EDDIE LOW

COMPREHENSIVE STORMWATER MASTER PLAN

CITY OF BOTHELL, WASHINGTON

Barrett Consulting Group

JUNE 1994

COMPREHENSIVE STORMWATER MASTER PLAN

CITY OF BOTHELL, WASHINGTON

Barrett Consulting Group

JUNE 1994

CITY OF BOTHELL
COMPREHENSIVE STORMWATER MASTER PLAN

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

During 1992 the City annexed approximately 6 square miles commonly known as the Canyon Park Annexation which doubled the area covered under the City's jurisdiction. Additionally, the state Growth Management Act of 1991 required cities and counties to address regional growth issues by developing Comprehensive Plans by July 1, 1994. As a result, the existing 1977 City of Bothell Stormwater Master Plan needed to be updated.

The update was prepared jointly by City staff and Barrett Consulting Group. Although focused on flood control and stormwater runoff, the Stormwater Master Plan recognizes the context in which flood control and water quality management must occur. The Plan provides for stormwater management standards which are consistent with state and adjoining jurisdiction's standards. Additionally, the Plan provides the City with the stormwater component of the Comprehensive Plan for Bothell required under the Growth Management Act.

The primary goal of the Stormwater Master Plan was to identify areas of frequent flooding and identify implementation actions or strategies to prevent, control, or reduce those flooding problems. Elements of the Stormwater Master Plan include:

- A characterization of the physical and regulatory environment which provides the basis for identifying nonpoint problems and evaluating solutions. Included in the characterization is a description of the study area, regulations affecting stormwater management, and an overview of the land uses.

- A water quality assessment which identifies potential non-point pollution sources and includes a summary of past water quality investigations.

- Results from the computer model developed to represent typical runoff patterns and drainage conveyance for use in evaluating alternative solutions.

- A recommended alternative which forms the basis of the Capital Improvement Plan for the City. Complementing the plan are program recommendations to enhance public involvement and establish drainage design standards, operation and maintenance policies, and monitoring activities which accommodate development while ensuring the environmental health of the area.

MASTER PLAN AREA

The area included in the Stormwater Master Plan is within the Urban Growth Boundary as described by the Comprehensive Plan and encompasses approximately 14 square miles as shown in the attached figure. Some of this land is presently outside the existing Bothell City limits; however, the Comprehensive Plan and the corresponding Stormwater Master Plan has been developed for the entire area so that the policies and development procedures applied in Snohomish and King Counties will be consistent with those reflected in the goals for the City of Bothell.

The majority of stormwater runoff in the Bothell area discharges to North Creek, Horse Creek, Sammamish River, or Swamp Creek. Horse Creek is the only basin located entirely within the City limits. The basins which were delineated and modeled for this Stormwater Master Plan include Horse Creek and tributaries to North Creek, the Sammamish River, and Swamp Creek which are located in the study area and contribute to the City's drainage system. Stormwater runoff in these basins and tributaries is primarily conveyed in well defined open channels with cross culverts at street crossings. It is estimated that within the existing boundaries of the City of Bothell, there is approximately 247,000 linear feet of underground pipes (46.8 miles) compared to 443,500 linear feet (84.0 miles) of open channels and streams. There is also an estimated 6,200 catch basins. Drainage basin locations and associated tributaries are shown on Plate 1 in Appendix F of this document.

North Creek and the Sammamish River were not evaluated or included in the Master Plan because significant portions of each basin are outside the City's influence. Snohomish County is in the process of initiating a study to address flooding and related problems in the North Creek Basin. King County will be developing a basin plan for the Lower Sammamish River to address water resource issues in the future. The City will be participating in these studies.

EXISTING STORMWATER-RELATED PROBLEMS

Stormwater related problems occur in the urban portions of the study area. Problems are often the result of inadequate systems or the lack of formal conveyance systems. Identification of the following problems was gathered primarily from City staff, the citizen complaint response database of the Snohomish County, and computer modeling results.

- Flooding of 9th Avenue S.E. near 226th Street S.E.
- Inadequate drainage system down 96th Avenue N.E. between N.E. 198th Street and N.E. 203rd Street causing flooding
- Piped conveyance of Horse Creek between Bothell Way to N.E. 188th Street is inadequate to convey large storm events
- Flooding on Waynita Way near Valhalla
- Insufficient pipe capacity on N.E. 185th Street between Beardslee Boulevard and Ross Road
- Pipe system on Bothell Way between Ormbrek Street and N.E. 180th Street is insufficient to convey 25-year storm
- Upgrade of cross culvert under 228th Street S.E. at 31st Avenue S.E.
- Localized flooding on 224th Street S.W. between 8th Avenue West and 4th Avenue S.E.
- 3rd Avenue S.E. cross culvert near 234th Street S.E. is undersized
- Insufficent pipe capacity of cross culvert under 240th Street S.W. east of 7th Avenue S.E.
- North Creek and adjacent properties flood during large storm events
- Crystal Ridge Detention Pond at 6th Drive S.E. and 223rd Place S.E. is not functioning as it was designed
- Crystal Ridge Detention Pond at 226th Street S.E. and 7th Drive S.E. is not functioning as it was designed

- Crystal Ridge Detention Pond at 4th Avenue S.E. and 5th Drive S.E. no longer functions
- Detention facility on northeast corner of 228th Street S.W. and SR 527 needs maintenance and outflow control
- Canyon Crest #1 detention pond does not function and requires maintenance
- The natural channel near Richmond Road and 212th Street S.E. may be at risk for bank erosion and sedimentation problems
- The Queensborough tributary to North Creek exhibits erosion and sedimentation problems from excessive flows
- Stream reach between 228th Street S.E. and 212th Street S.E. and 39th Avenue S.E. is at risk for erosion and sedimentation
- The two stream reaches between 45th Avenue S.E. and 35th Avenue S.E. south of 228th Street S.E. are at risk under future conditions to bank erosion and sedimentation problems
- Little Swamp Creek north of 240th Street S.E. is at risk to bank erosion and sedimentation under future conditions
- Perry Creek exhibits bank erosion and sedimentation problems
- Upper reaches of Horse Creek may be at risk to bank erosion and sedimentation problems under future conditions
- The open channels of Wayne Creek and its' tributaries between 145th Street and Wayne Golf Course display bank erosion and sedimentation problems
- The natural channel between the conveyance system on 96th Avenue N.E. to discharge point in Horse Creek shows signs of bank erosion and sedimentation
- The open channel between the conveyance system on 98th Avenue N.E. and discharge point in Horse Creek show signs of bank erosion and sedimentation
- Open channel on conveyance system under 100th Avenue N.E. is at risk to bank erosion
- The open channel portion of Horse Creek near N.E. 188th Street is highly eroded
- The Horse Creek channel at its discharge point to the Sammamish River exhibits bank erosion
- The natural channel downstream of Canyon Crest #1 detention pond is highly eroded causing sedimentation problems into North Creek
- Erosion is evident on the banks of North Creek through the Canyon Park Industrial Park
- Discharge of surface water runoff from Beardslee Boulevard onto private property causes seasonal flooding

RECOMMENDED ACTIONS

Once existing or potential future problem areas were defined, solutions were identified and projects which reduce the frequency and severity of flooding were targeted for future corrective action. Solutions were identified in terms of structural or capital improvement projects and nonstructural measures such and policies and programs. The following discussion presents the various alternatives considered for achieving the desired level of protection while addressing the prevention of future problems.

Four alternatives of capital improvement projects solutions were considered for the Capital Improvement Plan. Structural measures require construction activities such as pipe upgrades, highflow by-passes, and detention facility excavation. The level of protection provided by the alternatives is referenced in terms of a given year design storm. Design storms are the theoretical precipitation values used for the design of all stormwater facilities. Storm events are characterized as lasting 24 hours during which time the given amount of precipitation occurs. Each storm event is labeled by the chance of recurrence such that the "2-year storm" has a 50 percent chance of occurring in any year, likewise, the "100-year storm" has a 1 percent chance of occurring in any year. Since these probabilities are based on statistical analysis and storm events are random by nature, several storms with various recurrence frequencies (i.e., 2-year and 5-year) may occur in the same year.

The four alternatives presented below contain various levels of improvements to the existing drainage system. One alternative represents a level of service currently being performed. The remaining alternatives establish a level of service of 25 years for conveyance. The primary difference between the alternatives is in the utilization of detention facilities for both flood attenuation and water quality protection. The use of detention facilities is based on the impact to the existing regional conveyance systems primarily found in Horse Creek and the tributaries to North Creek from the west.

Table 1
SUMMARY OF CAPITAL IMPROVEMENT PROJECTS

	Alternative 1 **Existing Level of Service** 10-yr conveyance, 25-yr private detention No regional detention except 180th facility			**Alternative 2** **Low Level of Service** 25-yr conveyance, 25-yr private detention No additional regional detention except 180th facility			**Alternative 3** **Medium Level of Service** 25-yr conveyance 25-yr detention (enhance existing detention facilities which impact the regional system)			**Alternative 4 (Preferred)** **High Level of Service** 25-yr conveyance 25-yr detention (as in Alternative 3) 100-yr regional detention (new facilities)		
	YEARS 1-6	YEARS 7-20	20-YEAR TOTAL	YEARS 1-6	YEARS 7-20	20-YEAR TOTAL	YEARS 1-6	YEARS 7-20	20-YEAR TOTAL	YEARS 1-6	YEARS 7-20	20-YEAR TOTAL
Conveyance/Flood Control Improvements												
Project C-1				8,590		8,590	8,590	0	8,590	8,590	0	8,590
Project C-2				11,600		11,600	11,600	0	11,600	11,600	0	11,600
Project C-3				24,150		24,150	24,150	0	24,150	24,150	0	24,150
Project C-4				58,180		58,180	58,180	0	58,180	58,180	0	58,180
Project C-5				32,810		32,810	32,810	0	32,810	32,810	0	32,810
Project C-6				0	272,930	272,930	0	272,930	272,930	0	272,930	272,930
Project C-8	1)			600,000	1,400,000	2,000,000	600,000	1,400,000	2,000,000	600,000	1,400,000	2,000,000
Sub Total	252,000	588,000	840,000	735,330	1,672,930	2,408,260	735,330	1,672,930	2,408,260	735,330	1,672,930	2,408,260
Complaint Response												
Project C-9							120,000	280,000	400,000	120,000	280,000	400,000
Local problems												
Project L-1				26,460	0	26,460	26,460	0	26,460	26,460	0	26,460
Project L-2				3,615	0	3,615	3,615	0	3,615	3,615	0	3,615
Project L-3				6,900	0	6,900	6,900	0	6,900	6,900	0	6,900
Sub Total				36,975	0	36,975	36,975	0	36,975	36,975	0	36,975
Existing Detention Facility Enhancement												
Project D-1							19,030	0	19,030	19,030	0	19,030
Project D-2							13,805	0	13,805	13,805	0	13,805
Project D-3							17,450	0	17,450	17,450	0	17,450
Project D-6							12,670	0	12,670	12,670	0	12,670
Project D-8							18,710	0	18,710	18,710	0	18,710
Sub Total							81,665	0	81,665	81,665	0	81,665
Additional Regional Facilities												
Project D-4										116,145		116,145
Project D-5										57,515		57,515
Project D-7										0	160,540	160,540
Project D-9	48,000	102,250	150,250	48,000	102,250	150,250	48,000	102,250	150,250	48,000	102,250	150,250
Sub Total	48,000	102,250	150,250	48,000	102,250	150,250	48,000	102,250	150,250	221,660	262,790	484,450
North and Swamp Creeks Flood Control Projects 2)												
Project C-7				150,000	1,000,000	1,150,000	250,000	1,900,000	2,150,000	350,000	2,800,000	3,150,000
Natural Channel Enhancements												
Projects NC 1,2, and 4-16				390,700		390,700	390,700		390,700	390,700		390,700
Project NC3				0	103,200	103,200	0	103,200	103,200	0	103,200	103,200
Sub Total				390,700	103,200	493,900	390,700	103,200	493,900	390,700	103,200	493,900
TOTAL COST	300,000	690,250	990,250	1,361,005	2,878,380	4,239,385	1,662,670	4,058,380	5,721,050	1,936,330	5,118,920	7,055,250

1) Existing Level of Service costs are based on historical annual averages.

2) The cost shown for the North and Swamp Creeks Flood Control Projects is based on the assumption that the City will pay 20% of total improvements. The Plan is presently in a preliminary planning stage and due to be completed in 1996. Improvements are expected to range from primarily non-structural such as zoning, property purchase, and stronger development standard development (Alternative 2) to mostly structural such as dikes, overflow bypass channels, and regional detention (Alternative 4). As the Plan nears completion and a cost-sharing methodology is formulated, the cost may change.

Development of a comprehensive stormwater plan includes the use of nonstructural measures such as regulatory changes, water quality monitoring, conveyance system maintenance, enforcement of violations, public involvement, and interlocal agreements. These programs and administrative actions compliment structural effects to control stormwater by adding a preventive element. The following tables provide options for implementing the various programs and administrative measures recommended in the Plan.

