical Memorandum* (May 2001).

For predicting the design (20-year peak) I/I flows, a 60-year rainfall record was used to approximate future rainfall frequency and intensity. The 60-year rainfall record is an extended time series (ETS) based on precipitation records from Seattle-Tacoma International Airport (Sea-Tac). The ETS records represent the longest continuous record of rainfall data for the area[7]. For modeling purposes, it was assumed that the past ETS records are representative of future rainfall patterns likely to occur in the service area.

Eighteen significant rainfall events occurred during the second monitoring period; however, only 10 events caused a measurable and system-wide I/I response. These 10 events were used for the modeling process described in Section 3.2.4.

3.2.3 Flow Monitoring

The location and intensity of wastewater flows and I/I within the local agency systems was necessary for the benefit/cost analysis because it provided the basis for estimating the cost of regional conveyance system improvements (CSI) and I/I reduction efforts. To obtain this information, the County conducted a comprehensive flow monitoring study[8] during the winters of 2000/2001 and 2001/2002. Flow monitoring provided measured data for addressing the wet weather performance and geographic distribution of I/I throughout the local agency facilities tributary to the County's collection system. In addition, flow monitoring data provided input for developing and refining the hydrologic and hydraulic models that were used throughout the benefit/cost analysis (see Sections 3.2.4.2 and 3.2.4.4 for descriptions of the hydrologic and hydraulic models).

> **Mini-basins** were defined to provide manageable target areas for sewer system evaluation and rehabilitation. Mini-basins contained an average of 22,000 linear feet of sewer lines. Figure 3-3 shows mini-basin locations.
>
> **Model basins** were defined to facilitate modeling of I/I and sewage flows. Model basins represented the entire sewered area flowing to a specific flow meter location, and consisted of an average of 1,000 sewered acres and 100,000 linear feet of pipe. Each model basin encompassed an average of 5 to 7 mini-basins. Figure 3-4 shows model basin locations.

Flow monitoring objectives were to:

- Divide the entire system of local agency sewer lines into specific geographic areas called mini-basins and model basins.
- Quantify levels of I/I in each tributary local agency collection system.
- Track long-term flow trends within the County's conveyance system.

Three types of flow meters were placed throughout the regional and local agency service areas:

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[7] For a discussion of the application of Sea-Tac rainfall records to the service area, see Appendix A2 of the *Regional Needs Assessment Report* (March 2005).
[8] For more information about the flow monitoring study, see the *2000/2001 Wet Weather Flow Monitoring Technical Memorandum* (May 2001) and the *2001/2002 Wet Weather Flow Monitoring Technical Memorandum* (June 2002).

- **Long-term meters -** 75 long-term wastewater flow meters were placed at strategic locations in the County conveyance system where full-time flow data would be available for the next several years. This allowed monitoring and assessment of system operation to further calibrate and validate the hydrologic and hydraulic models.
- **Modeling meters -** 94 wastewater flow meters were placed at the model basin outlets to provide flow information for calibrating the hydrologic model. Modeling meters collected data only during the wet weather season. In addition to the 94 model basin meters, 53 of the long-term meters also functioned as modeling meters. In total, wastewater flow data were collected for 147 model basins.
- **Mini-basin meters -** 638 meters, in addition to the meters described above, were placed farther upstream in mini-basins to isolate the flow response of smaller areas. These were installed during the wettest portion of the wet weather season.

Figure 3-5 shows flow meter locations within the County service area.

During the first winter of flow monitoring, flow meters were installed in 807 mini-basins. Adjustments were made in mini-basin boundaries for the second winter of flow monitoring, and 774 mini-basins were monitored. During both winters of flow monitoring, all the basins were monitored simultaneously to achieve improved data consistency.

