CHAPTER 6

COLLECTION SYSTEM HYDRAULIC MODEL

INTRODUCTION

The District developed a hydraulic model of the sanitary sewer system as part the 2000 *Wastewater Comprehensive Plan*. The output from this model was used to evaluate the capacity of the existing system and to identify improvements. The model was developed with the intent that it would be updated and maintained by the District and used as a tool to aid in future planning and design efforts.

In 2004, the District began reviewing the findings of the 2000 *Wastewater Comprehensive Plan* and updating the District's capital improvement program (CIP). A new set of modeling tools was utilized to update the hydraulic model of the sanitary sewer system and to provide a greater level of detail. In 2006 the *Sewer Hydraulic Model Manual* (Manual) was completed; the Manual describes the updates to the hydraulic model, incorporating growth and system improvements. The model incorporates results of the 2000/2001 KCDNR I/I study. The output from the model was used to evaluate the capacity of the 2004, 2010, and 2026 systems.

As part of this Plan, the hydraulic model is further refined and updated to include growth and changes to the sanitary sewer system that have occurred up to January 1, 2006. The model incorporates the results of the 2001/2002 KCDNR I/I Study and the King County GIS Center Buildout Population Projection Study. The model has been refined to enhance the usability and to further increase the level of detail of the model results. The model results are used to update the District's CIP.

The development of the District's model is presented here, as well as recommended procedures for future use of the model. The following user's manual documents the construction, use, and capabilities for the District's wastewater collection system hydraulic model. The Sewer Hydraulic Model Manual is included in Appendix I.

A summary of the development of the model is given below.

- Approximately 90 percent of the collection system has been modeled. Invert elevations, manhole depths, and pipe roughness are examples of input parameters entered into the collection system data base. This information was obtained from District records.

- The major lift stations and force mains have been identified and incorporated into the model. Wet well volume, pumping rate, force main size and roughness, and static head are examples of the input parameters entered into the collection system data base.

- Parcels are assigned to collection basins based on the centroid of each parcel and the nearest manhole.

- Puget Sound Regional Council (PSRC) Transportation Analysis Zone (TAZ) population data is used to derive flows projected for the planning period.

- Water use for residential and commercial District sewer accounts is entered into the model by linking King County Geographic Information System (GIS) parcel information with District billing records.

- Land use information is used to derive flows when the land is fully built out.

- The input flow parameters developed in Chapter 5 (e.g., diurnal curves, per-capita wastewater flow rates, I&I rates) were entered into the model.

HYDRAULIC MODELING SOFTWARE

The District's wastewater collection system is modeled using MOUSE hydraulic modeling software by DHI, Inc. MOUSE has been selected for its acceptance in the wastewater field, specifically because it has been selected as the model of choice for KCDNR, its user-friendly graphical interface, its GIS capabilities, and its efficient calculation procedure. The graphical nature of MOUSE provides analytical flexibility and facilitates the maintenance of a large, complicated hydrologic model. Although a well-developed model can be a powerful tool, the results should be viewed with a certain amount of caution. Mathematical models are by nature only approximations of actual conditions and can provide erroneous output as a result of inaccurate input parameters.

The MOUSE modeling software is configured with a graphical user interface. Each model element, including pipes, manholes, force mains, lift stations, catchments, and discharge locations, is assigned a unique graphical representation within the program. Each element is also assigned a number of attributes specific to its function and representation. Element attributes include spatial coordinates, rim elevation, invert elevation, diameter, slope, and assigned flows, as well as pump characteristics. Model input is accomplished through the creation and manipulation of these objects and their attributes. The MOUSE modeling software is equipped with a number of tools that facilitate presentation of model results. The results for a simulation can be given graphically in plan or profile view or in tabular report format to indicate flow, depth of sewer flow, hydraulic grade, and wet well levels for various system elements.