Table 2
SUMMARY OF ANNUAL PROGRAMS

	Alternative 1 Existing Level of Service	Alternive 2 Low Level of Service	Alternative 3 Medium Level of Service	Alternative 4 (Preferred) High Level of Service
Public Education/Customer Service				
Project PE-1				10,000
Project PE-3			35,000	50,000
Project PE-4				4,000
Project PE-5		5,000	5,000	5,000
Sub-total		5,000[1]	40,000[2]	69,000[3]
Water Quality Monitoring				
Project A-2			5,000	5,000
Project A-4		4,810	61,500	61,500
Sub-total	2,500[4]	4,810[5]	66,500[6]	66,500[6]
Interlocal Agreements				
Project PE-2		2,500	2,500	2,500
Project A-3		5,000	5,000	5,000
Sub-total		7,500[7]	7,500[7]	7,500[7]
Development Review/Inspection				
Project A-6	61,000	61,000	88,000[8]	108,000[9]
Utility Billing Maintenance				
Project A-10		25,000[10]	25,000[10]	25,000[10]
TOTAL ANNUAL COST	63,500	103,310	227,000	276,000
TOTAL 6-YEAR COST	381,000	619,860	1,362,000	1,656,000
TOTAL 20-YEAR COST	1,270,000	2,066,200	4,540,000	5,520,000

1) Provides for some catch-basin stencilling.
2) Provides for 1 project plus approximately 1 staff working 60% of the year.
3) Provides for 3 projects plus 1 FTE (Full-Time Equivalent).
4) Interlocal with Snohomish County for limited monitoring.
5) Increases the monitoring provided by Snohomish County.
6) Provides for 1 FTE plus lab fees for increased monitoring, plus training to other staff for water quality issues.
7) Implements recommendations in the North Creek Watershed Plan.
8) Provides for existing staff plus 1 staff working 50% of the year.
9) Provides for an equivalent FTE beyond existing staff.
10) Provides for staff time (clerical and technician) to update utility records for accurate billing.

The level of service presented for the Maintenance and Operation Program is defined in terms of a low, medium, or high effort. Failure to provide for consistent maintenance results in an overall reduction of the system's conveyance capacity and reduces the pollutant removal efficiency of the system. More frequent maintenance reduces these problems and increases the hydraulic efficiency of the system.

Table 3
SUMMARY OF MAINTENANCE AND OPERATION PROGRAM

	Alternative 1[1] Existing Level of Service	Alternative 2[2] Low Level of Service	Alternative 3[3] Medium Level of Service	Alternative 4[4] (Preferred) High Level of Service
Detention Facilities				
Vegetation Control	1,890	2,280	3,040	5,700
Sediment Removal		0	3,728	9,320
Vaults	4,157	5,232	8,720	8,720
Storage Pipes	4,157	5,232	8,720	8,720
Total	10,204	12,744	24,208	32,460
Catch Basins (6,200)	36,235	68,016	115,104	158,704
Pipes (46.8 Miles)	33,987	38,368	120,336	137,776
Roadside Ditches				
Vegetation Control	14,100	10,296	10,296	10,296
Reshape	13,474	44,736	65,240	82,016
Total	27,574	55,032	75,536	92,312
Vactor Waste Disposal Fees	27,008	28,000	30,000	32,000
Sub-Total	135,008	202,160	365,184	453,252
Assumed supervisory and clerical personnel cost	7,001	15,000	25,000	50,000
TOTAL ANNUAL COST	142,009	217,160	390,184	503,252
TOTAL 6-YEAR COST	852,054	1,302,960	2,341,104	3,019,512
TOTAL 20-YEAR COST	2,840,180	4,343,200	7,803,680	10,065,040

Cost of Detention Facilities, Catch Basins, Pipes, and Roadside Ditches is based on four-person crew working at following levels:

1) Existing LOS - 30% of year (4-person crew, 80 days of work)
2) Low LOS - 45% of year (4-person crew, 120 days of work)
3) Medium LOS - 80% of year (4-person crew, 213 days of work)
4) High LOS - 100% of year (4-person crew, 266 days of work)

Table 4
SUMMARY OF NON-ANNUAL PROJECTS

	Alternative 1 Existing Level of Service	Alternive 2 Low Level of Service	Alternative 3 Medium Level of Service	Alternative 4 (Preferred) High Level of Service
Planning/Grant Match				
Project A-1		15,000	15,000	15,000
Project A-5				55,500
Project A-8	50,000	50,000	50,000	50,000
Project A-9	50,000	50,000	50,000	50,000
Project A-12		100,000	200,000	300,000
Sub-total	100,000[1)]	215,000[2)]	315,000[3)]	470,500[4)]
Utility Start-Up Costs[5)]				
Project A-11	50,000	50,000	50,000	50,000
TOTAL COST	150,000	265,000	365,000	520,500
TOTAL 6-YEAR COST	150,000	165,000	265,000	320,500
TOTAL 20-YEAR COST	150,000	265,000	365,000	520,500

1) Interlocal for North Creek Flood Control Study and Centennial Grant Match.
2) Provides for 1 update to the Stormwater Master Plan plus updating design standards.
3) Provides for 2 updates to the Stormwater Master Plan plus updating design standards.
4) Provides for 3 updates to the Stormwater Master Plan, updating design standards, and actions to obtain NPDES permit.
5) Includes efforts for Public Meetings, Notices, and Utility Rate Structure Analysis to initiate Stormwater Utility.

The Capital Improvement Plan (CIP) should combine regulatory, policy, program, and structural actions which reduce current flooding, control nonpoint pollutants, and address preventive measures to reduce further problems. Therefore, it is recommended that the CIP contain the following alternatives and actions:

- Alternative 4 of the Capital Facilities Alternatives,
- High Level of Service of Annual and Non-Annual Program Options, and
- Medium to High Level of Service Maintenance and Operation.

These recommendations are based on the following criteria:

- Level of service to the community and ability to resolve existing flooding problems and accommodate future growth;
- The ability to maintain or improve water quality;
- Impacts on conveyance systems, water quality, surface water, and groundwater; and
- Consistency with state requirements and plans and other water quality programs as shown below.

Table 5
REGULATORY ELEMENTS

	Department of Ecology Stormwater Manual	Puget Sound Water Quality Management Plan	Growth Management Act
Conveyance 25-year, 100-year Detention (level of service)	✓	✓	✓
Development Standards	✓	✓	✓
Maintenance and Operation Program	✓	✓	☼
Water Quality Monitoring	☼	✓	☼
Public Involvement and Education Plan	✓	✓	☼
Natural Channel Protection	✓	✓	☼
Spill/Complaint Response	✓	✓	☼
Facility Plans	☼	✓	✓
Financing Strategy	✓	✓	✓

☼ not addressed by state program

FINANCING STRATEGY

A financing strategy to ensure implementation of the CIP evaluated the current sources of on-going revenue. Establishing a City-wide utility is the best source of stable revenue to provide for the annual storm drainage needs as recommended in this plan. On an annual basis, about 75 percent of the costs identified in the plan relate to on-going annual needs, with only about 25 percent identified as the City's responsibility for one-time capital costs. Because of this mix of projects, a dependable on-going source of revenue will be needed if the plan recommendations are to be implemented.

The current sources of on-going revenue include motor vehicle fuel tax and general property taxes, along with utility fees in the Snohomish County portion of the City. The City's current situation provides several very good options to the *Status Quo*:

- provide for revenue generation separately for the two county portions of the City, or
- provide for a common revenue generation for all City residents and businesses.

The City's decision will have policy implications and should be evaluated carefully. The key issues for consideration include:

- Institutional options,
- Funding sources,
- Billing system alternatives,
- Drainage cost allocation and rate structures,
- Management options and implementation issues, and
- Highway rights-of-way.

Chapter 1 - INTRODUCTION

The following document is the Comprehensive Stormwater Master Plan for the City of Bothell. This document replaces the previous plan which was completed in 1977. An updated plan is proposed in response to new regional requirements pertaining to growth issues, compliance with the Growth Management Act, and the recent annexation of the Canyon Park area.

The Comprehensive Stormwater Master Plan contains recommendations for structural improvements in the form of a Capital Improvement Plan and non-structural improvements in the form of policies and programs to accomplish regulatory compliance. Recommendations for financing the improvements are also presented. The recommended improvements are based on the results of computer modeling constructed from the drainage inventory, aerial topography, and land uses both existing and future. Plate 1 illustrates the area considered for this Plan and the drainage basins which were characterized in the modeling.

1.1 PURPOSE

The Comprehensive Stormwater Master Plan study was undertaken in order to identify impacts of urban development on storm water discharge within the City's Urban Growth Area and to identify solutions to achieve a preferred level of protection from flooding and for the preservation of water quality. Solutions were based on an analysis of the existing conveyance system which identified deficiencies under current and future land use scenarios based on the City's newly proposed Comprehensive Plan.

1.2 AUTHORITY

Regional stormwater management is guided by the Puget Sound Water Quality Management Plan (PSWQMP) and the Growth Management Act. The PSWQMP identified urban stormwater as one of the significant pollution sources contributing to the degradation of Puget Sound. Implementation of drainage plans is an essential component of Puget Sound Action Plans which address urban runoff, non-point pollution, and shellfish protection. One of the objectives of the PSWQMP is to provide long-term protection for the region's aquatic resources. The 1991 plan contains 16 programs for cleaning up and preventing pollution of Puget Sound. Two of these programs pertain to stormwater and include the Nonpoint Source Pollution Program and the Stormwater and Combined Sewer Overflows Program. Direct element implications of each program for the City include:

- Nonpoint Source Pollution Program NP-2 A Storm Drainage Plan shall include a water quality assessment and characterization, problem definition, statement of goals and objectives, source control or pollutant control strategies, an implementation strategy, and a budget. Plans shall address nonpoint pollution, as applicable, from animal keeping/pasture management, on-site septic systems, stormwater, and any other potentially significant nonpoint sources in the watershed.

- Stormwater and Combined Sewer Overflows Program SW-1 All counties and cities in the Puget Sound basin shall adopt ordinances requiring stormwater controls for new development and requiring maintenance of public and private stormwater systems. Each city or county which adopts a comprehensive land use plan and development regulation shall incorporate the goals of the local stormwater program into the goals of the comprehensive plan and shall incorporate the ordinance required by this element into the development regulations.

- Stormwater and Combined Sewer Overflows Program SW-2 All urbanized areas shall develop and implement a stormwater management program. Each program shall seek to control the quality and quantity of runoff from public facilities and industrial, commercial, and residential areas including streets and roads.

The Growth Management Act calls for towns, cities, and counties to develop comprehensive plans by July 1, 1994. Elements of the comprehensive plans provide guidance for encouraging development in designated urban areas and ensure that permits are processed in a timely manner, maintain and enhance natural resource based industries, protect the environment, and identify and encourage the preservation of historical sites and structures. The land use element should consider the review of drainage, flooding, and stormwater runoff in the area and nearby jurisdictions and provide guidance for corrective actions to mitigate or cleanse those discharges that pollute water of the state.

As a result of these issues and many others that relate to growth management and water quality, this Stormwater Master Plan is adopted by reference by the City's Comprehensive Plan as a policy and implementation plan. The relationship between shoreline master programs, stormwater plans, comprehensive flood plain management plans, and the PSWQMP is examined in Chapter 3 of the plan.

1.3 GOALS AND OBJECTIVES

Incorporated into the City of Bothell's Stormwater Master Plan are goals which fulfill the PSWQP requirements and GMA goals for water quality and quantity. At a minimum, the goals and objectives provide for the identification of projects for reducing the frequency and severity of flooding, correcting and or preventing nonpoint pollution sources, guidance for instituting maintenance and monitoring programs, and alternatives for funding the programs.

The combined goals and objectives are summarized into the four main categories listed below.

Goal 1: Preserve and/or enhance water quality, wetlands, groundwater, fisheries/wildlife habitat, and aesthetic amenities in the community.

- Objective 1.1. Control bacteria, sediment, nutrient, and metal inputs to receiving waters.

- Objective 1.2. Further identify existing nonpoint pollutant problem areas.

Goal 2: Maintain federal and state water quality standards.

- Objective 2.1. Establish a database and monitoring program to assure compliance which is coordinated with adjacent jurisdictions.

- Objective 2.2. Develop policies and programs for design standards, maintenance, and Best Management Practices which are consistent with adjoining jurisdictions and comply with state guidelines for stormwater management.

- Objective 2.3. Maintain sufficient staff to have consistent and prompt enforcement of water quality violations.

Goal 3: Identify and analyze solutions to correct current water quality and quantity problems.

- Objective 3.1. Develop hydrologic models based on evaluation criteria which includes protection of current and future land uses for a designated level of service, environmental impacts, water quality, and recreation, scenic, aesthetic, and historic concerns.

- Objective 3.2. Select and prioritize alternative structural solutions to existing and potential problems related to the area's hydrology and geology which reduce flood damages and minimize impacts from stormwater.

- Objective 3.3. Protect existing land uses from flood hazards associated with increasing storm flows.

Goal 4: Develop action recommendations that include both ordinances for new development and remedial actions for existing development for relating surface water management issues to land use management decisions utilizing the City's Comprehensive Plan with area-wide policy elements and subarea plans as the guiding document.

- Objective 4.1. Coordinate storm water planning efforts as directed by the Comprehensive Plan and the Growth Management Act.

- Objective 4.2. Evaluate the impact of land use policies and regulations as established in the Comprehensive Plan for the ability to protect and enhance water quality and beneficial uses, and where necessary, propose new legislation.

- Objective 4.3. Promote sustainable development in the area by minimizing the impact on water resource and habitat.

- Objective 4.4. Develop the plan to function as an active process which responds appropriately to new information.