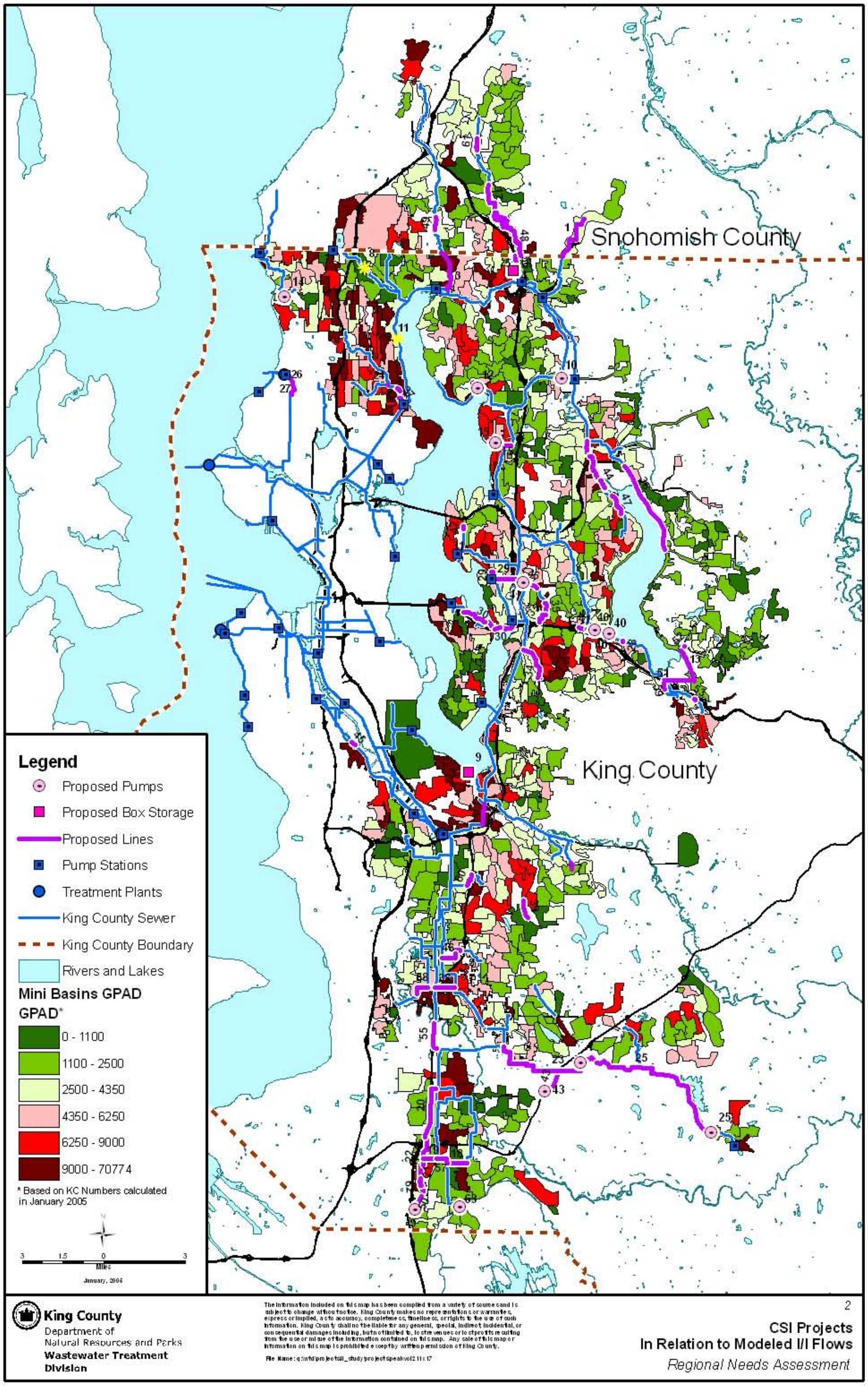


Figure 3-3. Mini-Basin Locations in Relationship to I/I Levels

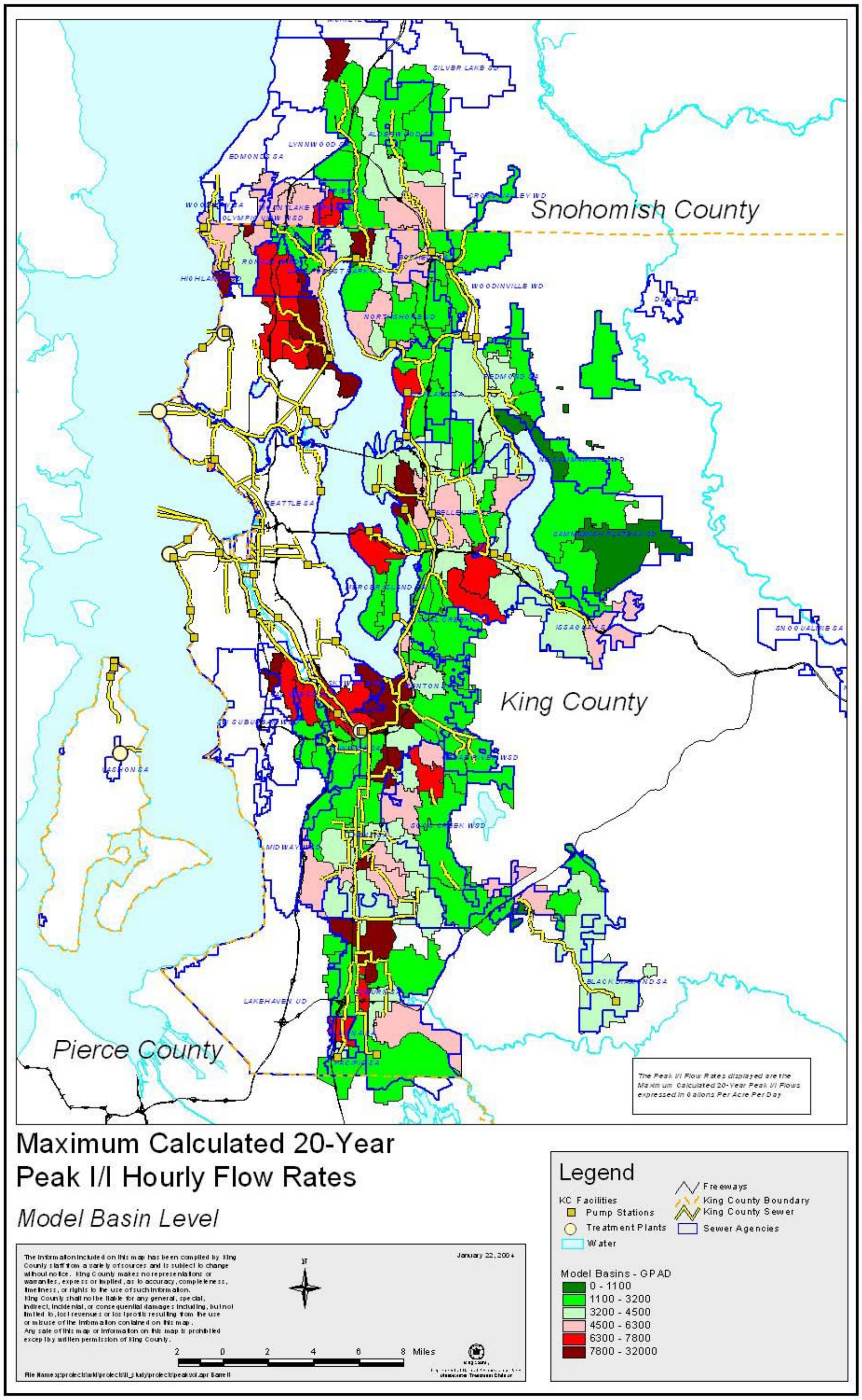


Figure 3-4. Model Basin Locations in Relationship to I/I Levels

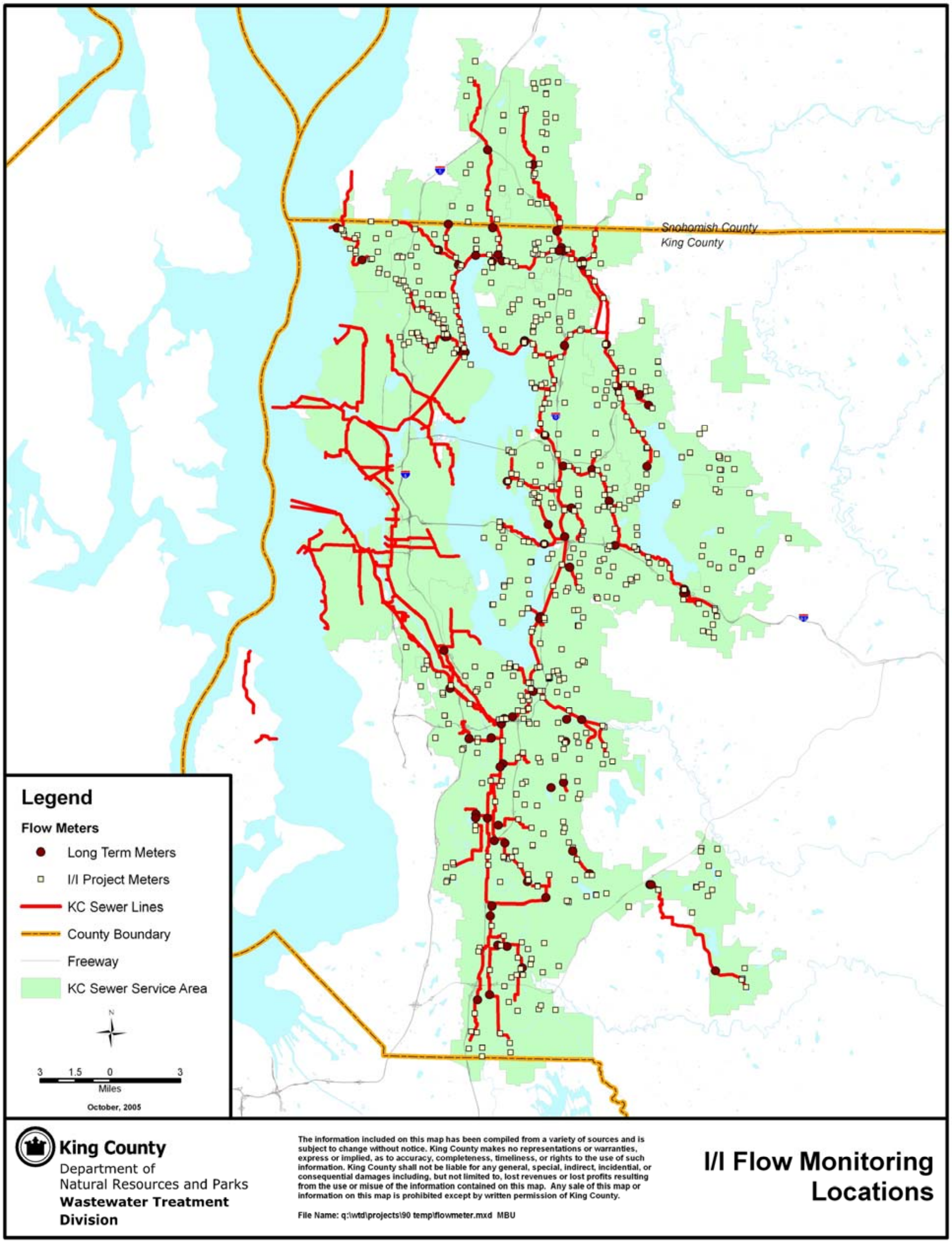
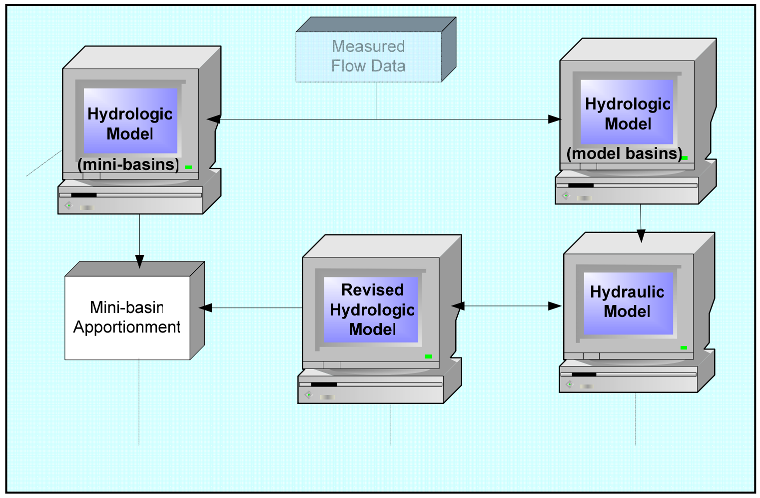


Figure 3-5. Flow Meter Locations

3.2.4 Modeling

3.2.4.1 Overview



To determine the required system capacity before and after implementing proposed I/I reduction projects, and to predict the impact of wet weather conditions on the system, the County simulated the conveyance system's processes and performance. This was accomplished by:

1. Using the measured data collected during flow monitoring and rainfall analysis to develop and calibrate a *hydrologic* model for 147 model basins in the service area (see Section 3.2.3 for a description of model basins).
2. Using a long-term (60-year) rainfall data set (see Section 3.2.2 for a description of the 60-year rainfall records from Sea-Tac) to simulate each model basin's long-term flow. The modeled long-term flows were analyzed statistically to determine the peak I/I flows produced within each model basin. The peak flows were then applied (input) to a *hydraulic* model of the County conveyance system. The hydraulic model was used to analyze how the system performed under the existing 20-year peak flow conditions.
3. Projecting future flow conditions into the previously developed hydraulic model of the regional conveyance system. The projections involved applying assumptions related to: (a) the increase in sewered areas due to growth, (b) existing I/I rates, (c) I/I rates from areas to be sewered in the future, and (d) an increase in existing and future I/I due to sewer system degradation[9]. The results of this analysis identified the need for additional or expanded conveyance system capital improvements.

3.2.4.2 Hydrologic Model

To provide the basis for cost estimates used in the benefit/cost analysis, hydrologic models were used to quantify the wastewater and I/I flow out of a basin in response to rainfall. The hydrologic model simulates the hydrologic transformation of rainfall into the I/I that enters the sewer system via cracked pipes, leaky manholes, improperly connected storm drains, downspouts, and sump pumps. The rainfall and wastewater flow data collected during the flow monitoring period were used to develop and calibrate the hydrologic model.

[9] Sewer system degradation refers to deterioration of existing pipeline conditions, allowing ever-increasing amounts of surface water and groundwater to enter the sewer system. The current rate utilized by the County is an increase in I/I at a rate of 7 percent per decade.

Hydrologic models were created for the mini-basins and 147 model basins using commercially available software called MOUSE (Modeling of Urban Sewers) from the Danish Hydraulic Institute (DHI). Each model basin contained multiple mini-basins. The hydrologic model included base sanitary flows as projected for the year 2050 based on total regional service area after buildout[10]. The County GIS provided detailed information on land use, growth projections, and septic sewer system conversions, and identified sewerable and unsewerable properties.

The calibrated model output was used to identify the estimated amount and types of I/I within local agency sanitary sewer systems under specific wet weather conditions in each model basin.

The input needed for MOUSE hydrologic models is based on the characteristics of each basin, and is briefly described below:

- **Basin description:** Basin characteristics such as total area, slope, and impervious/pervious surface area
- **Base wastewater flow data:** A flow record during dry periods to assess base wastewater discharge from industrial/commercial/residential land use, and to establish base infiltration[11]
- **Rainfall:** A continuous record of rainfall in a study area

Modeling Term Definitions:

Hydrologic model**:** A model used to numerically simulate the physical process of how rainfall ends up as inflow and infiltration.

Hydraulic model**:** A model of the actual pipes that convey the wastewater flows and I/I generated by the hydrologic model. The hydraulic model outputs flow depths and velocities within specific pipe segments and allows evaluation of how the system performs under existing and future demands.

Basin: A geographic area that contributes flow to a specific location, usually a flow meter or a facility. The two primary types of basins used in the assessment are **model basins** and **mini-basins**.

Model calibration**:** The process of adjusting model parameters so the model output matches the measured sewer flow for the same time period.

Peak flow by return period**:** A statistical analysis related to the probability that a given flow will be equaled or exceeded in a given year. The 20-year peak flow has a 1 in 20, or 5-percent chance of being exceeded in any given year.

The *hydrologic* model output is a series of hydrographs (graphs of flow versus time) for specified time periods at particular basin outlets. In turn, the hydrographs are inputs to a *hydraulic* model, which simulates the travel time[12] of flows through a conveyance system. Figure 3-6 shows a typical exchange of data between the hydrologic and hydraulic models.

Hydraulic models convey flows generated by hydrologic models from one basin to another. The models are typically based on a conveyance system's physical characteristics, such as pipe length, pipe material, pipe slope, roughness coefficient, manhole geometry, and others.

[10] Buildout is the maximum number of anticipated connections or discharges to the regional conveyance system.
[11] Base infiltration is infiltration that remains at relatively steady levels over weeks and months.
[12] Travel time is the amount of time it takes flows to travel through the conveyance system.