MOUSE System Requirements

The District's hydraulic model is run on a Windows-based desktop computer. Following is a partial list of hardware and software used in the creation of the model:

- **Excel and Access (by Microsoft):** Used to view and display tabular data and for simple repetitive data manipulations (such as changing elevations to account for different vertical data on record drawings).
- **ArcView (by ESRI):** Used to enter and store graphical data and to view horizontal plans of the collection system.
- **MOUSE GM (by DHI):** A program that runs inside ArcView, used to facilitate data entry and to view vertical profiles of the collection system.
- **MOUSE HD (by DHI):** Used as the calculation engine.
- **MIKE View (by DHI):** Used to view results from MOUSE HD. Results are seen as animated and color-coded plans and profiles of the collection system.
- **Hardware Key (by DHI):** All DHI programs require a small key to be plugged into the parallel port of the computer during operation.

GIS Capabilities

The MOUSE software operates using ESRI's ArcView GIS software program as a platform. GIS files for sewer system manholes, pipes, parcels, basins, etc., are imported into the model, and the MOUSE software performs the hydraulic calculations.

HYDRAULIC MODEL DEVELOPMENT

One of the primary goals in the development of the District's hydraulic model is to create a model that realistically represents the current wastewater collection system. The hydraulic model includes elements representing pipes, manholes, wet wells, pumps, and their associated elevations. Input information for each of these elements must be as accurate as possible in order to develop a realistic representation of the system as a whole.

DESCRIPTION OF COLLECTION SYSTEM

Over 90 percent of the total gravity pipelines in the District are modeled. This includes KCDNR facilities such as the Lake Line, portions of the Swamp Creek Trunk, and portions of the Kenmore Trunk that are integral to the District's System.

The location of the pipes has been taken from District AutoCAD drawings and GIS system. Inverts and pipe sizes have been taken from the District GIS database. The ULID 5 Contract 2 Project pipeline segment from MH No. 5119 to MH No. 5187 has been confirmed with as-built drawings and survey.

The collection system is divided into three separate systems, central, southwest, and southeast, each with its own discreet outfall. The central collection system includes the Kenmore Trunk and has an outfall in the approximate location of the Kenmore Lift Station. The Swamp Creek Trunk is also included in this portion of the collection system. The southern portion has been divided into an east and west basin. The southwest basin includes the Lake Line and has an outfall in the approximate location of the Juanita Lift Station. The southeast basin has an outfall adjacent to the outfall for the south west basin. Figure 6-1 shows the basin boundaries. It is assumed that the trunk lines and pump stations owned and operated by KCDNR into which the District discharges have no impact on the District flows. Therefore, the connections are modeled as free flowing outfalls to avoid any backwater conditions.

Ten of the eleven major lift stations presented in Table 4-1 are included in the model. Lift Station No. 18 has been modeled as a lift station, but Lift Station No. 17 has not been modeled. Private lift stations and both private and District-owned grinder pump stations are not included. Table 6-1 provides a summary of the modeled lift stations and force mains.

TABLE 6-1

Modeled Lift Stations and Force Mains

Lift Station	Rated Capacity (gpm)	Force Main Diameter (inch)
No. 1	180	6
No. 2	270	6
No. 3	100	4
No. 4	150	4
No. 10	800	10
No. 14	400	6 and 8
No. 15	500	6
No. 18	40	2
No. 19	80	4
No. 20	150	4