- Objective 4.5. Provide education opportunities in the community which promotes awareness and understanding of the relationship between human activities and nonpoint pollution.

- Objective 4.6. Increase the understanding of the citizens of the community about flood control and resource protection issues and encourage practices which protect and improve water quality.

- Objective 4.7. Actively support intergovernmental agreements which implement uniform, basin-wide strategies for dealing with drainage related problems.

Chapter 2 - DRAINAGE AREA CHARACTERIZATION

2.1 INTRODUCTION

The City of Bothell is primarily a residential community. A considerable portion of the land within the planning area remains undeveloped and contains significant sensitive features such as steep slopes, wetlands, and streams. Commercial activity is generally located within the downtown core, adjacent to State Route 527 northward toward the Canyon Park interchange, the Canyon Park Business Center, and in the North Creek Koll and Quadrant Business Centers. In general, commercial development is oriented toward the local service needs and specialized regional service needs.

The following elements describe the physical characteristics of the study area which affect how stormwater is conveyed through the system. A characterization provides the basis to develop the computer models which were used to evaluate the impact of stormwater runoff on the conveyance system, both constructed and natural.

Study Location and Boundaries describes the general geographic information such as location and size of the planning area;

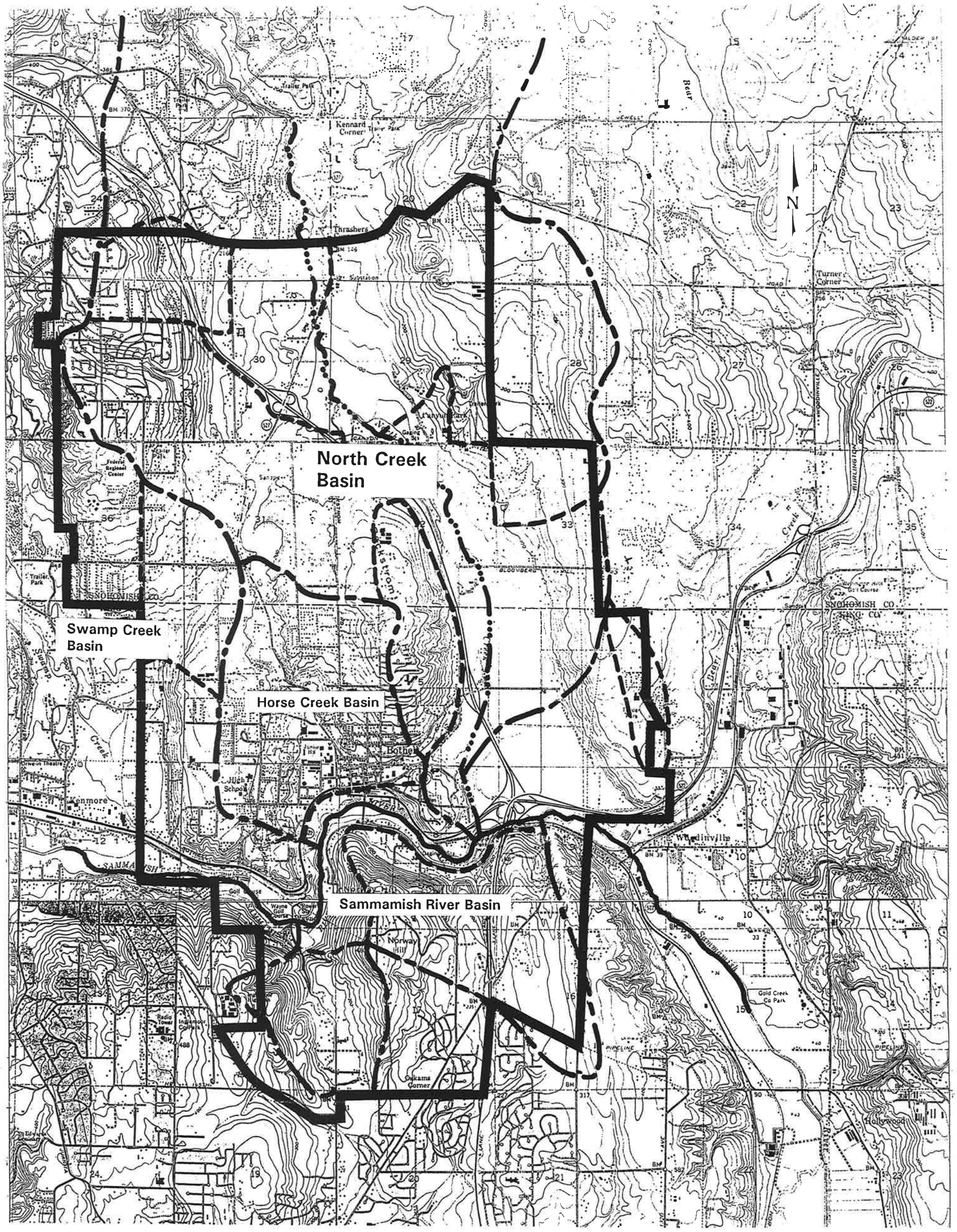
Hydrologic Resource Features include climate, topography, soils, drainage basin hydrology, and features critical to the hydrologic characterization; and

Overview of the **Land Uses**, both existing and future based on the City's Comprehensive Plan.

Information for this study was acquired from published soil reports, the Bothell Critical Areas Mapping Project, aerial photos and various maps, field data, and City staff.

2.2 STUDY LOCATION AND BOUNDARIES

The study area is within the preferred Urban Growth Boundary as described by the Comprehensive Plan and encompasses approximately 14 square miles (Figure 2-1). The area is centered around the City of Bothell. In Snohomish County the boundary extends north to 196th Street S.E., east to 35th Avenue S.E., west to Damson Road. The eastern boundary in King County is the crest of Bloomberg Hill. The boundary extends west to 80th Avenue N.E. and south to N.E. 145th Street. This area is the logical planning area and growth area for the City of Bothell. Much of this land is presently outside the existing Bothell City limits; however, the Comprehensive Plan and the corresponding Storm Water Master Plan has been developed for the entire area so that the policies and development procedures applied City-wide will be consistent with those reflected in the goals for the City of Bothell.



LEGEND

- STUDY AREA
- BASIN BOUNDARY
- SUB-BASIN BOUNDARY
- NORTH CREEK

Barrett Consulting Group
10800 N.E. 8th Street, Seventh Floor
Bellevue, WA 98004
206-455-9494 • FAX: 206-453-9470

CITY OF BOTHELL

COMPREHENSIVE STORM WATER MASTER PLAN

FIGURE 2-1 - DRAINAGE BASINS

2.3 HYDROLOGIC RESOURCE FEATURES

The natural appearance of the land is an expression of factors such as topography, soils, and climate. The topography influences the direction of surface water flow and drainage paths while the amount and type of vegetation is directly related to soil and climate. The following sections describe in more detail these physical attributes and include location maps illustrating the hydrologic basins.

2.3.1 Climate

The City of Bothell is part of the Puget Sound geographic region which experiences a marine climate characteristic of the West Coast region. The area receives about 38 inches of precipitation annually primarily in the form of rain. The rainy season begins in October and continues until April, thus causing fairly distinct wet and dry seasons. The rainfall is usually of light or moderate intensity and snowfall is normally very light.

2.3.2 Topography

Topography influences drainage patterns and runoff of the soil surface. The area surrounding Bothell lies within the bench area of glacial moraine and outwash plains of the morphologic area known as the Puget Sound Lowlands. This area is characterized by gently rolling hills. Elevations for the study area range from just under 500 feet on Norway Hill to 40 feet at the Sammamish River.

Stormwater in the planning area is influenced by three different types of orographic features. The North Creek basin area is characterized by a broad, flat floodplain defined by steep slopes. More than ninety percent of the creek basin is located upstream and outside of the City limits. Several small tributaries to North Creek originate within the study area and are fed by naturally occurring springs along the hillsides.

The Horse Creek basin originates and is contained entirely within the City. The basin is relatively small (1.5 square miles) and encompasses the downtown portion of the City. The remaining area is characterized by steep slopes and small drainages which discharge directly into the Sammamish River. The individual basins and tributary areas will be further characterized in the next section.

Steep slopes as defined by the Critical Areas Ordinance are found between the flood plain and plateau areas in the North Creek, Horse Creek, and Sammamish River valleys. The most significant of these areas are the north facing slopes of Norway Hill, the west slopes of Bloomberg Hill, and the east slopes between I-405 and Queensborough. Moderate to gentle slopes are characteristic elsewhere in the area.

2.3.3 Soils and Geology

The Puget Sound lowlands were invaded by glacial ice at least four times, retreating most recently only 14,000 years ago. The upland regions of Puget Sound are characterized by outwash and till covering older glacial drift. Most of the soils formed in deposits of glacial

drift laid down during the Vashon Period of the Fraser Glaciation. The major kinds of material deposited by the glacier are till, outwash, and some material mixed with volcanic ash.

Each time the massive glacier advanced a huge lake formed in the Puget Sound lowland since the Strait of Juan de Fuca was blocked by the ice. On the bottom of this glacial lake, "rock flour," the finely ground remains of rocks pulverized by glacier action, settled out. These deposits became the familiar "blue clays" of the Puget Lowlands. Each time the Ice Age glaciers advanced, their great weight compacted underlying sediments and deposited a concrete-like material called "till" (or hardpan) beneath it. Each time it retreated, water from the melting ice deposited thick layers of sand and gravel known as "outwash."

Clay, till, and outwash glacial sediments are present in the Bothell area in various combinations. They provide both the formations that hold the groundwater and the parent material for most of the different soils. The important factors in soil formation are parent material, climate, living organisms, topographic relief, and time.

The Soil Survey of Snohomish County Area (U.S. Soil Conservation Service, 1983) and the Soil Survey of King County Area (U.S. Soil Conservation Service, 1973) both classify most of the soil in the area surrounding Bothell as one major soil unit, the Alderwood-Everett complex. The stream valleys of North Creek and Sammamish River however are classified as Puget-Earlmont-Snohomish.

Typically, a unit consists of one or more major soils and some minor soils that each have a distinctive pattern of relief and drainage. The soils in any one unit differ from place to place in slope, depth, drainage, and other characteristics that affect water management. The Alderwood-Everett soil association is comprised of moderate to very deep, moderately well drained on nearly level to very steep soils. It is found on till plains and terraces. Slopes can range from 0 to 50 percent. The Puget-Earlmont-Snohomish complex contains poorly drained, nearly level soils that have layers of peat within a few feet of the surface.

Soils are classified into hydrologic groups based on their infiltration ability. Soils not protected by vegetation are assigned to one of four groups. The four hydrologic soil groups are:

> "A" soils which have a low runoff potential. Soils have high infiltration rates, even when thoroughly wetted, and consist primarily of deep, well-to-excessively drained sands or gravel. These soils have a high rate of water transmission.
>
> "B" soils have a moderately low runoff potential. Soils having moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
>
> "C" soils have a moderately high runoff potential. Soils have slow infiltration rates when thoroughly wetted, and consist chiefly of soils with a layer that

impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.

"D" soils have a high runoff potential. Soils have very slow infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

These soils are grouped according to the intake of water when the soils are thoroughly wet and receive precipitation from long-duration storms. The predominate hydrologic soil group within the Bothell area is classified as "C" or soils with moderately high runoff potential.

2.3.4 **Drainage Basin Characterization**

The majority of stormwater runoff in the Bothell area discharges to North Creek, Horse Creek, Sammamish River, or Swamp Creek. Horse Creek is the only basin located entirely within the City limits. The basins which were delineated and modeled for this Stormwater Master Plan include Horse Creek and tributaries to North Creek, the Sammamish River, and Swamp Creek which are located in the study area and contribute to the City's drainage system. Stormwater runoff in these basins and tributaries is primarily conveyed in well defined open channels with cross culverts at street crossings. It is estimated that within the existing boundaries of the City of Bothell, there are approximately 247,000 linear feet of underground pipes (46.8 miles) compared to 443,500 linear feet (84.0 miles) of open channels and streams. There are also an estimated 6,200 catch basins. Hydrologic characterization of these basins are discussed in more detail below. Drainage basin locations and associated tributaries are shown on Plate 1 in Appendix F of this document.

North Creek and the Sammamish River were not evaluated or included in the Master Plan because the most of each basin is outside the City's boundaries. Snohomish County is in the process of initiating a study to address flooding and related problems in the North Creek Basin. King County will be developing a basin plan for the Lower Sammamish River to address water resource issues in the future. The City will be participating in these studies.

Horse Creek Basin

Horse Creek drains approximately 952 acres. The creek's headwater is a large lake which is recharged by springs. Below this lake is a broad flat area that is primarily wetland with low shrubs and riparian vegetation. The lower portion of the creek flows through pipes in the downtown commercial corridor adjacent to SR 527 before discharging to the Sammamish River at The Park at Bothell Landing. Numerous springs located throughout the basin contribute baseflow to the creek. The primary land uses in Horse Creek are residential or undeveloped forest and pasture. Commercial and high density residential units constitute 13 percent of land use in the basin.