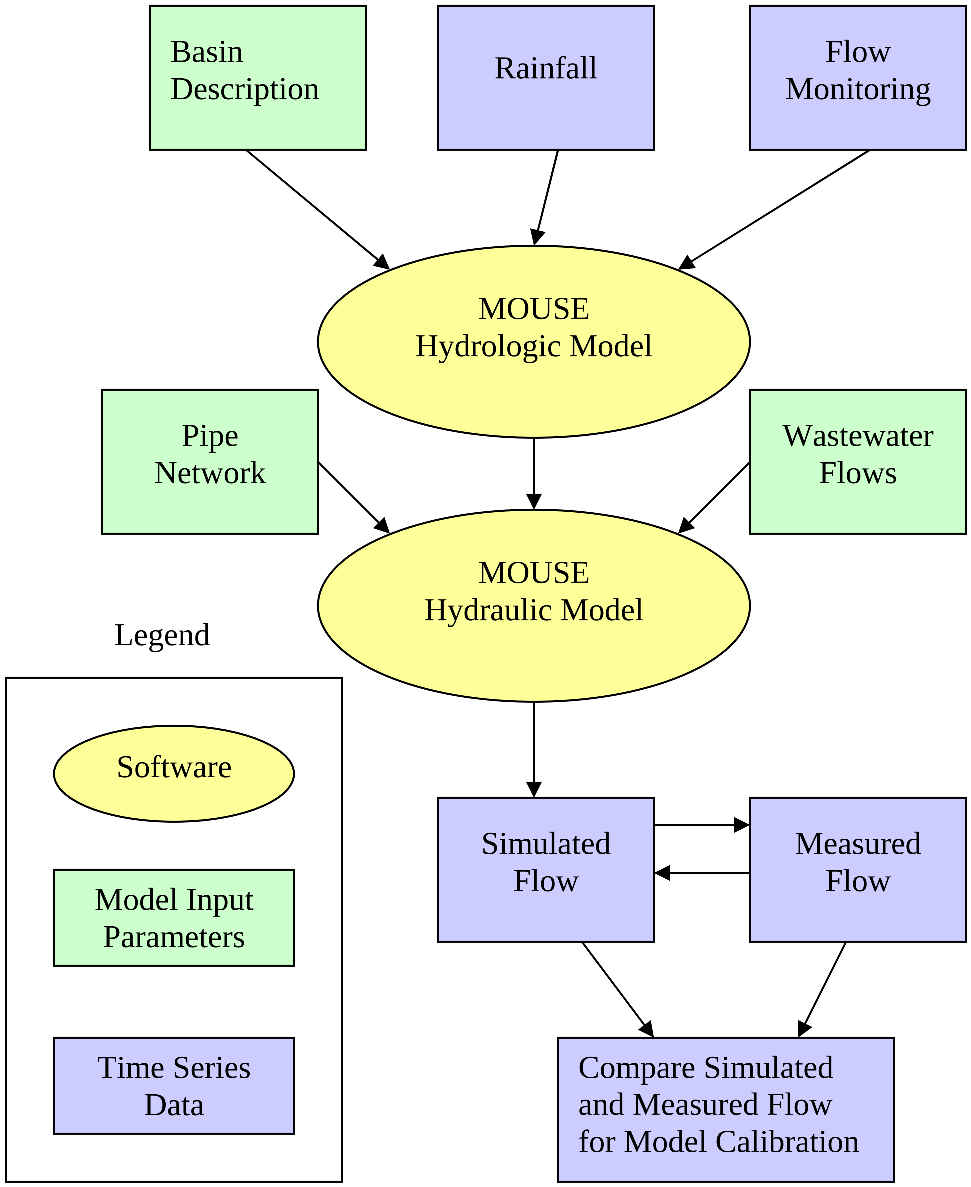


Figure 3-6. MOUSE Hydrologic and Hydraulic Model Components

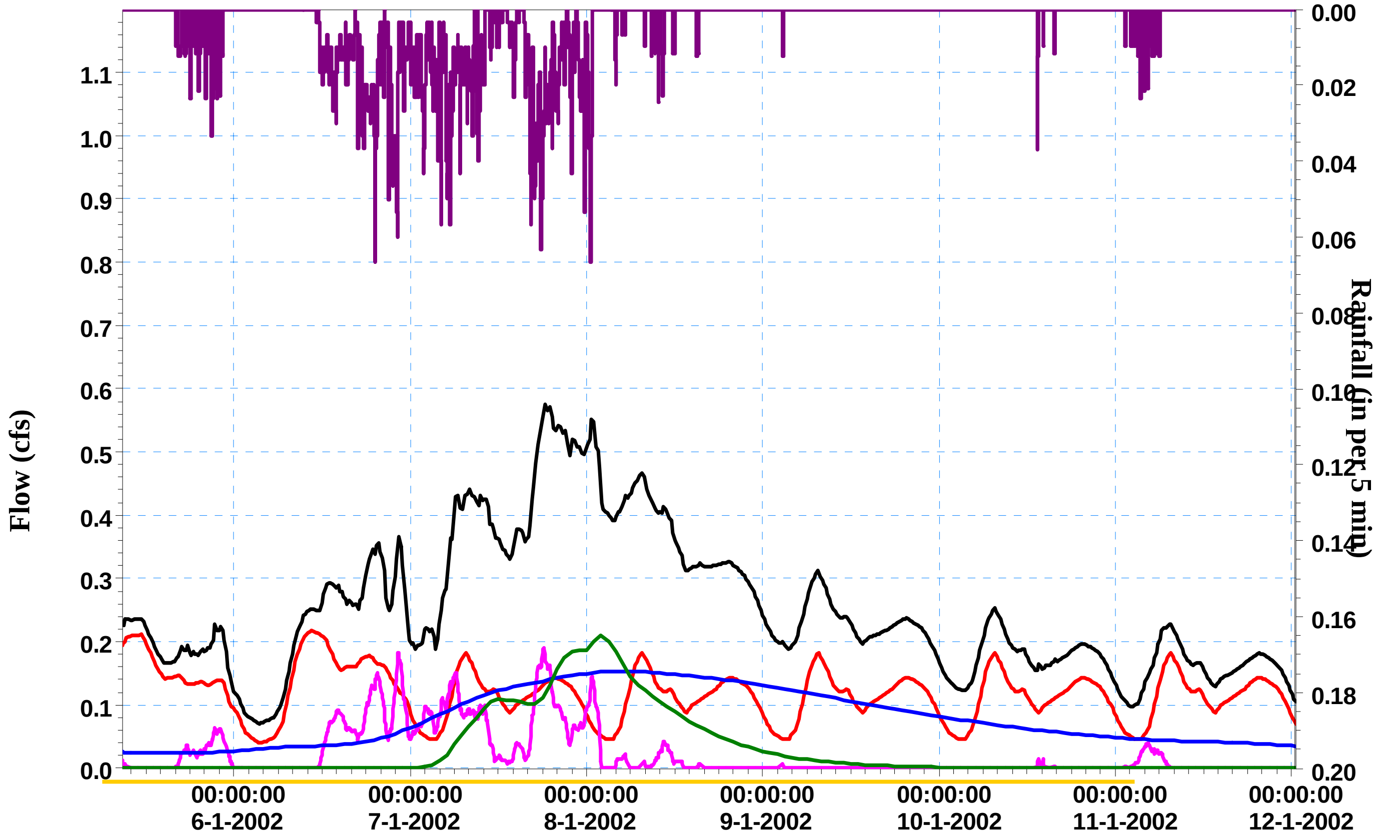
3.2.4.3 I/I Flow Components

As shown in Figure 3-6, the hydrologic and hydraulic models were coupled together to represent and quantify how the regional wastewater system behaves with respect to I/I. Modeled I/I consists of multiple flow components, as shown in Figure 3-7. During dry weather, only wastewater and a relatively constant amount of clear water, or infiltration flow, are present in the wastewater system. During wet weather, basins that are impacted by I/I typically exhibit one or all of the following wastewater flow characteristics: (a) a fast response almost immediately after rainfall begins and that response may continue throughout the rainfall event and subside quickly at the conclusion of the event; (b) a response that builds and declines more slowly in response to the rainfall event.

Table 3-1 lists the I/I flow components and their likely sources. Figure 2-1 illustrates locations where I/I typically enters the sewer system.

Table 3-1. I/I Flow Components and Sources

Response Type (component)	Flow Characteristics in Response to Rainfall	Likely Sources
Fast response	Sudden increase in flow	**Inflow:** catch basins, roof drains, or other direct connections; **Infiltration:** sources that respond rapidly to rainfall, such as shallow side sewers.
Rapid infiltration	Increase in flow during and/or shortly after a rainfall event, with gradual reduction in flow over a relatively short period after the event	**Infiltration:** shallow sources such as laterals, side sewers, foundation drains; manholes and sewer mains to a lesser extent
Slow infiltration	Slow increases in flow hours or days after a storm; increased flow may take several days or weeks after a storm to decline	**Infiltration:** deep sources such as manholes and sewer mains; reflects a rising groundwater level
Base infiltration	Present regardless of individual storm events	**Groundwater-based I/I:** Generally associated with high groundwater that seeps into the sewer system through defects in pipes.



Legend:

Dry Weather Flow	Total Simulated I/I Flow
Base Infiltration	Fast Response Component
Measured Rainfall	Slow Infiltration
Date Format (dd-mm-yyyy)	Rapid Infiltration

Figure 3-7. Simulated Flow Components

3.2.4.4 Hydraulic Model

Hydraulic models were used to simulate the facilities (pipes, pumps, and storage) that convey flows through the regional wastewater conveyance system. This information was then used to evaluate the capacity of the existing regional conveyance system, to estimate the size and costs for additional or expanded facilities, and to provide the basis for completing the benefit/cost analysis. For input, the hydraulic model required calibrated outputs from the hydrologic model and base sewage flow data. The hydraulic model output yielded flow depths and velocities within specific pipe segments and allowed evaluation of system performance under existing and future flow conditions.