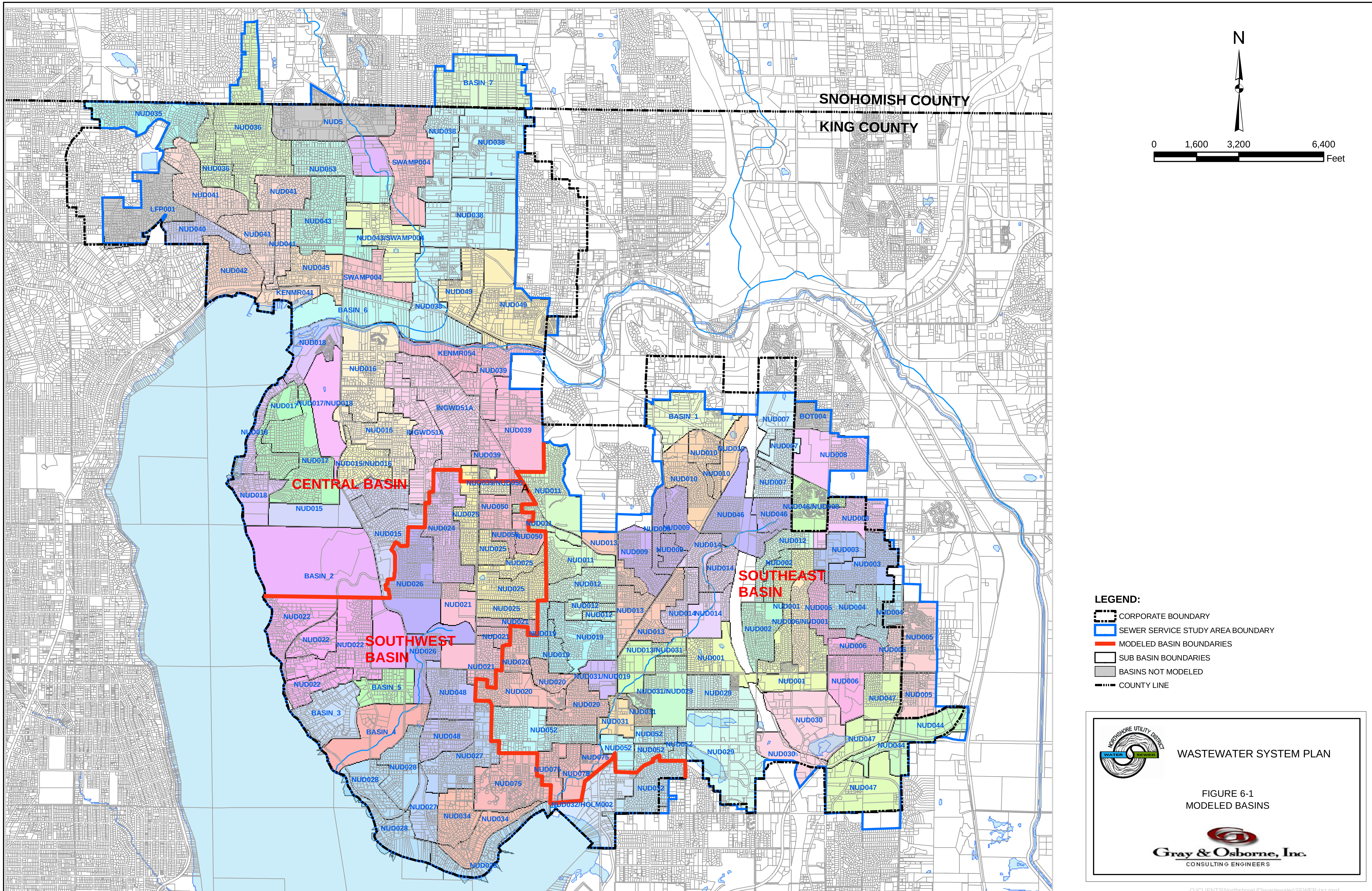

FIGURE 6-1
MODELED BASINS

MODEL LAYOUT AND CONSTRUCTION

The hydraulic model consists of two layers: the network layer and the catchment layer. The network layer contains three-dimensional data on the physical collection system (i.e., manholes, pipes, lift stations, and force mains). The catchment layer contains data on the areas served by each manhole of the collection system (i.e., area, population, domestic flow, and infiltration and inflow).

Network Layer

Information about the modeled gravity sewers, manholes, and lift stations is contained in the network layer. Necessary data for the network layer are shown in Table 6-2.