North Creek Tributaries

Perry Creek and Queensborough Creek drain 953 acres which discharge to North Creek near 228th Street S.E. and 20th Avenue S.E. Residential single-family dwellings constitute 65 percent of the land use in the basins. Forest, pasture, and wetlands cover 23 percent of the basins while the remaining land use is high density residential or commercial. This tributaries are comprised of several well defined creek channels. The largest of these channels is located in the ravine directly east of the Queensborough development. The channel then crosses under 4th Avenue S.E. before joining several smaller spring fed streams which cross 9th Avenue S.E. The stream continues eastward under I-405 to connect with North Creek on the east side of the Canyon Park interchange. Another significant stream crosses under 9th Avenue S.E. and continues east through the Canyon Park business area before converging with Perry Creek which originates from a large lake bordered by 19th Avenue S.E. near 232nd Street S.E.

Several drainage courses which discharge to North Creek from the east contain the tributaries of *Palm Creek and two unnamed creeks*. The largest of these drainages is Palm Creek which originates near 39th Avenue S.E. and Maltby Road. Water is collected from several branches and flows southwesterly where it crosses 228th Street S.E. near 31st Avenue S.E. One of the unnamed creeks is another significant tributary which originates north of 228th Street S.E. and 39th Avenue S.E. This stream flows southwesterly towards 35th Avenue S.E. and 236th Street S.E. Springs along the slopes in this area provide consistent baseflow to the stream. The remaining unnamed creek originates west of 39th Avenue S.E. and Maltby Road. This tributary flows westerly towards Thrashers Corner where it enters a piped conveyance system before it is discharged into North Creek near 20th Avenue S.E. Land use for these drainages is dominated by rural residential development and forest in the upper portion and by commercial and business parks in the area next to North Creek and the corridor along SR 527.

The *Royal Anne Road* tributary drains approximately 315 acres dominated by low density residential development. The stream channel collects water from the area west of I-405 and is conveyed easterly under the Interstate to discharge to North Creek above Canyon Park.

Swamp Creek Tributaries

The headwaters to *Little Swamp Creek* originate around 228th Street S.W. and Meridian Road. The tributary flows in a southerly direction through low density residential, small farms, and forest before discharging to Swamp Creek below N.E. 195th Street and 75th Avenue N.E. The Swamp Creek Watershed Plan (Snohomish County, 1993) describes the lower reaches of this tributary as good salmon spawning habitat.

Sammamish River Tributaries

The 362 acres draining through *Wayne Golf Course* is 74 percent undeveloped. The remaining land use is moderate to low density residential. Most of this basin has steep slopes as defined by the City's Critical Area Ordinance. Developed land is located in the area near 100th Avenue N.E. and N.E. 145th Street which is more gently sloping.

Tributaries to the *Sammamish River* from the south comprise 623 acres. Nearly one-third of this area is undeveloped. However, I-405 and the brickyard interchange represent most of the impervious area in this basin. The upper reaches of the basin are gently sloping while the middle portion is considered to be steep slopes as defined by Bothell code.

Stormwater on *Bloomberg Hill* is primarily conveyed through a drainage network within the high density residential development. The conveyance system is comprised of a series of pipes and detention ponds and discharges to Little Bear Creek near 132nd Avenue N.E. and SR 522.

The remaining portion of the study area not contained in these drainage basins is adjacent to the Sammamish River or North Creek. In general, land use for these areas is high density such as the apartments and mobile home parks along the River or commercial/industrial such as the Koll and Quadrant Business Parks next to North Creek.

2.3.5 **Wetlands**

Wetlands and riparian corridors perform valuable functions within the ecosystem. Clearing of vegetation, grading, filling, draining, and other activities associated with land development may destroy and decrease the ability of the riparian zone to provide drainage, stabilize stream banks, provide wildlife habitat, and filter pollutants from the water. Wetlands receive surface water from the surrounding area and filter pollutants entering these ecosystems by a combination of physical, chemical and biological processes.

Wetlands also play a major role in flood control. During flooding, rivers and streams overflow their banks and spread out across the floodplain. Wetland soils act like a groundwater reservoir, storing surplus water as groundwater during wet periods and discharging this stored water into streams later to augment baseflow. The wetland area also provides habitat and a source of food for wildlife.

The Bothell study area contains approximately 646 acres of wetlands as defined by the Critical Areas Mapping Project or approximately 8 percent of the land area within Bothell's Planning Area. The majority of the wetlands in the area are associated with the headwaters and riparian corridors of streams and tributaries, or the associated floodplains of the Sammamish River and North Creek. The primary source of water for these wetlands is floodwater, precipitation, and surface flow.

2.3.6 **Floodplain**

A Flood Insurance Study was conducted by the Federal Emergency Management Agency (FEMA, 1989) of the Federal Insurance Administration for King County and investigates the existence and severity of flood hazards. On June 1, 1982, a flood boundary map was published which indicates areas that are subject to 100- and 500-year floods with the City of Bothell. The 100-year flood has been adopted as the base flood for purposes of floodplain management measures. A 100-year flood area is defined as those lands which are subject to a one percent or greater chance of flooding in any one year. The 500-year flood is employed to indicate additional areas of flood risk in the community. The data from the engineering

study was transformed into flood insurance criteria. This process includes the determination of reaches, Flood Hazard Factors (FHFs), and flood insurance zone designations for each flooding source studied in detail.

Areas along the Sammamish River and the North Creek valley are designated as being with the 100-year flood plain. A "Limited Map Maintenance Study of Areas of Unincorporated King County and Bothell, Washington" was prepared for FEMA in April 1992. The study addressed flood risks along a 1.4-mile reach of North Creek extending from its mouth at the Sammamish River to the King-Snohomish County border.

2.4 LAND USE TYPES

The management of stormwater drainage in the Bothell area incorporates various existing and future land use types. Land use types refer to the hydrologic relationship with other factors such as streets, soils, and slopes. The land use was grouped according to changes in the effective impervious area which are those areas with direct runoff from impervious surfaces. An overview of these land use types that may impact the management and maintenance of water quality and quantity are presented in this section.

Land use in the Bothell area is currently guided by the Bothell Comprehensive Plan adopted by the City in 1971 and subsequent amendments through provisions enacted by the Planning Enabling Act (RCW 36.70). An update to the Comprehensive Plan is currently being prepared to comply with the Growth Management Act passed in 1990 by the State Legislature. The Comprehensive Plan contains a land use element which designates the general distribution, location, and extent of uses of land. The Comprehensive Plan also contains policies in 12 other elements which set the framework for decisions about future development within the City.

The physical size of the incorporated community was doubled when the Canyon Park area was annexed in 1992. Other factors affecting growth in the area include 1) a strong regional economy which supported significant employment growth during the 1980s; and 2) expansion and diversification of industry. Current population is estimated to be approximately 24,500.

The primary land use in the area is residential. Five general residential land use groups are proposed in the Comprehensive Plan update. These designations allow specific residential densities within a specified range expressed in dwelling units per acre (du/acre) and include:

- Mobile Home Parks which are considered planned unit development which incorporate amenities such as open space and protection easements. This land use type provides affordable detached single-family hoursing and are a functional and visual asset to the community.

- Residential (11-15+ du/acre) includes multi-family or apartment areas. Densities over 15 are proposed only for special populations such as senior housing.

- Residential (6-10 du/acre) provides for slightly higher density single family dwelling styles such as townhomes which offer affordable home ownership opportunities in a more clustered configuration.

- Residential (2-5 du/acre) is the largest single family dwelling land use within the Bothell planning area.

- Residential (1 du/acre) applies to a few areas with topographic constraints and to an area in the northeast section of the City proposed for growth reserve until growth occurs.

Commercial activity is generally located within the downtown core, adjacent to State Route 527 northward toward the Canyon Park interchange, the Canyon Park Business Center, and in the North Creek Koll and Quadrant Business Centers. In general, commercial development is oriented toward the local service needs and specialized regional service needs.

2.4.1 **Existing Land Use Type**

The existing land use within the study is shown in Table 2-1. The largest developed land use in the area (44 percent) is allocated to single-family residential uses. Urban and medium density residential land uses are distributed throughout the community. These single family areas are generally found in the upland or hilltop locations due in part to topography, utility services, access patterns, and public facilities. Typically, high density multiple-family residential development is adjacent to arterials or collector streets and comprise approximately 2 percent of the current land use.

Slightly more than 5 percent of the land use in the planning area is non-commercial agriculture and open fields. Activities included under the agricultural land use include pasturing, horse stable boarding, and nursery operations.

The remaining developed land use is currently being used for commercial and industrial activities. These activities are primarily located within the Central Business District, Canyon Park, and the Koll Creek and North Creek business parks. Commercial activities and business parks comprise 13 percent of the current land use.

Table 2-1
Existing Land Use Types

	Acres	% Total
Multiple Family Residential	219	2
Single Family Residential	3,982	44
Agricultural/Open Fields	410	5
Commercial/Industrial	1,166	13
Open Water and Wetlands	674	7
Forest/Undeveloped	2,558	28
TOTAL	9,009	99

2.4.2 Future Land Use Type

Future projections of land use patterns for the Bothell Urban Growth Area were based on the proposed Comprehensive Plan and were used to determine how storm water could be managed in the future. Growth will encompass residential areas of high, medium, and low density. Much of the currently undeveloped parcels will likely develop as large subdivisions. The development pattern will keep with the basic goal of the community to remain primarily a residential community.

In addition, there are numerous significant physical features of the community which will be preserved. These include views to the mountain areas and the Sammamish River Valley. In keeping with the Growth Management Act mandate, critical areas such as steep slopes, wetlands, and riparian zones will be protected while accommodating development. Table 2-2 shows the various land use categories and the expected number of acres they represent under future development.

Table 2-2
Future Land Use Type

	Acres	% Total
Multiple Family Residential	342	4
Single Family Residential	5,882	65
Agricultural/Open Fields	253	3
Commercial/Industrial	1,503	17
Open Water and Wetlands	674	7
Forest/Undeveloped	355	4
TOTAL	9,009	100

Under future conditions, approximately 65 percent of the city will be in the single family residential category. Additional commercial/industrial land use is expected primarily within the Koll or North Creek Business Park areas. Conversion of low density residential and agricultural land to higher intensities will will primarily occur in the Canyon Park basin.

Chapter 3 - REGULATORY ANALYSIS

Multiple federal, state, and local regulations address different aspects of stormwater management. Generally, stormwater management is included as an element in addressing other environmental features such as wetlands, water quality, and flood protection. Because of the complexity of stormwater issues, development of an effective local management plan requires integration of federal and state requirements through a local regulatory framework. Many of the federal and state regulations emphasize local control of land use activities. An overview of those federal, state, and local regulations that affect land use and resource areas in Bothell is presented in the following section. The overview is followed by an analysis of existing City codes which identifies conflicts or aspects of stormwater management which could be enhanced to complement federal and state mandates.

3.1 OVERVIEW

Regulatory programs dictate the need for flood protection, natural resource protection, and water quality. Historically, flood protection focused on structural measures such as dikes and levees. Unfortunately, negative impacts on other areas of the environment such as fisheries or water quality resulted. To address these issues, some agencies now require nonstructural measures such as zoning, sensitive area, and shoreline development regulations.

The regulations and codes adopted by local jurisdictions must be consistent with federal and state laws. These regulations are discussed below and focus on categories of regulations pertinent to surface water management including quantity control, water quality, critical area management, and land use management.

3.1.1 Federal

The principal federal laws that regulate water quality, wetlands, stream corridors, and floodplain protection include the Clean Water Act Sections 401, 402, and 404, the Flood Disaster Protection Act, and the River and Harbor Act. An overview of these regulations is presented below:

Clean Water Act Section 401 is implemented through a certification process. The purpose of the permit is to ensure that federally permitted activities comply with state water quality laws and any other appropriate state laws. The process requires a Water Quality Certification be issued by Washington Department of Ecology (Ecology) to ensure the activity will comply with water quality standards and discharge limitations for water of the State (WAC 173-201). The Certification is required by federal law as a prerequisite to obtaining a federal permit.

Clean Water Act Section 402 provides that the discharge of any pollutants to waters of the United States from any point source is unlawful, unless the discharge is in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. NPDES permits for municipal and industrial storm water discharges are required in order to stop illegal discharge

of waste waters and other pollutants into storm sewers; to reduce the amount of pollutants in storm water; and to eliminate water quality standards violations caused by storm water discharges.

Currently, municipalities with populations greater than 100,000 and certain industrial activities including construction sites greater than 5 acres are required to obtain permits. NPDES permits are issued by the Environmental Protection Agency (EPA), or by a state agency delegated authority. In Washington State, the Department of Ecology (Ecology) has the authority to issue NPDES permits.

Clean Water Act Section 404 is regulated and enforced by the U.S. Army Corps of Engineers (COE). Section 404 provides for government and public review on projects that alter or destroy waters of the U.S. by filling or dredge spoil disposal. Permit approval must comply with guidelines developed by the Environmental Protection Agency (EPA). If a project does not comply with the guidelines, the permit application will be denied, modified to minimize impacts, or compensation for unavoidable impacts will be required.

Flood Disaster Protection Act requires the purchase of flood insurance by residents as a condition of federal funding for acquisition or construction of buildings in the floodplain. No federal financial assistance can be provided for the permanent repair or reconstruction of insurable buildings in the floodplain if a presidentially declared flooding disaster occurs in a non-participating community.

River and Harbor Act, Section 10 prohibits the unauthorized obstruction or alteration of navigable water of the United States without a permit from the COE. The provisions apply to all structures or work below the mean high water mark of navigable tidal waters and the ordinary high water mark of navigable fresh waters. The provisions also apply to proposed actions "in, over, or affecting" navigable waters and are applied to wetlands within these limits.