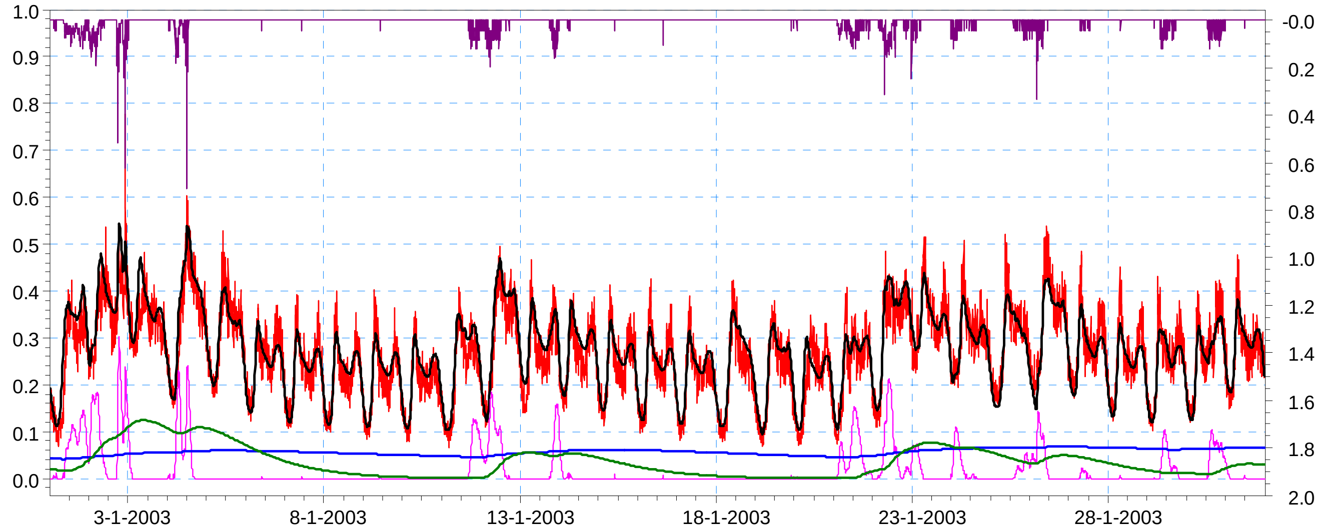
After simulating the system's physical properties with the hydrologic model and calibrating the output, the County used its existing hydraulic model to evaluate the wastewater system. The modeled (hydrologic) flows that provided input into the hydraulic model were associated with a specific physical location. This was necessary because connections to the conveyance system in the model basins varied from a single point to as many as nine points per model basin.

Using calibrated flows (see Section 3.2.4.5 for a description of the calibration process) allowed for spot-checking the original model basin calibrations by comparing combined model basin flows to actual flow measurements in the system. Comparing these measured flows allowed the County to make adjustments to both base sewage flow and I/I model parameters to better simulate the base sewage and I/I contributions to the system.

3.2.4.5 Model Calibration

Calibrating hydrologic and hydraulic models was necessary to test the accuracy of their outputs and to provide a level of confidence for a critical element used in the benefit/cost analysis. Calibration was accomplished by comparing hydrologic and hydraulic model results to actual measured flow data collected during the flow monitoring period. Both the hydrologic and hydraulic models were calibrated to the two wet seasons of flow data collected in 2000 through 2002, and to the dry-weather sewage flow pattern. Calibration involved adjusting the wet-weather flow parameters of the hydrological model until the output substantially matched actual measured wet-weather flows from the model basins. A second calibration was then completed to balance the hydrologic model with the measured flow from the 75 long-term meters located in the regional conveyance system. This effort resulted in revisions to both hydrologic and hydraulic model parameters to achieve an acceptable calibration of both models. The dry-weather flow calibration process involved taking measured sewer flow data from dry-weather periods and identifying recurring daily wastewater flows patterns based on measured flows on weekdays and weekends.

Figure 3-8 is a graphical example of how the calibrated hydrologic model output closely matched the measured flow data for a variety of storms during the 2001 through 2002 monitoring period.



Legend: Measured Flow; Measured Rainfall; Total Simulated I/I Flow; Fast Response Component; Slow Infiltration; Rapid Infiltration

Date Format (dd-mm-yyyy)

Figure 3-8. Comparison of Modeled Flow Data to Measured Flow Data

3.2.4.6 Estimated 20-Year Peak Flows

Once the hydrologic and hydraulic models were calibrated, 20-year peak flow demands on the system were simulated with the hydraulic model. The output from the long-term simulations was analyzed to determine the probability of exceeding a given peak flow during a given year.

The County adopted a 20-year flow capacity standard[13] for conveyance facilities that transport wastewater from local agencies to County treatment plants. This means that the facilities must have capacity for flows of a magnitude that can be expected on an average of once every 20 years (20-year return period). This corresponds to a 5-percent chance of such flows or higher occurring in any given year.

To maintain consistency with County capacity standards, the difference in the 20-year peak flow established for pre-rehabilitation versus post-rehabilitation was used to estimate rehabilitation effectiveness. This was done both in the pilot projects (see Section 3.2.5 for a description of the pilot projects) and in the benefit/cost analysis described in Chapter 4.

The method used to estimate the pre-rehabilitation 20-year peak flow for each basin consisted of conducting an extended simulation and performing a frequency analysis on the simulated flows. Through calibration of the continuous simulation model to measured flows, the parameters

[13] For more information about the 20-year flow capacity standards, see the *Regional Wastewater Services Plan*, available at http://dnr.metrokc.gov/wtd/rwsp/rwsp.htm.

describing each basin were adjusted to represent the processes that transform rainfall into infiltration and inflow. The model was then used to simulate flow response from a long-term rainfall time series that includes large, infrequent rainfall events. By simulating a continuous, long-term period, this approach accounted for the effects of antecedent conditions (ground moisture increases due to rainfall) on I/I volumes.

3.2.4.7 Apportioning I/I Flows to Mini-Basins

The benefit/cost analysis required that flows associated with the 20-year peak event be established at each target regional conveyance facility. Under ideal conditions, the sum of the simulated flows using individual mini-basin models should equal the simulated flows for the model basin that they comprise. However, there were typically differences between the sum of the simulated flows for the mini-basins and the simulated flows for the model basins. These differences were due largely to variability in calibration, measured flow data, and travel time for mini-basin flows through the local agency collection systems. As a result, an apportionment process was developed to resolve the differences and enable the revised mini-basin values to be used in the benefit/cost analysis.

The apportionment process applied adjustment to the identified individual I//I flow components. The I/I flow components subject to the apportionment process were identified as the Fast Response Component (FRC); Slow Response Component (SRC) (which includes Rapid Infiltration and Slow Infiltration; and Base Infiltration (BI):

- Fast Response (FRC) I/I is an indicator of direct connections of stormwater sources to the sewer system such as downspouts and flooded manholes.
- Slow Response (SRC) I/I is an indicator of stormwater entering the sewer system after either traveling overland some distance or saturating the ground and then seeping through structural defects. Slow Response (SRC) I/I was further broken down into Rapid Infiltration and Slow Infiltration. The Rapid Infiltration component was derived for each mini-basin by subtracting the Slow Infiltration component from Slow Response (SRC).
- Base Infiltration (BI) is generally associated with high groundwater that is present regardless of individual storm events, that seeps into the sewer system through defects.

Mini-basin apportioned I/I values were derived for the event selected to represent the theoretical model basin I/I peak (20-year) flow. The I/I flow components for the mini-basins, as identified by the calibrated models, were then extracted for the corresponding simulation.

The apportionment process varied slightly for the different flow component types:

- The FRC for each mini-basin was calculated as a percentage of the sum of the FRC components for all mini-basins within the model basin. The FRC percentage calculated for each mini-basin was then multiplied by the 20-year model basin FRC value to establish the apportioned FRC component value for use in the benefit/cost analysis.

- The BI for each mini-basin was calculated as a percentage of the sum of the BI components for all mini-basins within the model basin. The BI percentage calculated for each mini-basin was then multiplied by the 20-year model basin BI value to establish the apportioned BI component value for use in the benefit/cost analysis.
- SRC was further broken down into Rapid Infiltration (RI) and Slow Infiltration (SI).
- The RI for each mini-basin was calculated as a percentage of the sum of the RI components for all mini-basins within the model basin. The RI percentage calculated for each mini-basin was then multiplied by the 20-year model basin RI value to establish the apportioned RI component value for use in the benefit/cost analysis.
- The SI for each mini-basin was calculated as a percentage of the sum of the SI components for all mini-basins within the model basin. The SI percentage calculated for each mini-basin was then multiplied by the 20-year model basin SI value to establish the apportioned SI component value for use in the benefit/cost analysis.

The result of the apportionment process was an adjusted value for each of the I/I flow components within each of the mini-basins. The sum of a mini-basin's revised I/I flow components provided the mini-basin's apportioned total I/I value, which then allowed the apportioned mini-basin flows to approximate the model basin flows.

3.2.4.8 Mini-Basin Confidence Factors

Due to the number of parameters that influenced or impacted the wastewater flow and I/I values for each mini-basin, it was necessary to complete an evaluation for each mini-basin to determine its confidence for use in the benefit/cost analysis. Confidence levels varied from low to high, with low-confidence mini-basins presenting a lower potential for achieving the estimated I/I removal required. Two primary conditions had the potential to negatively impact the confidence of a mini-basin:

1. If the apportionment process between the model basin and the mini-basin resulted in changing a mini-basin's I/I value more than 20 percent, then a low level of confidence score was assigned to the mini-basin; or,
2. If the mini-basin flow data quality was poor, then a lower level of confidence was assigned to the mini-basin[14].

Mini-basin apportionment factors were of concern because mini-basins with I/I values apportioned "up" might overestimate the amount of I/I present and underestimate removal costs. Mini-basins apportioned "down" might result in missed opportunities for I//I removal and overestimation of removal costs.

[14] For additional information about conditions that impacted measured flow data, see the *2000/2001 Wet Weather Flow Monitoring Technical Memorandum* (May 2001) and the *2001/2002 Wet Weather Flow Monitoring Technical Memorandum* (June 2002).

In order to evaluate and categorize the modeling results for the various basin models, a level of confidence (LOC) analysis was performed for all mini-basins that had simulated flow of 3,500 gpad or more[15]. The LOC analysis included a review of the following:

- Calibration flow data quality
- Quality of simulation match to measured flow
- Derived mini-basin apportionment factor
- Magnitude of dry weather flow
- Number of subtractions used to derive calibration flow data

Based on the review, each mini-basin was then placed in one of the following categories:

- High confidence
- Moderate to high confidence
- Moderate confidence
- Moderate to low confidence
- Low confidence
- No confidence

For use in the benefit/cost analysis, it was preferred to select mini-basins as potential I/I reduction projects with at least a “moderate” level of confidence or better unless no other alternative mini-basins were available. In those cases when a mini-basin with a “low” level of confidence needed to be used to make an I/I reduction project cost effective, it was specifically noted as such and flagged for additional review and consideration prior to further investigation and implementation. A total of 10 mini-basins with low levels of confidence were used in the benefit/cost analysis and they impacted 8 of the 9 cost-effective projects (see Section 5.1 for more information about the 9 cost-effective projects; see Appendix A1 for details about confidence levels).