Collection system information is from the District's GIS database. If invert elevations of manholes are not known, the invert elevations are linearly interpolated between known inverts. If upstream inverts are unknown, then inverts have been assumed, allowing a minimum slope between manholes denoted in the Department of Ecology's Criteria for Sewage Works Design (this was done for approximately 120 manholes of approximately 7,000 manholes). If manhole rim elevations are not known, an arbitrary elevation of 10.00 feet above the invert is selected.

TABLE 6-2

Collection System Information

Category	Gravity Sewers	Manholes	Lift Stations
Dimensions	Length (calculated from X and Y coordinates of manholes and Lift Stations)	Location (X and Y coordinate)	Location (X and Y coordinate)
Identification No.	Upstream and downstream manhole names	Name(1)	Name
Base Elevation	--	Rim Elevation(2)	Ground Elevation(2)
Depth	Upstream and downstream invert elevations	Bottom elevation(3)	Bottom elevation and float settings(3)
Size	Pipe diameter	Manhole diameter	Wet well diameter
Flow Criteria	Pipe material (4)	--	Pump capacity (each pump)
Vertical Datum	NVGD 29	NVGD 29	NVGD 29

(1) Each manhole has been given a unique name; either the manhole number from the District is used and the manhole numbers from the previous model evaluation or a manhole number is given the prefix 2006 to denote the manholes added for the Plan.

(2) If the manhole or Lift Station did not have a base elevation denoted in the District's GIS mapping system then a base elevation 10 feet above the invert elevation has been assumed.

(3) Invert elevations have been taken from the District's GIS mapping system and in cases where the invert elevation are not known, an invert elevation has been assumed allowing a minimum slope denoted in the Department of Ecology's Criteria for Sewage Works Design.

(4) The pipe material is denoted concrete (n = 0.013).

Lift Stations

Lift stations are modeled as constant flow pumps based on the rated capacity of the lift station. Lift station "on" and "off" call points have been established in the model to allow the wet well to fill and draw as in reality. When a pump is called in the model, the lift station will pump at a constant rate, regardless of head conditions. This allows the model to simulate the surges in the gravity system downstream of the lift station to identify any capacity limitations. This method of modeling the lift station also identifies when flows upstream of the lift station exceed the rated capacity.

CATCHMENT LAYER

The catchment layer contains data on the areas served by each manhole of the collection system (i.e., area, population, and infiltration and inflow). The model uses the catchment basin as the area of influence for both I/I and domestic and commercial flow. For modeling purposes, each manhole within the District serves a unique catchment basin.

Each catchment basin is a unique area composed of a number of parcels. Each parcel has been reconfigured to determine the nearest manhole to the centroid of the parcel. It has been assumed the nearest manhole to the centroid of each parcel will serve that parcel; however, this assumption has limitations. It is recognized that for larger parcels, the centroid of a parcel may not be located near the sewer connection. For modeling purposes, this limitation provides a simplification and allows a greater extent of the entire system to be evaluated.

Each catchment basin is within a KCDNR flow monitoring basin. The KCDNR mini basins have been divided further into sub basins following parcel lines; those areas that were not monitored by KCDNR have been given a subbasin. The I/I rate of each corresponding KCDNR flow monitoring basin is applied to all catchment basins within the KCDNR flow monitoring basin.

Each catchment basin is within a TAZ. The growth rate of each corresponding TAZ is applied to all undeveloped parcels within a TAZ. The growth for each undeveloped parcel has been totaled for each sub basin and distributed equally amongst all the catchment basins within the subbasin. The modeled subbasins and the corresponding KCDNR I/I flow monitoring basins are shown in Figure 6-1.

MODEL LABELING

When possible, identifying names for pipes and manholes have been taken directly from the District's GIS database to be consistent with the District's identifications. The model requires each pipe and manhole to be designated with a unique identifier. The District's database contains a number of pipes and manholes with duplicate identifiers. It was necessary in these instances to change the identification of these elements for the model.