3.1.2 **Washington State**

A summary of state regulations which apply to stormwater issues are described below. These regulations comply with federal statutes governing water quality, general environmental, and flood protection.

Shoreline Management Act (SMA, RCW 90.58) protects the public's interest in public resources such as water, fish, and wildlife and the habitat that supports those species by regulating public and private development in shoreline areas. The SMA defines several shoreline designations; provides guidance to Ecology and local jurisdictions when developing procedures, rules, and plans for shoreline activities; establishes time lines for the development of local shoreline management plans; and identifies activities generally exempt from certain shoreline permits. This regulation provides for a variety of means of enforcement, including civil and criminal penalties, orders to cease and desist, orders to take corrective action, and permit rescission.

The SMA includes significant regulatory requirements applicable to all major shorelines of the state: the ocean coastline, Puget Sound, the Strait of Juan de Fuca, lakes of 20 acres or larger, rivers and streams with mean annual flows of 20 cubic feet per second or greater, and their associated wetlands. Both North Creek within the boundary of the study area and the Sammamish River are regulated under the SMA. The area of jurisdiction includes associated wetlands, floodplains, and any other land 200 feet landward of the ordinary high water mark of the shoreline.

Floodplain Management Program (RCW 86.16) was first enacted be the State Legislature in 1935 and gave the state the authority to form flood control zones along streams and rivers for the purpose of controlling the stream system for the protection of life and property, the preservation of public health, and the preservation of the natural resources of the state. The Act specified state regulatory authority over designated flood control zones, including the authority to regulate construction and planning within flood plains and floodways.

The statute has been extensively revised since passage of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. Originally known as "Flood Control Zones by State," RCW 86.16 gave the state regulatory authority over all waters in Washington State through the issuance of orders and permits for flood control projects in designated flood control zones. In 1987, the statute was renamed "Floodplain Management" and the State's permitting responsibility was abolished. Under the new version of the statute, the State Department of Ecology is responsible for coordinating the floodplain management regulation elements that are required for participation in the National Flood Insurance Program (NFIP).

Generally, Ecology acts in an oversight capacity with respect to local governments. Ecology is directed to help local governments, when asked, in preparing as well as enforcing floodplain management ordinances. In turn, local governments are required to submit to Ecology any new floodplain management ordinance or amendment to an existing ordinance for approval within thirty days. Under the Floodplain Management Act, Ecology also has supervisory control over all dams and obstructions in streams, and therefore the power to regulate flows as necessary to minimize potential downstream flood damages. To fulfill this role, Ecology has established minimum state requirements for floodplain management that exceed the minimum federal requirements for participation in NFIP. The Act also gives Ecology the authority to examine and approve or reject future developments or modifications to existing developments located within a floodway, although this power is rarely exercised. Both state and local floodplain management regulations are based on Federal Emergency Management Agency (FEMA) maps that designate special flood hazard areas (100-year floodplains). A community's participation in this program is required for its residents and property owners to be eligible for federally subsidized flood insurance.

State Water Pollution Control Act is implemented by Ecology which has the authority to develop, maintain, and administer the federal statutes and programs required by the federal Clean Water Act. All activities within receiving waters of the state require a Water Quality Certification/Modification permit (WAC 173-225) from Ecology which also has the authority to enforce violations of state water quality standards.

Hydraulic Code (RCW 75.20) is administered by the Washington Department of Fisheries (WDOF) or Wildlife (WDOW) for Hydraulic Project Approval (HPA) permits. The primary function of the Code is to protect the state's fisheries resources, including spawning and rearing habitat. Therefore, any construction or other work that will use, divert, obstruct, or change the natural flow of any state waters requires agency approval.

Puget Sound Water Quality Act (RCW 90.70) was enacted to create a single entity with adequate resources to develop and oversee implementation of a Comprehensive Plan for water quality protection in Puget Sound. As a result, the Puget Sound Water Quality Management Plan was first issued in 1987, followed by revisions in 1989 and 1991. In 1988 Puget Sound was designated an Estuary of National Significance under the Federal Clean Water Act and the Environmental Protection Agency approved the plan as the federal Comprehensive Conservation and Management Plan for Puget Sound in 1991.

The Puget Sound Water Quality Authority (PSWQA) is composed of 11 members, nine of which are appointed by the governor. The Commissioner of Public Lands and the Director of Ecology serve as ex officio members. The Authority's powers include the ability to conduct studies and research relating to Puget Sound water quality; obtain information relating to Puget Sound from other state and local agencies; conduct appropriate public hearings; and adopt rules under RCW 34.05 as it deems necessary to implement RCW 90.70.

The enabling legislation requires state agencies and local government to evaluate and incorporate applicable provisions of the plan into their policies and activities. However, the Authority lacks clear legal authority to direct local governments to adopt stormwater regulatory programs. Programs in the Puget Sound Water Quality Management Plan (PSWQMP) are guidelines to protect water quality in Puget Sound. If violations of state water quality standards occur, Ecology has the authority under RCW 90.48 to enforce those violations. Enforcement actions may include notices of violation and regulatory orders; levying of civil penalties; or initiation of criminal proceedings.

Department of Ecology Stormwater Program establishes guidelines to prevent and control pollution of waters to the Puget Sound Basin from urban stormwater runoff. Guidelines were developed by Ecology to assist counties and cities to establish stormwater controls for new development and standards for maintenance on public and private stormwater systems. The recommended criteria for new development includes a release rate of 50 percent of the 2-year, 24-hour design event for streambank protection and detention of the 50 percent 2-year, the 10-year and 100-year, 24-hour design storm based on performance standards for quantity control of stormwater runoff. The guidelines also address density controls to limit development in critical areas; development standards to limit the amount of impervious surfaces; criteria for regional detention ponds, oil separators, or other treatment facilities; grading and drainage ordinances; erosion control programs; buffers next to waterways; and preservation of wetlands.

Highway Runoff Program Rule requires Washington State Department of Transportation (WSDOT) to control runoff from freeways and highways in the Puget Sound Basin. The program contains several elements including implementation of BMPs, erosion and sediment control plans, vegetation management plan, and maintenance plan. A priority ranking system

establishes an implementation schedule for retrofitting existing facilities based on criteria for vehicle use and site-specific constraints of implementing BMPS. A public draft detailing implementation of the program will be available spring of 1993.

Growth Management Act adopted in March 1991 (RCW 36.70A) requires jurisdictions to update existing Comprehensive Plans to reflect a coordinated and consistent effort among jurisdictions. Goals adopted by the Act include encouraging urban growth development where adequate public facilities and services exist; reducing urban sprawl; encouraging the retention of open space and conservation of habitat; protecting the environment and quality of life; encouraging the involvement of citizens in planning activities; and ensuring public facilities are adequate. Regulations to assure the conservation of agricultural, forest, and mineral resource lands will be developed through this effort.

Mandatory elements of the Comprehensive Plan which address stormwater management include:

(1) a land use element designating the proposed general distribution and general location and extent of land uses within the growth boundary. The land use element must include a review of drainage, flooding, and storm water run-off in the area and nearby jurisdictions and provide guidance for corrective actions to mitigate or cleanse those discharges that pollute water of the state.

(2) a capital facilities plan element consisting of a) an inventory of existing capital facilities owned by public entities; b) a forecast of future needs; c) proposed locations or new facilities; d) at least a six-year plan to finance construction of facilities; and e) a requirement to reassess the land use element if probable funding falls short.

Each county, and each city within the county, is required to adopt development regulations which preclude land uses or development that is incompatible with critical areas including wetlands and areas with a critical recharging effect on aquifers used for potable water. Counties are required to coordinate the efforts during this process with local jurisdictions.

3.1.3 **Snohomish County**

Various regulations, policies, goals, and objectives which address federal and state requirements for stormwater management are currently being used by Snohomish County for stormwater management and resource protection. The primary regulation which applies to stormwater issues is Title 24; however, other County codes and programs also affect stormwater management. The following is a discussion of codes and regulations which are relevant to surface water issues.

The Shoreline Management Master Program (Title 21) is intended to guide the future conservation and development of the county's major shoreline areas. The program combines elements of the long range plan and a detailed regulatory permit structure. Elements include provisions for shoreline use, economic development, public access, recreation, circulation,

historical/cultural/scientific/education; and conservation. Snohomish County added two additional elements to its master program, agriculture and implementation.

A system which classifies the County's shorelines into five basic and distinct environments (natural, conservancy, rural, suburban, and urban) allows the County to plan and effectively manage shoreline resources. The basic intent of the system is to utilize performance standards which regulate use activities in accordance with goals and general development policies.

Bodies of water that have a surface area of twenty acres or a mean annual flow of twenty cubic feet per second (cfs), flood hazard areas, and areas within 200 landward feet of wetlands fall under the jurisdiction of the Master Program. Variances are granted for applicants if compliance with the provisions prohibits reasonable use of property. All of North Creek from Maltby Road south is designated as urban environment under the Snohomish County program.

The Snohomish County Drainage Ordinance (Title 24) regulates runoff from most new development in the county. Standards to control flooding and erosion are defined in the ordinance. The primary focus of the ordinance is on water quantity and not on quality. The minimum design event selected for facilities is a 10-year, 24-hour return period storm. When development exceeds fifty (50) acres or the design discharge exceeds twenty (20) cfs, then the minimum design is a 25-year 24-hour design storm. An update is currently in progress to assure compliance with the Puget Sound Water Quality Management Plan for water quality.

Environmental Policy Ordinance provides for full public disclosure of potential environmental impacts of developments in the county. The County has authority to condition or deny a development to avoid environmental impacts. However, short plats and individual single family homes are exempt from review. This ordinance provides limited control of development-related activities in the study area since most development in the county will be single-family dwellings.

Grading Permits (Title 24) for all fills and excavations of more than 500 cubic yards are required. Drainage and erosion control measures are required as conditions for the permits. Clearing activities are not addressed in this code and many small grading projects are exempt from County review.

3.1.4 **King County**

The primary policies or ordinances which address storm and surface water runoff in King County are the Surface Water Design Manual and the Sensitive Area Ordinance. These regulatory vehicles detail the permit requirements and enforcement responsibilities for new development for the protection of natural resources in the County. The following is a discussion of the Manual and Ordinance.

The Surface Water Design Manual provides for policies for surface and storm water management with a comprehensive approach. The Manual contains requirements and

standards for the design of surface and storm water management systems in unincorporated King County and addresses water quantity and quality issues. The Manual regulates proposed projects by a mixture of requirements, performance, and design standards. Requirements are quite specific. Performance and design standards are less specific, directing the design engineer to accomplish a defined goal in a consistent manner considering site constraints, project objectives, and technical limitations.

Specific policies related to surface water management and special consideration in land use decisions, as well as to those which reduce hazards and prevent adverse environmental impacts are detailed in the Manual. In addition to water quantity control measures, the Manual considers the protection of water quality a high priority.

King County encourages the use of land use plans and land development that preserve the amenity and ecological functions of water features. To ensure this type of water resource management, a variety of approaches are discussed for the design of surface water systems used in the mitigation of a new development impacts. The primary approach is to minimize the impact of new development on natural and constructed drainage systems downstream is to require on-site detention facilities to limit the peak rates of runoff from design storm events to levels which exist in the undeveloped state. Each system design must consider the hydrology, hydraulics, and environmental constraints in critical resource areas early in the planning process.

Currently King County requires that more than one design storm frequency be used to define a performance curve. The 2-, 10-, and 100-year 24-hour storm event are used as the threshold for determining the curve. The objective of this performance curve is to limit the developed peak runoff rates to predeveloped levels for a range of design storm frequencies. The 2-year and 100-year storms were chosen to address the lower and upper range of frequencies. Pipe, ditch, or channel systems must provide for the conveyance of the 25-year peak rate of runoff.

State-of-the-art measures intended to preserve existing water quality or reduce potential pollutant loadings have been incorporated into many of the requirements of the manual. These measures include design criteria and requirements such as detention facility performance to control erosive discharges from detention basins, detention basin designs that promote controlled sedimentation, and special water quality controls and vegetation-lined channels for biofiltration.

Requirements and standards are enforced by two divisions within two separate departments of King County: The Department of Development and Environmental Services (DDES) and the Surface Water Management Division (SWM). The SWM Division of the Department of Public Works prepares Basin Plans and other policies to address issues of regional facilities planning and engineering, and the development and enforcement of drainage regulations. The DDES Division of the Parks, Planning and Resources Department performs the actual review of drainage plans for new development. Community Plans are prepared by the Community Development Division of Planning. Basin Plans and Community Plans provide specific policies on which requirements are based. Community Plans provide detailed land use plans for local geographic areas.

Five major river basins are situated completely or partially in King County. These basins subdivide into 67 subbasins. In the basins with adopted Basin Plans, the drainage requirements may differ from standard King County requirements because of special geographic conditions and special solutions. In addition to providing special drainage requirements, the Basin Plans may include information useful in the preparation of drainage plans. Basin plans adopted as of November 1992 include Coal Creek, Soos/Jenkins Covington Creeks, and Bear Evans Creek.

A basin plan for the Samammish River is currently being planned. Bothell is located within this basin, and may be affected by the plan's recommendations.