3.2.4.9 Planning Assumptions for I/I Modeling

A number of conditions drive the timing, sizing, and costs of facilities that occur in the future and each requires assumptions to arrive at a value. To accurately project conveyance system improvement (CSI) needs, the County used assumptions specifically developed for the I/I control program. After completing the I/I reduction pilot projects (see Section 3.2.5 for more

[15] A 3,500-gpad threshold was established based on the results of the 10 pilot projects; in some mini-basins, rehabilitation of sewer system components did not result in I/I reduction levels of less than 3,500 gpad. For more information about I/I reduction and rehabilitation effectiveness, see Sections 8.6 and 8.7 of the *Pilot Project Report* (October 2004).

information about the pilot projects), local agencies and the County collaborated to develop these assumptions. Table 3-2 summarizes several of the more significant planning assumptions[16].

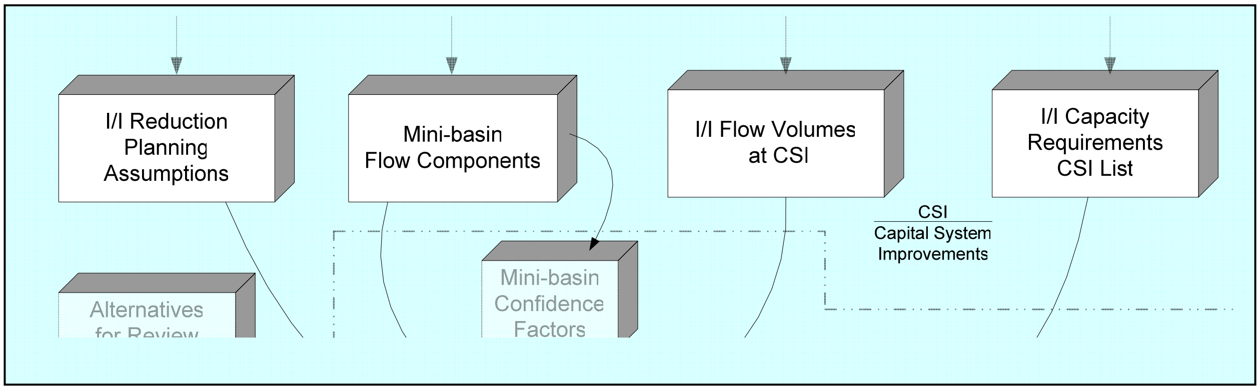


Table 3-2. Planning Assumptions for I/I Modeling

Sensitivity Factor	I/I Modeling Assumption
Water conservation (base flow projections)	10% reduction by 2010, no additional reduction thereafter
Septic conversion	90% of unsewered but sewerable area in 2000 sewered by 2030; 100% by 2050
New system I/I allowance	1,500 gallons per acre per day (gpad)
Design flow	20-year peak flow, based on Sea-Tac 60-year rainfall record, adjusted per annual average rainfall over each part of the service area
Degradation	7% per decade starting in 2000 up to 28% for existing pipe; 7% per decade starting after date of construction up to 28% for new construction
Sizing of facilities	Design flow at saturation plus 25% safety factor (when sizing facilities, a safety factor of 25% of additional capacity will be used)
Discount rate	6%
Inflation rate	3%

[16] For more information about planning assumptions, see Appendix A5 of the *Regional Needs Assessment Report* (March 2005).

Sensitivity Factor	I/I Modeling Assumption
Operation and maintenance analysis	Update the following from the *Regional Wastewater Services Plan* (RWSP): • New pipes: $0.15 per linear foot annually • New pump stations: $4,104 per million gallons per day (mgd) + $60,384 • New storage facilities: $34,091 per million gallons (MG) + $4,546 • Treatment plants: $15,000-$30,000 per mgd of average annual flow reduction (plant specific); covers energy and disinfection costs

Table 3-3 lists the assumptions made about conveyance facility construction and allied costs. These costs were generated by TABULA, a planning level software tool developed by the County, which extends unit costs and applies construction cost indices.

Table 3-3. Conveyance Facility Construction and Allied Cost Assumptions

Cost Item	Costs Factor
Construction estimate	Based on TABULA with factors for traffic, utility conflicts, and groundwater
Utility conflicts	None: $0 Average: $20/linear foot Heavy: $40/linear foot
Traffic control	None: $0 Average: $5/linear foot of main Heavy: $10/linear foot of main
Dewatering	None: $0 Average: $20/linear foot Heavy: $50/linear foot
Sales tax	8.8% of construction estimate
Planning, predesign, design, construction, closeout, land acquisition, construction contingency	51.4% of construction estimate
Project contingency	30% of construction estimate
Mitigation (environmental, land use, public disruption, private property, etc.)	Project-specific

Regional Conveyance System Needs List

The County identified 63 CSI projects necessary to manage projected 20-year peak flows. These projects (listed in Table 3-12 included at the end of this chapter) have an estimated total capital cost of approximately $780 million (2003 dollars) and address the region's projected capacity needs through 2050[17].

The CSI project locations in the County service area are shown in Figure 3-9. The projects, along with estimated costs and online dates, are based on projected 20-year peak flow volumes and provide the basis for conducting benefit/cost analyses of potential I/I reduction projects. For this benefit/cost analysis, I/I reduction projects were considered cost effective when the total estimated CSI project savings after I/I reduction were greater than the total estimated cost of the I/I reduction.

[17] For more detailed information regarding the development of the list of CSI projects, see the *Regional Needs Assessment Report* (March 2005).

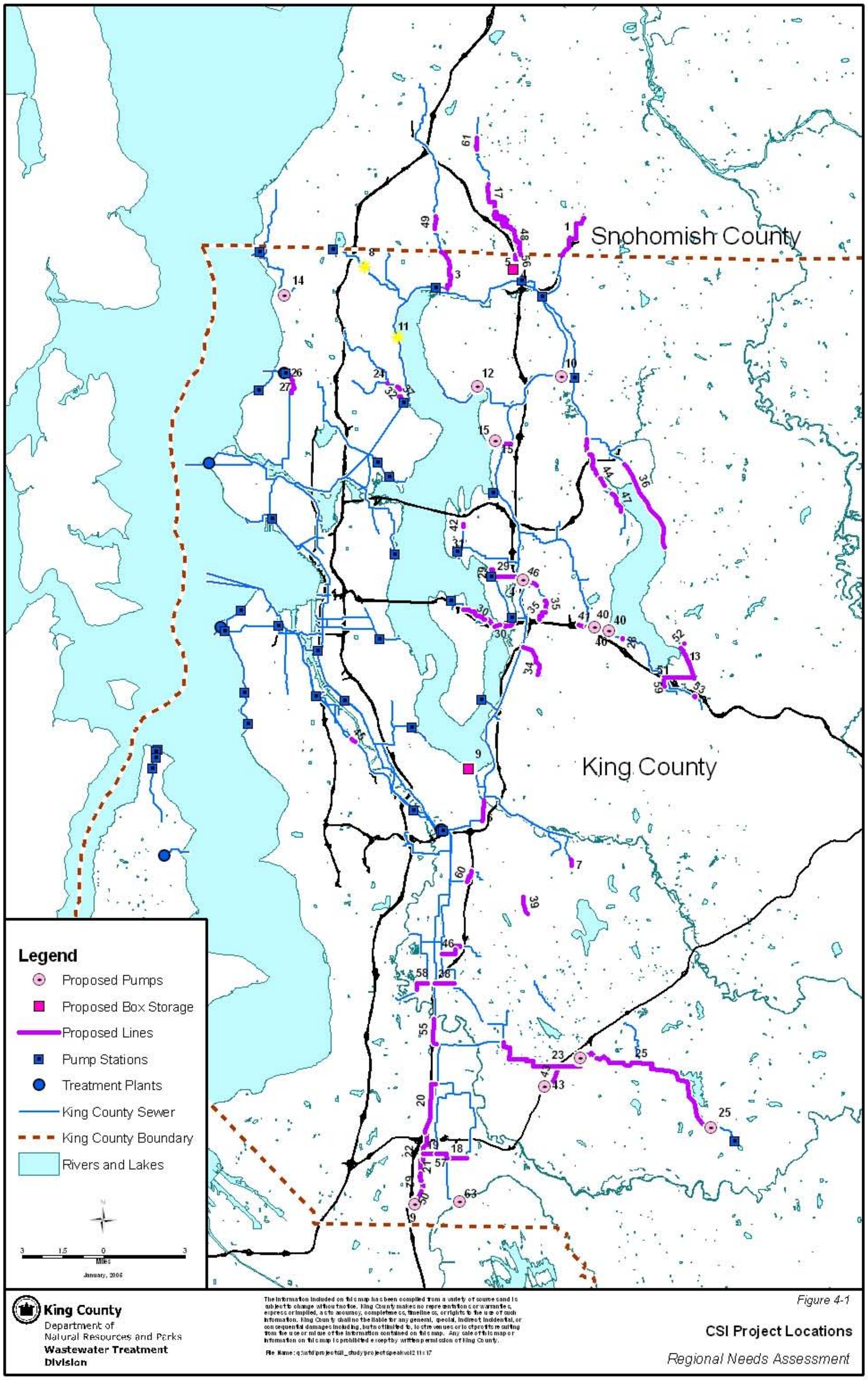
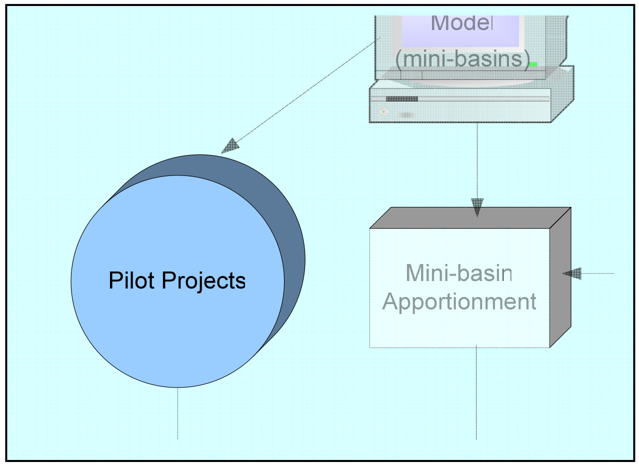


Figure 3-9. Conveyance System Improvement Project Locations

3.2.5 Pilot Projects

3.2.5.1 Overview



To gain a better understanding of the costs and I/I reduction rates associated with implementing I/I reduction projects and to establish target I/I reduction levels, the County constructed 10 pilot projects in local agency systems[18]. The information obtained via the pilot projects was used, in part, to develop planning assumptions related to project cost and I/I reduction rates for this benefit/cost analysis.