MODELING SCENARIOS

Four scenarios, as described below, have been modeled, reflecting anticipated growth within the District. When the model results showed capacity issues, the scenario was revaluated with a decreased I/I rate of 1,100 gpad for each basin to determine if I/I or growth is the primary cause of the capacity issue.

2005 Flows, Existing System: Models a 48-hour extended period simulation applying the most conservative measured peak instantaneous I/I rate established by KCDNR, existing domestic flows, and a domestic peaking factor of 2.5.

2012 Flows, Existing System: Models a 48-hour extended period simulation applying the peak instantaneous I/I rate established by KCDNR and applying TAZ growth rates to existing flows, and a domestic peaking factor of 2.5.

<u>2026 Flows, Existing System</u>: Models a 48-hour extended period simulation applying the peak instantaneous I/I rate established by KCDNR and applying TAZ growth rates to existing flows with a diurnal curve, and a domestic peaking factor of 2.5.

<u>Buildout Flows, Existing System</u>: Models a 48-hour extended period simulation applying the peak instantaneous I/I rate established by KCDNR and population based on land use zoning for each municipality, and a domestic peaking factor of 2.5.

The commercial flow is based on TAZ employee projections for 2030.

MODEL ASSUMPTIONS

The following sections outline the assumptions used in developing the model.

Existing and Future Domestic and Commercial Flow

Existing domestic flow in the model is distributed based on actual water meter consumption data. Winter water use data from each parcel was loaded into the model using GIS techniques.

Future flows in the model are based on updated TAZ data provided by PSRC. The growth rates from the TAZ projections have been applied to undeveloped parcels to represent the growth in domestic and commercial flow. This assumes that the per capita sewer use remains constant as population and employees increase. Table 6-3 provides a summary of the TAZs located within the District and the growth rates for each TAZ. TAZ projections were used to estimate domestic and commercial flows for the 6-, 10- and 20-year scenarios.

Buildout occurs when the service area is fully developed and sewered. A buildout scenario is necessary since many wastewater facilities have a useful life of at least 20 years and should be sized for flows greater than predicted by the 20-year TAZ projections. As discussed in Chapter 3, residential buildout within the District is expected to occur sometime after the 20-year planning interval. Individual zoning maps from each municipality were used to calculate domestic buildout flows. Consistent with the densities presented in Table 3-2, the various zoning densities for each municipality were assumed for the buildout scenario. Commercial buildout within the District is expected to occur at approximately the 25-year planning interval. The commercial flow was projected using 2030 TAZ growth rates applied to parcels zoned commercial.

The future land use has been determined using zoning maps provided by the individual cities and King County. The future land use classifications are shown in Figure 3-6. The projections do not exclude sensitive or critical areas that may not be buildable.

Individual zoning maps from each municipality have been used to calculate commercial buildout flows. All areas zoned as Business Districts, Industrial, or Commercial are classified as Commercial.