Sensitive Areas Ordinance (SAO) is designed to meet the challenges and satisfy the requirements of the Growth Management Act with regard to all critical areas except aquifer recharge areas. The ordinance provides the regulations to protect property owners by preventing and avoiding activities which would have adverse impacts on property. Areas covered by the ordinance include coal mine, erosion, flood, landslide, seismic, steep slope, and volcanic hazard areas, and streams, wetlands, and protective buffers.

The SAO provides for a permit review process and details exempted activities for proposed projects. All proposed development which contains critical areas or their buffers within the site, must comply with the requirements established in the ordinance.

The ordinance provides for three wetland classifications, minimum buffers for the various classes, and replacement ratios for unavoidable impacts. Additionally, setbacks and buffers, mitigation, and compensation for the protection of steep slopes and geologically unstable soils to prevent erosion, sliding, and/or damage as a result of earthquakes or other geological events are provided in the ordinance. Development in frequently flooded areas as identified on the technical report *The Flood Insurance Study for King County* prepared by the Federal Insurance Administration must conform to all requirements in the SAO.

Flood Hazard Reduction Plan (FHRP) addresses policies to guide floodplain land use and flood control activities in King County. The process for analyzing flooding problems along major rivers was initiated in late 1988 and culminated with the release of the Draft FHRP in September 1991. Although flooding occurs along many different types of water bodies and drainage systems in King county, the scope of the plan focused on 1) the six major river basins and 2) large tributaries located in the eastern two-thirds of the County. Recommendations for new capital projects were made only for those areas. The Sammamish River is one of those large tributaries. Problems were considered in a basinwide context. Therefore, the policy recommendations, and many of the program and planning recommendations apply throughout those basins and tributaries. Plan recommendations are most effective if adopted on a basinwide basis, with the full cooperation of cities, other counties, and agencies. Therefore, other jurisdictions can benefit from solutions identified in the Plan.

During the 1991 legislature, SB5411, or the Flood Bill, was passed in response to the November 1990 floods. The bill states:

> Following adoption by the County, city, or town, a comprehensive flood control management plan shall be binding on each jurisdiction that is located within the area of the plan. If within 120 days of the county's adoption, a city or town does not adopt the comprehensive flood control management plan, the city or county shall request arbitration on the issue or issues in dispute (RCW 86.12.210). Any land use regulations and restrictions on construction activities contained in a comprehensive flood control management plan applicable to a city or town shall be minimum standards that the city or town may exceed.

The FHRP is an example of a comprehensive flood control management plan. The Flood Bill provision that comprehensive flood control plans are binding on the jurisdictions within the planning area reflects the importance of consistent floodplain planning, regulation, and management.

Policies issues presented in the plan which may affect Bothell include:

> Floodplain Land Use Policies - Development in the floodplain is at risk from inundation and/or erosion and can increase risks to neighboring properties by creating a barrier to the conveyance of floodwaters. Therefore:

- Regulations should apply to the 100-year future conditions floodplain as expected under buildout of current land-use plans.
- New development should be prohibited within the one-foot floodway delineated on the FIRM maps.
- The placement of structures and/or fill in the floodplain should not cause any increase in the 100-year flood elevation (zero-rise).
- Compensatory storage in the form of excavation of equivalent volumes at equivalent elevations will be required of all structures and fill placed in the floodplain.
- Land uses that leave wide areas of the floodplain open will help preserve storage and conveyance functions therefore agriculture, recreation, and open space are the preferred land use within the floodplain in areas outside of existing municipal boundaries.

The Sammamish River is within the Surface Water Management Program Service Area. The channel was designed to reduce agricultural damages during spring floods, and has only the capacity to contain flows of 5- to 10-year magnitudes. The river is influenced by hard rains in the lowlands. This coupled with extensive development in the entire basin creates flood problems along the river channel which will increase in frequency and severity as full build-out is approached. These problems are better addressed through the development and implementation of a comprehensive basin plan initiated by King County in cooperation with the cities and towns adjacent to the River.

Shoreline Management Act is intended to protect the county's major shoreline areas and public resources such as water, fish, and wildlife and the habitat that supports those species by regulating public and private development in shoreline areas. The King County program provides for procedures, rules, enforcement measures, and plans for activities within shoreline management areas. Areas covered under this program include bodies of water that have a surface area of twenty acres or a mean annual flow of twenty cubic feet per second (cfs), flood hazard areas, and areas within 200 landward feet of wetlands. Variances can be granted for applicants if compliance with the provisions prohibits reasonable use of property. North Creek within King County and the Sammamish River are governed by the Shoreline Program.

3.1.5 **City of Bothell**

The City Code addresses federal and state requirements for stormwater management through several regulatory and planning tools. In this section, the following City regulations were reviewed for applicability to the development and implementation of the Comprehensive Storm Water Master Plan:

- Interim Critical Area Ordinance (Chapter 20.10)
- Water and Sewers (Title 13)
- Shoreline Management (Title 18)
- Surface Water Runoff (Chapter 20.08)

Interim Critical Area Ordinance affects portions of Titles 15, 17, and 20 of the Bothell Municipal Code (BMC) and is codified in Chapter 20.10 of the BMC. The adoption of the Ordinance is in response to the state Growth Management Act which requires the protection of critical areas. Critical areas include the following areas and ecosystems: wetlands, geologically hazardous areas, frequently flooded areas, fish and wildlife habitat conservation areas, and areas with a critical recharging effect on aquifers used for potable water.

All proposed development which contains critical areas or their buffers within the site, must comply with the requirements established in the ordinance. Administrative Rules describe the written procedures which enforce the ordinance. Prior to any development which would alter a critical area or its buffer, a Critical Area Alteration Permit is required. As a minimum, a boundary delineation is required to determine if alteration will occur as a result of the proposed activity.

The ordinance provides for three wetland classifications, minimum and maximum buffers for the various classes, and replacement ratios for unavoidable impacts. Additionally, requirements for steep slopes and geologically unstable soils to prevent erosion, sliding, and/or damage as a result of earthquakes or other geological events are provided in the ordinance. The regulation of development within frequently flooded areas which reduce, minimize and/or prevent the public and private losses are based on *The Flood Insurance Study for the City of Bothell* (12/1/81) as identified by the Federal Insurance Administration and included in the Critical Area Ordinance. The ordinance established more performance oriented requirements for critical aquifer recharge areas and wildlife habitat conservation areas.

Title 13 Water and Sewers contains chapters which establish uniformity for rates and charges, and methods of development and construction for Sewer and Water Utilities. The installation of storm sewers and the establishment of storm sewer street boundaries are covered in Chapter 13.04 of the Code. The code defines installation specifications which provide for right-of-way dedication and connection costs. Provisions are also made for the establishment of a "storm drainage cumulative reserve fund" which can be used for construction, maintenance, repair of drainage facilities, and/or property acquisition.

Shoreline Management (Title 18) was developed in compliance with the Shoreline Management Act passed by the State Legislature in May 1971. The Act applies to marine water areas of the State, streams with a mean annual flow greater than 20 cubic feet per second, and lakes larger than 20 acres. It also applies to land extending landward 200 feet from the ordinary high-water mark and wetlands associated with these water areas.

Bothell's Shoreline Program utilizes this concept and has designated much of the Sammamish River's south side as a Conservancy Environment by limiting the kinds of shoreline use to those which retain or enhance existing natural or recreational resources. Another significant portion of the Sammamish River shoreline is classified as Rural Environment. While the setback zone along the Sammamish River prevents encroachment of structures within 80 feet of the centerline of the channel, some low-density development is permitted upland of that boundary.

The area on both sides of North Creek within the City limits is designated as primarily Urban and Urban-Special Management (USM). The USM designation embodies the Urban and Conservancy Environment characteristics. Within areas designated USM, natural resource protection is given primary emphasis, but a balance will be considered for accommodating reasonable and appropriate urban expansion. Performance standards and some general design guidelines are included in the Master Program to allow a reasonable range of alternative land uses while assuring that new development retains aesthetic qualities valued by the entire community.

The City's Interim Critical Area Ordinance and Shoreline Management Program are currently not consistent with regard to wetland and floodplain protection standards. Those inconsistencies will be resolved when regulations are reviewed in 1994 for consistency with the newly adopted Comprehensive Plan.

Chapter 20.08 Surface Water Runoff was codified to minimize water quality degradation and to protect property owners adjacent to developing land from increased runoff rates. All new development is required to submit a drainage plan which contains provisions for erosion and sediment control; and computations for sizing drainage facilities based on existing and proposed peak flows. An exception is made for single-family residential structure with less than five thousand square feet of development coverage. Retention/detention facilities must be provided to mitigate the difference in discharge from pre-developed to post-developed condition. The design storm frequency used to develop conveyance facilities is specified by the Director of Public Works. In general, a 25-year, 24-hour storm event is used.

Facility maintenance is performed by City staff on public property or in public rights-of-way. Maintenance of storm water facilities on private property is the responsibility of property owners, but is subject to an annual inspection by the City staff and corrective action is required within thirty calendar days.

3.2 REGULATORY SUMMARY

Key regulatory agencies involved in stormwater management and their responsibilities are illustrated in Table 3-1. Included in this information will be a summary table of regulations affecting the city.

Table 3-1
Overview of Regulations and Programs for Stormwater Management

Regulation (code)	Stormwater Management Element	Jurisdiction	Implementing Agency
FEDERAL			
Clean Water Act Section 401	• Receiving Water Protection	Federal permits affecting waters of the state.	Ecology
Clean Water Act Section 402	• Municipal and Industrial Stormwater Discharge	Industrial uses and Municipalities greater than 100,000 population.	Ecology
Clean Water Act Section 404	• Receiving Water Protection • Stream Corridors • Wetlands	Applies to all waters of the U.S.	U.S. Army Corps of Engineers and Environmental Protection Agency
Flood Disaster Protection Act	• Floodplain Protection	Construction in floodway and/or floodplain that may affect flood elevations and/or flood protection.	Local jurisdictions/Ecology
River and Harbor Act	• Stream Corridors • Wetlands • Navigation	Navigable waters to the mean high water mark of tidal waters and the ordinary high water mark of fresh water.	U.S. Army Corps of Engineers
WASHINGTON STATE			
Shoreline Management Act	• Stream Corridors • Steep Slopes • Wetlands	Shorelines of the state including streams with flows greater than 20 cfs or lakes 20 acres or larger, landward 200 feet.	Local jurisdictions/Ecology
Floodplain Management Program	• Floodplain Protection	Construction in floodway and/or floodplain that may affect flood elevations and/or flood protection.	Local jurisdictions/Ecology
Water Pollution Control Act	• Receiving Water Protection	Allows for state to develop, maintain, and administer federal statutes and programs required by Clean Water Act.	Ecology
Hydraulic Code	• Stream Corridors • Fishery Habitat	Below the ordinary high water mark of state waters	WDOF/WDOW
Puget Sound Water Quality Act	• Receiving Water Protection • Wetlands	Applies to all jurisdictions within the Puget Sound	PSWQA
Stormwater Program	• Receiving Water Protection	Provides model ordinances, standards, and policies for water quality protection to all jurisdictions.	Local jurisdictions/Ecology

Regulation (code)	Stormwater Management Element	Jurisdiction	Implementing Agency
Highway Runoff Program	• Stormwater Facilities	State Highways	WDOT
Growth Management Act	• Stormwater Facilities • Stream Corridors • Steep Slopes • Wetlands • Land Use	Counties which have a population of 50,000 or more and have experienced a ten percent population increase in the last ten years.	Local jurisdictions/ Counties
SNOHOMISH COUNTY			
Shoreline Management	• Stream Corridors • Steep Slopes • Wetlands	Shorelines of the state including streams with flows greater than 20 cfs or lakes 20 acres or larger, landward 200 feet.	Local jurisdictions/Ecology
Drainage Ordinance (Title 24)	• Receiving Water Protection	All proposed activities requiring one or more County permits or approvals.	County
Environmental Policy Ordinance	• General Environmental	All local actions.	County
Grading Permits	• Receiving Water Protection	Applies to 50 cubic yards or more of grading actions.	County
KING COUNTY			
Shoreline Management	• Stream Corridors • Steep Slopes • Wetlands	Shorelines of the state including streams with flows greater than 20 cfs or lakes 20 acres or larger, landward 200 feet.	Local jurisdictions/Ecology
Flood Hazard Reduction Plan	• Floodplain Protection	Construction in floodway and/or floodplain that may affect flood elevations and/or flood. protection.	County in coordination with local jurisdictions
Surface Water Design Manual	• Stormwater Facilities • Receiving Water Protection	All proposed activities requiring one or more County permits or approvals.	County
Sensitive Area Ordinance	• Stream Corridors • Steep Slopes • Wetlands	All proposed activities requiring one or more County permits or approvals.	County
CITY OF BOTHELL			
Shoreline Management (Title 18)	• Stream Corridors • Steep Slopes • Wetlands	Shorelines of the state including streams with flows greater than 20 cfs or lakes 20 acres or larger, landward 200 feet.	Local jurisdictions/Ecology

Regulation (code)	Stormwater Management Element	Jurisdiction	Implementing Agency
Interim Critical Area Ordinance (Chapter 20.10)	• Stream Corridors • Steep Slopes • Wetlands	All proposed activities requiring one or more City permits or approvals.	City
Water and Sewers (Title 13)	• Stormwater Facilities	All storm sewers	City
Surface Water Runoff (Chapter 20.08)	• Receiving Water Protection	All proposed activities requiring one or more City permits or approvals.	City

3.3 RECOMMENDATIONS

The previous discussion focused on those regulations or programs which apply to water quantity and quality aspects of stormwater management. Federal regulations provide the foundation for general environmental protection of wetlands and sensitive areas. Generally, states are designated to implement and enforce the federal mandates. In Washington, development activities are regulated through the programs discussed above. On the local level, development activity is conditioned on a variety of mechanisms including Comprehensive Plans, zoning ordinances, and floodplain management regulations.