The overall objectives of the pilot projects were to demonstrate that:

- I/I can be found.
- I/I reduction can be achieved.
- Project costs can be accounted for.

Work on each pilot project consisted of identifying I/I sources through field investigations, designing and constructing rehabilitation improvements, and monitoring post-construction flows to determine the effectiveness of the rehabilitation.

The selected pilot projects (see Figure 3-10) included a mix of projects on public and private property in 12 local agency jurisdictions: City of Auburn, City of Brier, Skyway Water and Sewer District (formerly known as Bryn Mawr), Coal Creek Utility District, City of Kent, City of Kirkland, City of Lake Forest Park, City of Mercer Island, Northshore Utility District, City of Redmond, Ronald Wastewater District (formerly known as Shoreline Wastewater Management), and Val Vue Sewer District. The combined Coal Creek, Northshore, and Val Vue projects made up the "Manhole Project."

The pilot projects were located within defined mini-basins (see Section 3.2.3 for a description of mini-basins). Within the mini-basin, the specific location where the rehabilitation work took place was termed a "pilot basin". To obtain data that could be compared to the pilot basin data, "control basins" were simultaneously monitored in the vicinity of the pilot basins. No rehabilitation work was done in the control basins.

The selected technologies included lining pipes using a cured-in-place material; replacing pipes by pipe bursting or open-cut methods; replacing manholes; rehabilitating manholes using chemical grouting, coatings, or cured-in-place liners and adjusting frames and covers; and installing cleanouts.

[18] For more information about the pilot projects, see the *Pilot Project Report* (October 2004).

To compare I/I removal effectiveness based on the rehabilitation of specific system components (sewer mains, manholes, laterals, and side sewers), only selected components and combinations of components were rehabilitated (see Table 3-4).

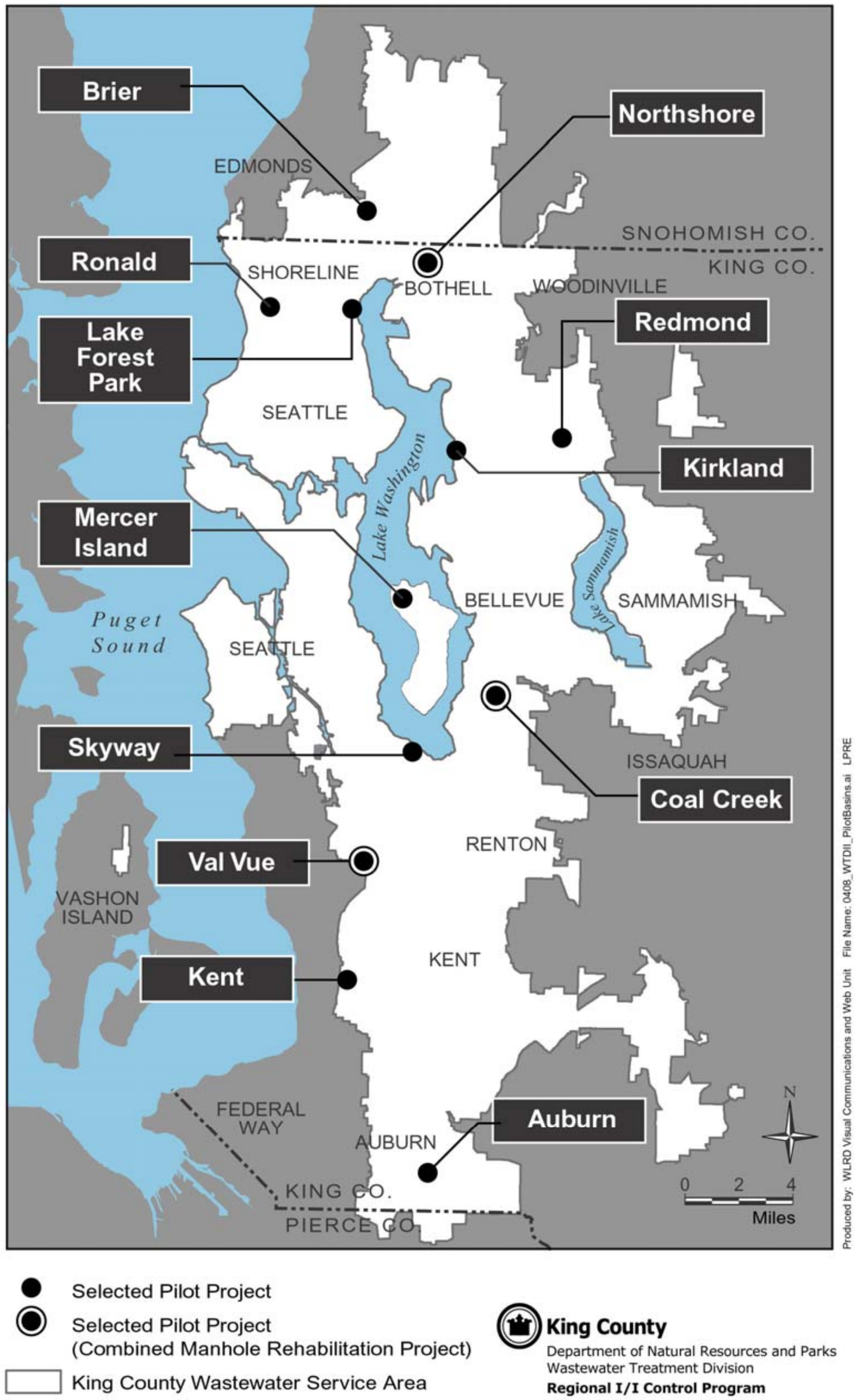


Figure 3-10. Pilot Project Locations

Table 3-4. Sewer System Components Selected for Rehabilitation

Pilot Project	Sewer Main	Manhole	Lateral	Side Sewer
Auburn Pilot A	●	●	●	●
Auburn Pilot B		●		
Brier	●	●		
Kent			●	●
Kirkland	●	●	●	
Lake Forest Park	●	●		
Manhole - Coal Creek		●		
Manhole - Northshore		●		
Manhole - Val Vue		●		
Mercer Island Pilot A	●			
Mercer Island Pilot B	●			
Redmond Pilot A	●	●	●	
Redmond Pilot B	●	●	●	
Ronald				●
Skyway	●	●	●	●

3.2.5.2 I/I Reduction Estimated with Modeling

To quantify I/I reduction, the change in flow response of the pilot basin between the pre-rehabilitation and post-rehabilitation monitoring seasons was compared with the change in flow response of a control basin without I/I reduction (see Section 3.2.3 for a description of flow monitoring).

Hydrologic and hydraulic models (see Section 3.2.4 for a description of modeling) were developed and then calibrated to the pre- and post-measured flow responses to a continuous 60-year record of rainfall. The primary purpose for quantifying rainfall in each pilot and control basin was to develop input for flow modeling (see Section 3.2.2 for a description of rainfall analysis and the use of CALAMAR technology). Flow modeling of the pilot and control basins was used to determine whether rehabilitation improvements resulted in reduced peak I/I (see Section 3.2.4 for a description of modeling and the use of MOUSE software). In addition to providing information related to I/I reduction costs and reduction rates, the data collected during the pilot projects were used in the hydrologic and hydraulic models to help establish a common basis for determining I/I reduction effectiveness and to project the 20-year peak flow rates in each basin.

3.2.5.3 I/I Rehabilitation Assumptions

To establish target I/I reduction levels, the County needed to develop assumptions about what I/I reduction levels could be achieved with selected I/I reduction techniques. A range of I/I reduction techniques was considered and selected. The County and its consultant identified six candidate I/I reduction techniques for the benefit/cost analysis, as shown in Table 3-5. The techniques included a full range of responses to different types of I/I, from inflow alone (Technique 1), through infiltration and inflow on public right-of-way (Techniques 2 through 4) and private property (Techniques 5 through 6).

Table 3-5. Candidate I/I Reduction Techniques

Technique	Description	Comments
1	Direct disconnects[19]	Downspouts, catch basins, yard drains, and manholes
2	Replace everything and direct disconnects	Sewer mains, laterals, side sewers, manholes, and direct disconnects
3	Rehabilitate public sewers	Sewer mains, laterals, and manholes
4	Replace public sewers and direct disconnects	Sewer mains, laterals, manholes, and direct disconnects
5	Private property and some laterals	Side sewers and some laterals
6	Private property and some laterals and direct disconnects	Side sewers, some laterals, and direct disconnects

Initial Assumptions

The six candidate I/I reduction techniques were evaluated so that assumptions could be made about the hydraulic and cost estimating programs used by the County. The information sources for these Initial Assumptions were the pilot project results, research into other I/I programs throughout the U.S.[20], and input from the local agencies.

The Initial Assumptions for each technique are shown in Table 3-6, and include the percent of a mini-basin rehabilitated and the resulting I/I reduction. I/I reduction assumptions for the six

[19] Direct disconnects occur when “illicit” connections to the sewer system (that is, pipes carrying something other than sewage) are disconnected and routed to an alternative disposal system such as a ditch or storm sewer.

techniques range from 15 to 80 percent based on an I/I threshold value[21] of 1,500 gallons per acre per day (gpad)[22].

Table 3-6. Initial Assumptions

Technique	Description	% Basin Rehabilitated	% I/I Reduction
1	Direct disconnects (DD)	4%	15%
2	Replace everything and direct disconnects	95% plus DD	80%
3	Rehabilitate public sewers	50%	40%
4	Replace public sewers and direct disconnects	50% plus DD	45%
5	Private property and some laterals	70% Side sewers (SS) 25% Laterals/SS	70%
6	Private property and some laterals and direct disconnects	70% Side sewers 25% Laterals/SS plus DD	75%
	Minimum remaining I/I after rehabilitation	1,500 gpad	

E&P Assumptions

At a meeting of the County and the Metropolitan Water Pollution Abatement Advisory Committee's (MWPAAC's) Engineering and Planning (E&P) Subcommittee (May 26, 2004), it was determined that the Initial Assumptions needed revision to be more conservative. This considered the fact that the pilot projects were relatively small in scale; a larger program effort could be more expensive and not as effective in removing I/I.