TABLE 6-3

TAZ Growth Rate Projections

	Domestic			Commercial		
TAZ No.	2000-2010 Growth Rate	2010-2020 Growth Rate	2020-2030 Growth Rate	2000-2010 Growth Rate	2010-2020 Growth Rate	2020-2030 Growth Rate
223	0.48%	0.31%	0.24%	1.01%	2.54%	1.92%
236	0.46%	0.32%	0.23%	0.91%	3.05%	2.44%
237	0.46%	0.44%	0.32%	2.01%	1.69%	0.57%
238	0.46%	0.43%	0.31%	1.87%	1.76%	0.83%
239	0.68%	1.20%	0.98%	0.65%	0.70%	0.65%
242	0.03%	0.61%	0.38%	0.86%	1.00%	1.09%
243	0.02%	0.63%	0.38%	-0.35%	0.59%	0.32%
244	1.04%	1.22%	0.92%	1.56%	1.63%	1.53%
245	0.96%	1.18%	0.86%	1.68%	1.54%	1.45%
246	0.61%	0.52%	0.12%	0.38%	1.28%	0.99%
247	0.02%	0.61%	0.37%	0.75%	1.08%	1.18%
248	0.13%	0.27%	0.00%	0.78%	1.10%	1.09%
249	0.95%	1.17%	0.86%	1.52%	2.61%	1.72%
250	0.98%	1.19%	0.88%	1.34%	2.10%	1.46%
251	0.48%	0.45%	0.33%	2.63%	1.02%	1.00%
252	0.46%	0.43%	0.31%	3.03%	0.52%	0.63%
253	0.08%	0.22%	-0.05%	1.31%	1.41%	1.30%
254	0.09%	0.24%	-0.04%	0.35%	1.00%	0.98%
255	0.09%	0.22%	-0.05%	1.00%	1.29%	1.20%
256	0.09%	0.22%	-0.05%	1.85%	1.63%	1.44%
257	0.96%	1.15%	0.87%	1.55%	2.26%	1.09%
261	0.68%	0.98%	0.88%	1.68%	0.52%	0.49%
263	1.15%	1.13%	0.71%	0.59%	1.13%	1.16%
599	2.18%	1.81%	0.90%	1.44%	2.92%	2.66%
602	2.00%	2.06%	1.74%	2.26%	2.66%	1.44%
603	2.03%	2.04%	1.74%	2.61%	2.07%	1.71%

Domestic Peaking Factor

The Department of Ecology recommends a minimum peaking factor of 2.5, which was applied to the domestic flow values used in the model.

Snohomish County

There are three areas within Snohomish County that are not included in the existing sewer service area; however, these areas are included in the sewer service study area since flows from these areas will be treated at the KCDNR treatment facilities and are transported via District sewer lines. The domestic, commercial, and I/I flows, for each of the three individual areas in Snohomish County are combined and introduced into one manhole for modeling purposes. The Snohomish County projections are summarized in Appendix J.

Infiltration and Inflow

Infiltration and Inflow rates in the model are based on the information provided by KCDNR in the 2001/2002 Wet Weather Flow Monitoring Technical Memorandum. The mini basins established by KCDNR were reconfigured to follow parcel lines and the District sewer service area boundary; Figure 5-3 presents the I/I basins used for the model and Table 5-5 summarizes the I/I rate for each basin. I/I values in the I/I Study are based on a 30-minute peak. The model was established so that the 30-minute peak occurs simultaneously with the peak domestic flow. In order to ensure the 30-minute peak occurs simultaneously with the peak domestic flow, the 30-minute peak value is applied for the entire 48-hour simulation.

Other Modeling Assumptions

Several assumptions have been made in the development of the District model. Most are necessary to resolve conflicts in the data or to account for missing information. The assumptions used in the development of this model are as follows:

- The model is evaluated under the most conservative conditions; the peak factor is applied to domestic and commercial flows and the peak I/I rates are applied to all basins simultaneously.

- Per Ecology design criteria, the Manning's friction coefficient, "n" was chosen to be 0.013. This value is somewhat conservative, especially for PVC pipe. The District can incorporate individual "n" values based on pipe type or age if desired.

- Pipe sizes and invert elevations are taken from District records; however, ULID 5 survey work was performed and is used in the model.

- In areas with missing data, pipe sizes are assumed to be equal to the adjacent upstream pipe, and invert elevations are interpolated linearly from the nearest known data points. In cases where the upstream manhole is unknown, an invert elevation is assumed allowing for a minimum slope between manholes recommended in the Department of Ecology's Criteria for Sewage Works Design.

- Since the invert elevations of King County pipes are not available and analysis of these pipes is outside the scope of this Plan, the invert elevations of King County pipes are assumed so that they would not limit the capacity of District facilities. That is, inverts are assumed to be lower than the downstream invert of the adjoining District pipe.

Results from the model and the identified pipe deficiencies are presented in Chapter 8.