Two state programs which directly affect Bothell are the Growth Management Act (GMA) and the Puget Sound Water Quality Management Plan (PSWQMP). Through these two programs, local government is required to develop specific standards for new development to protect the unique resource of Puget Sound. The PSWQMP requires that all cities adopt ordinances requiring stormwater control for new development and maintenance of public and private stormwater systems. These ordinances and maintenance programs should meet the goals of the Puget Sound Water Quality Plan by working to preserve water quality as well as solve specific flooding problems. The Ecology Stormwater Management Manual implements stormwater requirements identified in the PSWQMP by providing specific guidelines for meeting these goals.

The GMA was enacted to address the effects of the rapid growth Washington State experienced in the 1980s. Much of the concern surrounding the growth issue was focused on urban sprawl, economic issues, and siting of needed major facilities. However, growth and development result in more impervious surfaces which cause more stormwater runoff which has important implications for water quality and discharge to receiving waters. The land use element of the City's Comprehensive Plan must review drainage, flooding, and storm water run-off in the area and provide guidance for corrective actions (RCW 36.70A.070).

The following recommendations encompass guidelines established in the GMA and PSWQMP for new development projects. The target date for compliance of element SW-1 (Stormwater Programs) of the PSWQMP is May 1, 1993. Deadlines for GMA elements require the Urban Growth Boundary to be designated by October 1, 1993, and all other elements including the Plan must be adopted by July 1, 1994. Recommendations are presented in terms of design criteria and policy issues for water quantity control and water quality considerations.

3.3.1 Design Criteria

Design standards with development controls for preventing future flooding and water quality problems are presented in the Ecology Stormwater Manual. The Manual can be used as a resource for the design of Best Management Practices and stormwater detention and conveyance. The King County Surface Water Design Manual contains more precise methodology for determining detention and conveyance design. The following recommended

modifications to Bothell Municipal Code would provide consistency with King County which meets or exceeds state stormwater standards.

RECOMMENDATION C-1: REQUIRE OFF-SITE ANALYSIS

An off-site analysis will evaluate drainage system problems upstream, on-site, and downstream of the proposed project. The analysis will ensure that the project does not increase the magnitude, frequency, or duration of an existing drainage problem not create a new problem.

The upstream portion of the analysis would encompass the entire tributary drainage area. The downstream analysis would extend downstream of the proposed project discharge location to a point on the drainage system where the proposed project site constitutes a minimum of 15 percent of the total tributary drainage area, but not less than 1/4 mile.

RECOMMENDATION C-2: REQUIRE DETENTION OF THE 2-, 10-, AND 100-YEAR, 24-HOUR EVENTS BASED ON PERFORMANCE CURVES

The analysis of the 2-, 10-, and 100-year, 24-hour frequency storm event allows a "performance curve" to be plotted which represents allowable peak runoff rates for a range of storm events. The curve measures the performance of peak rate runoff control facilities. Selecting the 2- and 10-year, 24-hour duration storm events as minimum design criteria to produce post-development peak runoff rates at or below this curve will provide consistency with King County requirements. More restrictive runoff control may be required for a higher frequency event depending upon the significance of downstream impacts.

RECOMMENDATION C-3: REQUIRE A RELEASE RATE OF 50% OF THE 2-YEAR, 24-HOUR DESIGN EVENT

Limiting the peak rate of runoff from individual development sites to 50 percent of the existing condition 2-year, 24-hour design storm and maintaining the existing condition peak runoff rate for the 10-year, 24-hour and 100-year, 24-hour design storms will decrease adverse impacts to streams. Selecting this level of release rate will provide consistency with Ecology requirements. More restrictive runoff controls may be required for a higher frequency event depending upon the significance of downstream impacts.

RECOMMENDATION C-4: ESTABLISH A MINIMUM STORM FREQUENCY EVENT FOR PIPE CONVEYANCE

Establishing a minimum storm frequency event for pipe conveyance determines the "level of service" for that conveyance system. The required level of service which must be met by a proposed development is dependant upon existing drainage basin conditions. New development could occur on sites with existing drainage systems or with no existing drainage systems.

Proposed projects on sites with existing drainage systems need to include an analysis of current performance of existing drainage and detention facilities. The drainage system of the proposed project should not impact the existing system level of service. On sites with no existing drainage system, a level of service for the conveyance system should be established. The level of service should be designed to convey and contain at least the peak runoff rate for the 25-year design storm to be consistent with King County standards. Analysis for the proposed project, and future projects, would conform to this established performance.

RECOMMENDATION C-5: ESTABLISH A MINIMUM PIPE SIZE FOR CONVEYANCE SYSTEMS

The minimum pipe size for stormwater conveyance facilities should be a twelve-inch (12") diameter or equivalent pipe. This size is selected because of maintenance needs and the constraint of equipment required to perform the maintenance.

RECOMMENDATION C-6: REQUIRE FACILITIES TO INCLUDE WATER QUALITY FEATURES

Design measures which provide settlement and/or filtration of stormwater should be incorporated into stormwater facilities. Structural control measures can provide valuable water quality enhancement to surface water runoff. The two types of water quality control facilities recognized by King County to treat stormwater runoff are wet ponds and swales. They are primarily used to treat runoff from developed areas prior to discharge to sensitive natural drainage features such as wetlands, lakes and streams, and prior to infiltration. Both of these facilities utilize sedimentation, biofiltration, and biologic activity as the mechanisms for removal of pollutants.

3.3.2 Policy Issues

Policy issues established by the City are considered non-structural criteria. Examples include procedures for permit review, easement acquisition, and maintenance programs. Other types of policy issues such as inspection and enforcement are mandated by ordinance. The Ecology Stormwater Manual and the Puget Sound Water Quality Management Plan contain general policy considerations for stormwater management. The following policy recommendations will provide consistency with state policies for stormwater quality and quantity management.

RECOMMENDATION P-1: DEVELOP A CONSISTENT OPERATION AND MAINTENANCE PROGRAM

The objective of a consistent maintenance management system is to assure the reliability and dependability of the stormwater infrastructure. Management of the system is designed to minimize life-cycle costs, protect the lives and property of the residents living in the area, and enhance water quality. Retention/detention facilities and conveyance systems that are

maintained improperly may not effectively improve water quality or control flows which can cause flooding, erosion, and habitat damage.

RECOMMENDATION P-2: INCLUDE DETENTION AND WATER QUALITY TREATMENT FACILITIES IN THE DESIGN OF NEW PUBLIC WORKS PROJECTS

The construction of new roads, widening of existing roads, or replacement of bridges should include stormwater treatment facilities. It is estimated that streets contribute approximately 25% of the runoff in urban areas. The impervious surfaces caused by streets and parking lots contribute to increased flows which cause erosion by conveying stormwater more efficiently to streams. The quality of the runoff also contains heavy metals, oil and grease byproducts, and other pollutants which contribute to poor water quality in the streams.

Chapter 4 - HYDROLOGIC ANALYSIS

The hydrologic analysis for this report was performed using the methods and standards presented in the Stormwater Management Manual for Puget Sound developed by Washington State Department of Ecology (Ecology). The manual details minimum technical requirements which apply to all proposed development and redevelopment.

Three basic steps were involved in the computer modeling analysis. First, the model was calibrated for existing land use using a continuous gage placed in Horse Creek near its discharge point to the Sammamish River. Second, models for the other basins were developed based on the calibrated parameters and adjusted to represent future land use conditions. The models were then used with selected design storm event precipitation levels to create a synthetic sequence representing future flows. Third, various proposed control and conveyance measures were modeled to determine their effect on future flood flows at various points in the basins. This model calibration, current condition analysis, and simulation of future flows are discussed in this chapter.

4.1 MODEL BACKGROUND

Several models and techniques are available which estimate stormwater runoff rates and volumes. The Soil Conservation Service (SCS, 1972) SCS method provides a means of estimating a peak discharge of specified recurrence interval and the required storage volume of a detention facility. Application of the method requires basin area, identification of hydrologic soil groups, and determination of percent imperviousness and overall slope. The SCS method converts the incremental runoff depths for a given basin and design storm hydrographs of equal time base according to basin time of concentration and adds them to form the runoff hydrograph.

The Santa Barbara Unit Hydrograph (SBUH) method is based on the SCS Curve Number (CN) approach and utilizes basic SCS equations for computing soil absorption and precipitation excess and was developed by the Santa Barbara County Flood Control and Water Conservation District, California. The SBUH method directly computes a runoff hydrograph without going through an intermediate unit hydrograph process as the SCS method does. Incremental runoff depths are converted into instantaneous hydrographs which are then routed through an imaginary reservoir with a time delay equal to the basin time of concentration.

Hydrologic modeling for the Bothell Storm Water Master Plan was performed using the WaterWorks model (Engenious Systems, 1992). WaterWorks maintains a database in which the basin data is maintained throughout the process. The data consists of basin data, the description of all storage and discharge structures, and description of all reaches within the watershed. WaterWorks provides for two hydrograph computation methods, the SCS curvilinear unit hydrograph method and the SBUH method. Both methods are event-based to

simulate stream flow for individual storm events. The SBUH was selected as the model for the Bothell plan.

4.1.1 Design Storm Development

In general, the frontal storms that generate runoff in the Puget Sound basin are relatively homogeneous throughout the region. The data selected to characterize precipitation events for this study was based on isopluvials published by King County in the Surface Water Design Manual.

All storm event hydrograph methods require the input of a rainfall distribution or design storm hyetograph. The design storm hyetograph is essentially a plot of rainfall depth versus time for a given design storm frequency and duration. The hyetograph is the standard SCS type 1A rainfall distribution resolved to 10-minute time intervals for greater sensitivity in computing peak rates of runoff in urbanizing basins.

Design storms are the theoretical precipitation values used for the design of all stormwater facilities. Storm events are characterized as lasting 24 hours during which time the given amount of precipitation occurs. Each storm event is labeled by the chance of recurrence such that the "2-year storm" has a 50 percent chance of occurring in any year, likewise, the "100-year storm" has a 1 percent chance of occurring in any year.

Recurrence intervals of 2-, 10-, 25-, and 100-year were selected for use in the analysis of the drainage system and are consistent with guidelines recommended by Washington State Department of Ecology for stormwater management. Values of annual peak 24-hour precipitation totals were obtained from the King County Surface Water Design Manual and are presented in Table 4-1.

Table 4-1
Precipitation Recurrence Interval Totals

Recurrence Interval	Precipitation (inches)
2-yr	1.70
10-yr	2.50
25-yr	2.90
100-yr	3.60

The use of 24-hour storm events to design detention facilities in Puget Sound may not be appropriate for the hydrologic conditions found in the Puget Sound area. Current standards allow peak flow releases from detention ponds to be substantially higher when compared with

undeveloped conditions. This indicates that the volume required to fully mitigate peak flows with detention is actually much greater than the current methods estimate.

To address this discrepancy, stringent detention standards are proposed in the Ecology Stormwater Management Manual. The approach of the manual is to reduce degradation of streams and prevent flooding by requiring post-developed 2- and 10-year flows be reduced to predeveloped 2- and 10-year levels, respectively. The approved design event methodology is the single event approach. The manual recommends the use of the Santa Barbara Urban Hydrograph (SBUH) method, which incorporated much of the Soil Conservation Service (SCS, 1972) approach.

4.1.2 **Input Parameters**

Hydrograph analysis utilizes the standard plot of runoff flow versus time for a given design storm. The physical characteristics of the site and the design storm determine the magnitude, volume, and duration of the runoff hydrograph. Other factors such as the conveyance characteristics of channel or pipe, merging tributary flows, branching of channels, and flooding of lowlands can alter the shape and magnitude of the hydrograph.

One of the key advantages of hydrograph analysis is the ability to accurately describe the cumulative effect of runoff from several basins and/or sub-basins having different runoff characteristics and travel times. Data necessary for this analysis includes the acreage of the basin area, acres of impervious surfaces within the area, time of concentration in minutes, and the SCS soils curve number.

The study area was divided into basins characterizing Horse Creek, basins within the City Urban Growth Boundary which contribute to North Creek, Little Swamp Creek, and the basins contributing to the Sammamish River within the City as shown in Plate 1. The basins were delineated according to topographic divides that separate surface runoff into different basins. Sub-basins and reaches were further separated based on the division of the surface drainage network and are shown on Plate 1 in Appendix F. All sub-basins discharge surface drainage at the outlet of their respective reach.

The WaterWorks model requires the division of each drainage basin or sub-basin into pervious and impervious land use types, each with distinctive but reasonably uniform physical (soil, slope, and land cover) and hydrologic traits. Land types were delineated from SCS soil survey maps, city zoning designations, critical resource maps, and topographic maps.