In addition, the six techniques were re-configured into four by eliminating Techniques 3 and 5. Techniques 3 and 5 of the Initial Assumptions (see Table 3-6) did not include direct disconnects;

[20] For information about research conducted into other I/I programs, see the description of the National I/I Program Review in the *Regional Wastewater Services Plan Annual Report, 2001*.
[21] The *Regional Wastewater Services Plan* requires that establishment of a mandatory I/I threshold be considered for local agencies. Such a threshold would set a maximum allowable level of I/I that could enter the regional treatment and conveyance system during periods of peak flow. For more information about I/I thresholds, see Section 1.3.1 of the *Alternatives/Options Report* (March 2005).
[22] 1,500 gpad is the current threshold value used for County conveyance system planning and modeling. In its planning efforts, the County assumes that this volume of I/I will come from land that is currently unsewered once development occurs.

however, the E&P Subcommittee agreed that each I/I reduction technique should involve direct disconnects. Technique 6 was modified for the amount of basin rehabilitation work and the assumed I/I reduction percentages were lowered. The resulting final E&P Assumptions used in the benefit/cost analysis are shown in Table 3-7. I/I reduction assumptions ranged from 10 to 80 percent based on an I/I threshold value of 3,500 gpad.

Table 3-7. E&P Assumptions

Technique	Description	% Basin Rehabilitated	% I/I Reduction
1	Direct disconnects	4%	10%
2	Replace everything and direct disconnects	95% Sewer mains 95% Manholes 95% Laterals and side sewers 4% Direct disconnects	80%
3	Replace public sewers and direct disconnects	50% Sewer mains 50% Manholes 50% Laterals 4% Direct disconnects	40%
4	Private property and some laterals and direct disconnects	50% Laterals and side sewers 45% Side sewers only 4% Direct disconnects	60%
	Minimum remaining I/I after rehabilitation	3,500 gpad	

Sensitivity Analysis (Initial) Assumptions

A Sensitivity Analysis was conducted using the Initial Assumptions to determine the effect on the benefit/cost analysis results (see Section 4.6 for a discussion of the Sensitivity Analysis). The Sensitivity Analysis Assumptions are shown in Table 3-8. The Sensitivity Analysis Assumptions utilized: (a) the percentages from the Initial Assumptions for "percent basin rehabilitated" and "percent I/I reduction", and (b) the four techniques as listed for the E&P Assumptions.

Table 3-8. Sensitivity Analysis (Initial) Assumptions

Technique	Description	% Basin Rehabilitated	% I/I Reduction
1	Direct disconnects	4%	15%
2	Replace everything and direct disconnects	95% Sewer mains 95% Manholes 95% Laterals and side sewers 4% Direct disconnects	80%
3	Replace public sewers and direct disconnects	50% Sewer mains 50% Manholes 50% Laterals 4% Direct disconnects	45%
4	Private property and some laterals and direct disconnects	25% Laterals and side sewers 70% Side sewers only 4% Direct disconnects	75%
	Minimum remaining I/I after rehabilitation	1,500 gpad	

Technique Selection

A selection tree/logic diagram was developed to select I/I reduction techniques for the benefit/cost analysis. The diagram for the E&P Assumptions is shown in Figure 3-11. It is based on a threshold I/I value of 3,500 gpad. The selection tree chooses from the four I/I reduction techniques based on system age (pre- or post-1961[23]) and the combination of I/I types within a mini-basin, as determined by the hydraulic model.

Technique Selection Tree

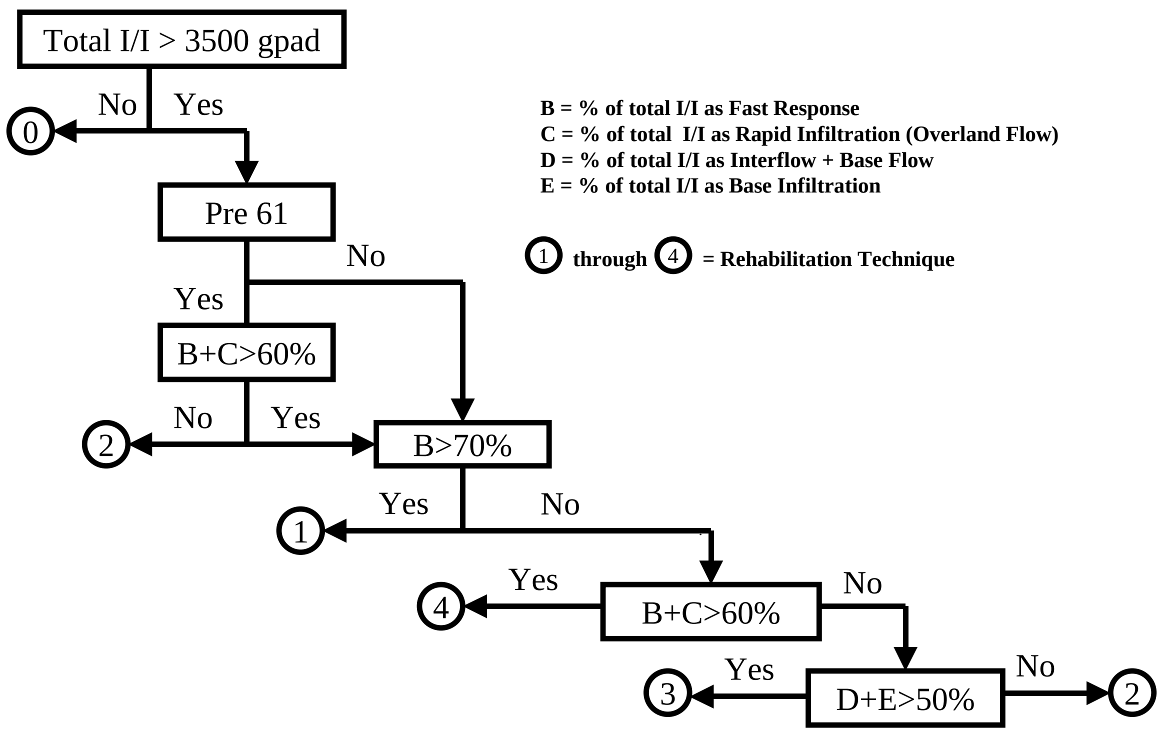


Figure 3-11. Technique Selection Tree

3.2.5.4 Cost Assumptions

Unit costs for I/I reduction techniques were developed based on: (a) the I/I pilot project costs, and (b) historic sewer rehabilitation costs available locally and nationally. These costs were

[23] The regional conveyance system was established in 1961 when local agencies signed contracts with the Municipality of Metropolitan Seattle (Metro) to send their wastewater to Metro's treatment plants. The contract provisions exempt pipelines built before 1961 from standards and fees associated with "clean" water (groundwater or surface water) entering the sewer system. Pipelines built before 1961 can be significant contributors to I/I and may affect the feasibility of establishing a maximum I/I threshold. For more information about including pre-1961 pipe systems in the I/I program, see Section 4.3.2 of the *Alternatives/Options Report* (March 2005).

reviewed by the E&P Subcommittee, and unit cost assumptions were established as shown in Table 3-9 (E&P consensus).

Table 3-9. Unit Costs, E&P Consensus

Technique	Description	Assumed Unit Costs
1	Direct disconnects	$3,000 each
2	Replace everything and direct disconnects	Sewer mains: $110/linear foot Manholes: $3,600 each Laterals and side sewers: $6,800 each Direct disconnects: $1,000 each
3	Replace public sewers and direct disconnects	Sewer mains: $110/linear foot Manholes: $3,600 each Laterals: $3,900 each Direct disconnects: $1,000 each
4	Private property and some laterals and direct disconnects	Laterals: $3,900 each Side sewers: $3,500 each Laterals and side sewers: $6,800 each Direct disconnects: $3,000 each

Table 3-10 lists the allied costs used in the benefit/cost analysis for I/I reduction projects.

Table 3-10. Allied Costs, E&P Consensus

Allied Cost Item	Costs Factor
Utility conflicts	None: Trenchless construction assumed
Traffic control	None: $0 Average: $5/linear foot of sewer main Heavy: $10/linear foot of sewer main
Dewatering	None: Trenchless construction assumed
Sales tax	8.8% of construction estimate
Planning, predesign, design, construction, closeout, land acquisition, non-construction contingency	Techniques 1, 3, and 4: 52% of construction estimate Technique 2: 30% of construction estimate
Project contingency	30% of construction estimate for E&P analysis 0% of construction estimate for sensitivity analysis
Mitigation (environmental, land use, public disruption, private property, etc.)	Project-specific

The I/I reduction unit costs were input into the Benefit/Cost Analysis Tool described in Section 4.2.

The unit cost assumptions used in the sensitivity analysis are shown in Table 3-11. The Sensitivity Analysis is discussed in Section 4.6.

Table 3-11. Unit Costs, Sensitivity Analysis

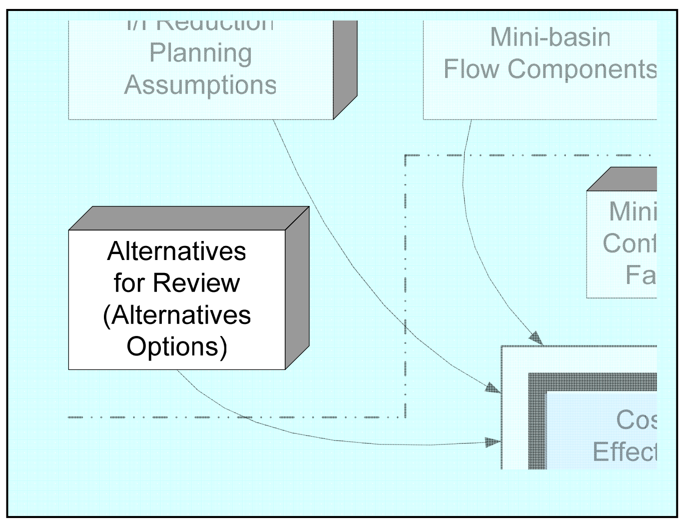
Technique	Description	Assumed Unit Costs
1	Direct disconnects	$1,000 each
2	Replace everything and direct disconnects	Sewer mains: $90/linear foot Manholes: $2,800 each Laterals and side sewers: $3,900 each Direct disconnects: $1,000 each
3	Replace public sewers and direct disconnects	Sewer mains: $90/linear foot Manholes: $2,800 each Laterals: $3,900 each Direct disconnects: $1,000 each
4	Private property and some laterals and direct disconnects	Laterals: $3,900 each Side sewers: $2,800 each Direct disconnects: $1,000 each

3.2.6 Alternatives

To consider alternative approaches to I/I reduction[24] and to begin developing a recommended I/I program, the County collaborated with local agencies through the E&P Subcommittee. Lessons learned from the pilot projects were also used in developing the alternatives and program components.

Each of the three alternatives chosen for evaluation includes these core elements:

- A distinct approach to defining the target level of I/I reduction
- Measures of cost-effectiveness for I/I reduction projects
- Methods for funding I/I reduction projects



[24] For more information about alternatives, see the *Alternatives/Options Report* (March 2005).

Alternative 1: 30-Percent Removal – Reduce peak I/I by 30 percent in the regional service area from the peak 20-year level.

Alternative 1 emphasizes a 30-percent reduction in 20-year peak I/I flows on a regional basis. It is taken from the overall I/I control objective articulated in the *Regional Wastewater Services Plan* (RWSP) Policy I/IP-2.4[25]. Thus, the goal for this alternative is removal of 135 million gallons per day (mgd) of I/I from the County system. This gallon-per-day estimate is based on a total estimated I/I flow contribution of 450 mgd.

Alternative 2: Regional – Implement I/I reduction projects that are found to be cost effective based on a *region-wide* evaluation.

Alternative 2 emphasizes I/I reduction projects that are cost effective based on a region-wide evaluation. It is based on RWSP Policy I/IP-1[26], wherein I/I reduction projects are implemented as long as they are more cost effective than conveying and treating the I/I flow in the County's regional system. Under Alternative 2, all I/I reduction projects with a benefit-to-cost ratio greater than 1[27] are implemented. Cost savings realized from the cost-effective projects are re-invested to fund additional I/I reduction projects as needed until the savings are used up and the overall cost of I/I reduction equals the cost of regional conveyance and treatment of equivalent I/I flows.

Alternative 3: Project-Specific – Implement I/I projects that are found to be cost effective based on a *project-specific* evaluation.

This alternative reflects RWSP Policy I/IP-1, as described in Alternative 2 above. However, it is different, and less expensive, than Alternative 2. Alternative 3 emphasizes implementation of specific I/I reduction projects that are cost effective based on their own cost savings, compared with conveying and treating their own I/I flows. Under Alternative 3, only I/I reduction projects with a benefit-to-cost ratio greater than 1 are implemented. Cost savings are not used to fund additional I/I reduction projects that are not cost effective.

The benefit/cost analysis for each of the alternatives is discussed in Chapter 4.

[25] RWSP Policy I/IP-2.4: "The overall goal for peak I/I reduction in the service area should be thirty percent from the peak twenty-year level identified in the report."
[26] RWSP Policy I/IP-1: "King County is committed to controlling I/I within its regional conveyance system and shall rehabilitate portions of its regional conveyance system to reduce I/I whenever the cost of rehabilitation is less than the costs of conveying and treating that flow."
[27] The benefit/cost ratio is the cost of the regional conveyance system improvement project divided by the cost of the proposed I/I reduction project. See Section 4.1 for more information about the benefit/cost ratio.

Table 3-12. Conveyance System Improvement (CSI) Projects and Estimated Project Costs[28]

Project #	Project List	Project Type	Year Online[1]	Estimated Project Cost[2]
1	Bear Creek Interceptor Extension	Gravity Line	1998	$400,000
2	Alderwood	Acquisition of Facilities	2001	$16,700,000
3	Swamp Creek	Gravity Line	2003	$10,700,000
4	ESI-11 - Wilburton Siphon/Wilburton Odor Control	Gravity Line	2003	$3,900,000
5	Off-line Storage at North Creek	Storage Facility	2004	$33,800,000
6	ESI-1 (2)	Gravity Line	2004	$8,700,000
7	Fairwood Interceptor (formerly Madsen Creek)	Gravity Line	2005	$21,600,000
8	McAleer I/I Work	I/I rehab work (opportunity)	2005	$3,200,000
9	Pacific Pump Station	Pump Station Upgrade	2006	$7,800,000
10	York PS Subtotal	Pump Station Upgrade	2007	$10,000,000
11	Lake Line Connections and Flap Gates	Gravity Line	2007	$1,400,000
12	Juanita Bay Pump Station	Pump Station	2007	$33,100,000
13	Sammamish Plateau WSD	Acquisition of Facilities	2007	$9,400,000
14	Hidden Lake PS/Boeing Trunk	Pump Station Upgrade and Gravity Line	2008	$28,500,000
15	Kirkland Pump Station and Force Main Upgrade	Pump Station and Force Main Upgrade	2008	$9,600,000
16	Auburn	Interceptor Extension	2008	$11,500,000
17	[CSI] North Creek 1-A	Gravity Line	2009	$16,900,000
18	[CSI] Stuck River Diversion 1	Gravity Line	2009	$5,200,000
19	[CSI] Stuck River Diversion 2	Gravity Line	2009	$2,300,000
20	[CSI] Auburn West Valley Replacement - Section C	Gravity Line	2009	$12,400,000
21	[CSI] Auburn West Valley Replacement - Section A	Gravity Line	2009	$2,900,000
22	[CSI] Auburn West Valley Replacement - Section B	Gravity Line	2010	$25,200,000

[28] See Section 3.2.4.9 for a discussion of this table.

Project #	Project List	Project Type	Year Online[1]	Estimated Project Cost[2]
23	[CSI] Soos Alternative 3A(3) - PS D w/ Conveyance	New Pump station, Force Main and Gravity Sewers	2010	$35,700,000
24	South Lake City: NWW13-02 TO NWW10-01	Gravity Line	2011	$100,000
25	[CSI] Soos Alternative 3A(3) - PS H w/ Conveyance	New Pump station, Force Main and Gravity Sewers	2011	$42,700,000
26	Piper Creek: T-12 to T-5	Gravity Line	2012	$500,000
27	Piper Creek: T-23 D TO T-12	Gravity Line	2013	$2,200,000
28	Issaquah1 Trunk Pipeline Bifurcation	New Gravity Line	2014	$1,400,000
29	Bellevue Influent Trunk	New Gravity Line	2015	$2,600,000
30	North Mercer and Enatai Interceptors	New Gravity Line	2016	$10,800,000
31	Medina Trunk Minor Upgrade	New Gravity Line	2019	$100,000
32	[CSI] Thornton Creek Interceptor - Sections 1 & 2	New Gravity Line	2019	$3,300,000
33	Bryn Mawr Storage	New Storage Facility	2020	$8,200,000
34	[CSI] Coal Trunk Replacement	New Gravity Line	2020	$6,800,000
35	Factoria Trunk and Wilburton Upgrade	New Gravity Line, Pump Station Upgrade	2020	$27,900,000
36	[CSI] Sammamish Plateau Diversion	New Gravity Line	2020	$18,800,000
37	[CSI] Thornton Creek Interceptor - Section 3	New Gravity Line	2022	$2,400,000
38	[CSI] Mill Creek Relief Sewer	New Gravity Line	2022	$5,000,000
39	North Soos Creek Interceptor	New Gravity Line	2022	$5,600,000
40	Heathfield/Sunset Pump Station and Force Main Upgrade	New Force Main, Pump Station Upgrade	2022	$16,000,000
41	Eastgate Trunk	New Gravity Line	2022	$1,800,000
42	Medina New Storage	New Storage Facility	2023	$3,600,000
43	[CSI] Soos Alternative 3A(3) - PS B w/ Conveyance	New Force Main, New Pump, New Gravity Line	2023	$10,600,000
44	Northwest Lake Sammamish Interceptor	New Gravity Line	2024	$28,900,000
45	Rainier Vista Trunk	New Gravity Line	2024	$600,000
46	Garrison Creek Trunk	New Gravity Line	2024	$12,900,000

Project #	Project List	Project Type	Year Online[1]	Estimated Project Cost[2]
47	Lake Hills Trunk Fourth Barrel Addition	New Gravity Line	2025	$12,400,000
48	[CSI] North Creek 2-A	Gravity Line	2026	$45,500,000
49	[CSI] Swamp Creek Parallel - Section 1B	New Gravity Line	2026	$7,300,000
50	Algona Pacific Trunk Stage 1	New Gravity Line	2026	$4,300,000
51	[CSI] Issaquah New Storage	New Storage Facility	2026	$15,100,000
52	[CSI] Sammamish Plateau Storage	New Storage Facility	2027	$20,500,000
53	Issaquah Creek Highlands New Storage	New Storage Facility	2029	$3,900,000
54	Planning, Studies, Administration, and Program Development	Ongoing Program	2030	$15,200,000
		Sub-Total of Projects Needed by 2030		***$648,000,000***
55	Auburn3 New Storage	New Storage Facility	2030-2050	$33,800,000
56	[CSI] North Creek 3-A	New Gravity Line	2030-2050	$6,700,000
57	Lakeland Trunk	New Gravity Line	2030-2050	$4,800,000
58	ULID 1 Contract 4	New Gravity Line	2030-2050	$2,300,000
59	Issaquah2 Trunk	New Gravity Line	2030-2050	$2,300,000
60	South Renton Interceptor	New Gravity Line	2030-2050	$6,900,000
61	North Creek Trunk	New Gravity Line	2030-2050	$4,000,000
62	Algona Pacific Trunk Stage 2	New Gravity Line	2030-2050	$1,300,000
63	Lakeland Hills Pump Station Upgrade	New Force Main, Pump Station Upgrade	2030-2050	$3,700,000
34-2nd phase	[CSI] Coal Trunk Replacement	New Gravity Line	2030-2050	$7,000,000
30-2nd phase	North Mercer and Enatai Interceptors	New Gravity Line	2030-2050	$12,000,000
36-2nd phase	[CSI] Sammamish Plateau Diversion	New Gravity Line	2030-2050	$4,600,000
40-2nd phase	Heathfield/Sunset Pump Station and Force Main Upgrade	New Force Main, Pump Station Upgrade	2030-2050	$21,900,000
52-2nd phase	[CSI] Sammamish Plateau Storage	New Storage Facility	2030-2050	$7,200,000
51-2nd phase	[CSI] Issaquah New Storage	New Storage Facility	2030-2050	$4,900,000
48-2nd phase	[CSI] North Creek 2-A	Gravity Line	2030-2050	$7,200,000

Project #	Project List	Project Type	Year Online[1]	Estimated Project Cost[2]
		Sub-Total of Projects Needed between 2031 & 2050		***$130,600,000***
		Total of Project Cost Estimates[1]		**$778,600,000**

[1] Year online balances capacity needs with estimated funding availability.
[2] All estimated costs are in 2003 dollars.