Eleven land use classes consisting of one undeveloped pervious segment (forest, pasture, golf course, etc), and ten effective impervious area segments were determined. Effective impervious area segments represent areas with direct runoff from impervious surfaces hydraulically linked to the pipe or ditch network. The percent effectiveness for each of the classes of impervious land covers is shown in Table 4-2. Commercial and industrial zoning

designations correspond to the City OP, CB, GC, and LI categories. Multifamily high density residential designations correspond to R 16-25, MHP, and NB categories. Multifamily low density residential correspond with R 11-15 and CE designations. Other residential uses were divided into 1, 2, 3, 4, and 6 du/acre because of the changes in effective impervious values. Rural housing was not included in the residential designation because impervious areas are not usually connected to conveyance systems particularly in the area east of 35th Avenue S.E. Non-effective impervious areas in residential and commercial areas were assumed to have the same hydrologic characteristics as the non-forested underlying pervious soils.

Table 4-2
Effective Impervious Percentages
for City of Bothell Land Uses

Land Use	% Impervious
1 du/acre	15
2 du/acre	25
3 du/acre	34
4 du/acre	42
6 du/acre	52
Multifamily low density	55
Multifamily high density	60
Commercial/Industrial	90

Travel time is the time it takes water to travel from one location to another in a basin. The time of concentration is the time for runoff to travel from the hydraulically most distant point of the basin to the discharge point and is the summation of all travel times for consecutive components of the drainage conveyance system.

The time of concentration influences the shape and peak of the runoff hydrograph. Undeveloped areas produce very slow and shallow overland flow due to interception of the rain by vegetation. Urbanization usually decreases the time of concentration. What results is that flow is then delivered to streets, gutters, and storm sewers that transport runoff downstream more rapidly. Runoff flow velocity increases and travel time decreases because these conveyance systems have efficient hydraulic characteristics.

The Soil Conservation Service (SCS) conducted studies into the runoff characteristics of various land types. Relationships between land use, soil type, vegetation cover, interception,

infiltration, surface storage, and runoff were developed. The relationships have been characterized by a single runoff coefficient called a "curve number." The combination of these factors is called the "soil-cover complex." The soil-cover complexes were assigned to one of four hydrologic soil groups, according to their runoff characteristics. Table III-1.6 in the February 1992 Draft DOE Stormwater Management Manual lists the hydrologic soil groups of the most common soils in the Bothell planning area.

Typical hydrologic characteristics of each hydrologic soil group are described below.

"A" soils are characterized as having a low runoff potential. Soils have high infiltration rates, even when thoroughly wetted, and consist primarily of deep, well-to-excessively drained sands or gravel. These soils have a high rate of water transmission.

"B" soils have a moderately low runoff potential. Soils having moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

"C" soils have a moderately high runoff potential. Soils have slow infiltration rates when thoroughly wetted, and consist chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.

"D" soils have a high runoff potential. Soils have very slow infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Table 4-3 illustrates Curve Numbers for average antecedent runoff conditions representing each land use in the Bothell study area. The numbers represented in the table assume impervious areas are directly connected to the drainage system.

Table 4-3
SCS Curve Numbers for Soil Groups in Bothell

Land Use	CN (SCS Soil Groups)			
	A	B	C	D
Residential	68	80	86	90
Commercial/Industrial	68	80	86	90
Wetland	77	85	90	92
Open Water	76	85	89	91
Pasture	65	78	85	89
Forest	55	72	81	86

The SBUH model has the capability of routing flow from sub-basins along connected reaches of the drainage network to the outlet of a drainage basin. Routing allows the simulated runoff from different parts of a drainage basin to be correctly sequenced in time. In order to utilize the routing capability, the linked network of channels, drainage pipes, ponds, and wetlands that form the conveyance of each of the basins were divided into reaches. Drainage pipe routing assumes gravity flow conditions. The ditch reach utilizes the modified ATT-Kin routing technique developed by the Corps of Engineers. Pipes were assumed to be in "fair" condition for estimating the roughness coefficient. Tables III-1.4 and III-1.5 in the February 1992 Draft DOE Stormwater Management Manual list typical roughness coefficients for channels and values used in time calculations.

4.1.3 Model Assumptions

The development of the computer model for the City was based on several underlying assumptions. These assumptions can be divided into model requirements and physical limitations. The above section described the type of data necessary for the computer model. Assumptions relating to that data include recurrence interval and hydrograph information, conveyance characteristics, pervious/impervious land uses, and curve numbers. Other considerations that directly affect the model include basin and sub-basin delineation, reconciling land uses with pervious categories, and regionalized soil types into groups.

The previous sections addressed recurrence interval determination, hydrograph distribution, and curve number assumptions. The following discussion focuses on assumptions about the physical system and topography of the area surrounding Bothell.

Delineation of basins and sub-basins forms the basis of the hydrologic analysis. Contributing area is one of the most important input parameters for the model. The existing City maps of

the drainage system were instrumental in determining sub-basin tributary areas. For undeveloped areas, the 1"=100' topographic maps were used to determine basin divides. Without this type of information large delineation errors can result which carry into the computations for stormwater runoff rates and volumes.

Input parameters for land use within the City of Bothell were categorized using the procedures described above. These classifications are based on data from the Ecology Stormwater Management Manual and work performed by the U.S.G.S. which characterized rainfall-runoff relationships in the Puget Sound area (Dinicola, 1990).

The future analysis assumed new development will comply with the recommended design standards, operation and maintenance programs, and that the basins will be developed to the fullest extent as planned within the Urban Growth Boundary. New residential development designated as 2-5 du/acre was assumed to be developed at a density of 4 du/acre. Residential designations of 6-10 du/acre were assumed to be 6 du/acre. It was also assumed that only eighty percent of future development would be required to comply with new drainage regulations due to density or amount of impervious surface as described in the exemptions of the regulations. Further, all 1 du/acre residential development was assumed to be exempt from on-site detention requirements.

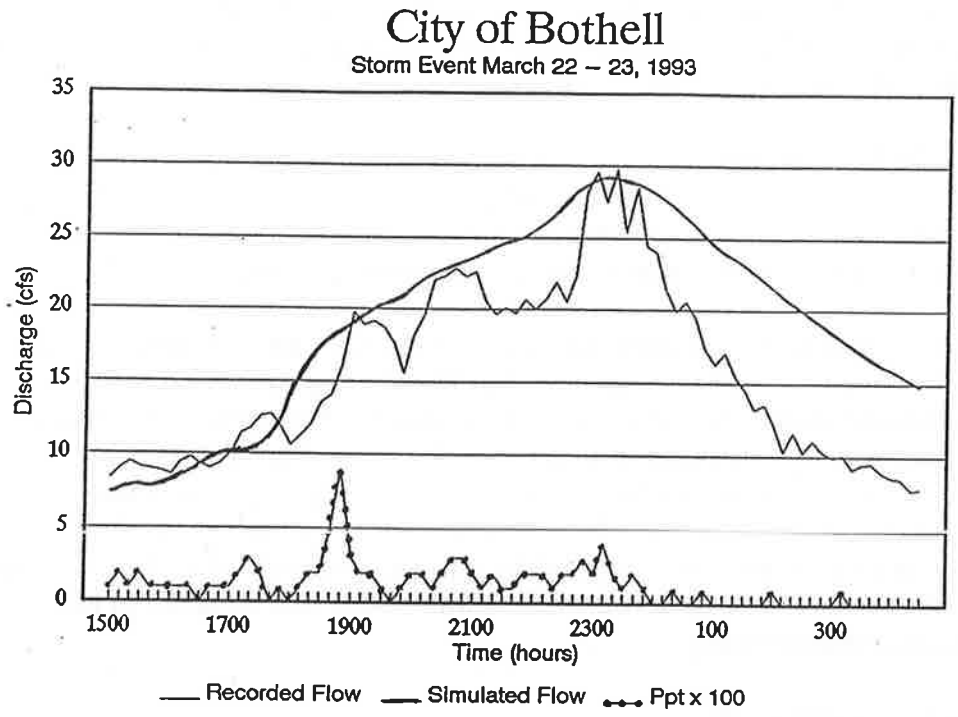
4.2 MODEL CALIBRATION

The computer model simulation requires a complete record of precipitation and stream discharge to describe the rainfall runoff relationship. A continuous stream gage was installed on Horse Creek near the discharge point to the Sammamish River. Data was collected at 10-minute intervals during March, April, and May. A stage discharge relationship was developed and verified with field measurements. Concurrently, rainfall data was also collected continuously at 10-minute intervals.

Two large precipitation events were selected to calibrate the model for Horse Creek basin. During March 22 and 23, 1993, 1.35 inches of rain accumulation was recorded. The period April 29 to 30, 1993, yielded 1.71 inches of rain. The events were chosen because they represent the two largest rainfall accumulations during the recorded time period. They also represent discreet events since they were preceded by a period of no measurable rainfall. This criteria is important for developing the model because of the single-event nature of the model methodology.

Simulated flows for the model calibration were based upon the parameters discussed above and on existing land use conditions. Table 2-1 provides a summary of commercial and residential land uses found in the subbasins for all modeled basins.

Figure 4-1 Simulation versus Recorded Flow in Horse Creek



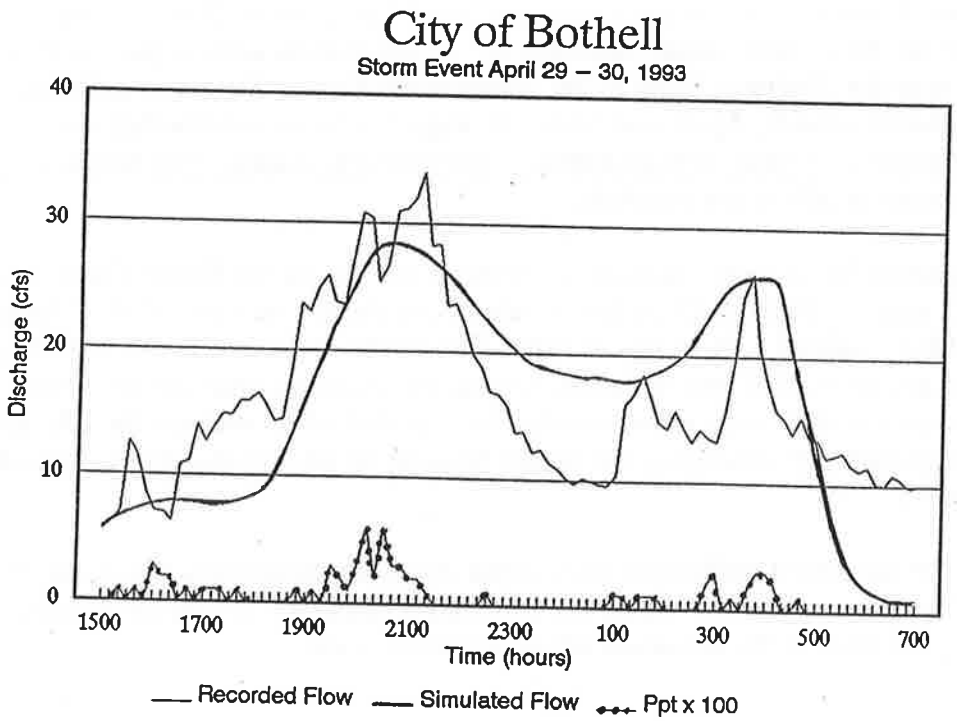


Figure 4-1 illustrates the simulation versus recorded flows for these two events. The model calibration matched observed peak flows and the general shape of the recorded discharge. However, model volumes for each event were overestimated from actual. A discrepancy between the recorded and simulated flows for the first peak on April 29 is probably due to residual base flow from an earlier rain shower on April 27. The primary conveyance in Horse Creek is through drainage pipes. Therefore, both timing and magnitude of peak flows are more important than total storm volume to determine pipe capacity.

Model parameters for the remaining basins were developed from the Horse Creek calibration data. The primary conveyance in the remaining basins is through open channels. The capacity of natural channels is generally considered to equal a 2-year 24-hour storm event. Therefore, the resulting depth of simulating the 2-year event should correspond to the full bank level of the open channel. Field measurements of the channels discharging from the Canyon Park, Wayne Golf Course, and East basins showed the model results represented full bank conditions.

Like all currently available rainfall-runoff models, the WaterWorks model represents simplification of the many complex physical processes that affect the various components of runoff generation in drainage basins. Although the model attempts to rigorously describe and account for most of the naturally occurring runoff processes, the inherent simplification or generalization of those processes produces differences.

4.3 CURRENT CONDITION ANALYSIS

The current condition analysis of the drainage network utilizes the existing land use to identify where problems occur for the 25-year, 24-hour return period precipitation event. Peak discharges for the 2-, 10-, and 100-year, 24-hour recurrence interval storm events were also simulated for further use in evaluating detention facility performance. The results of this analysis are discussed below.

4.3.1 Recurrence Interval Peak Flows

Stormwater in the study area is conveyed through a series of open ditches, natural channels, and pipes. In general, areas with a higher, more developed land use utilize a series of pipes and detention vaults to convey runoff. This type of system is more efficient at conveying the runoff resulting in a rapid response and elevated peak flow. Conversely, basins with a higher percentage of undeveloped land, wetlands, and open channels retain the runoff for a longer period of time. This is illustrated in Table 4-4, on the following page.

Table 4-4
Current Condition Peak Flows

Drainage Basin	Tributary Area	Current Peak Flows (cfs)			
		2-yr	10-yr	25-yr	100-yr
Horse Creek	951.68	27.00	45.78	55.84	74.38
North Creek Tributaries					
Queensborough Creek	282.78	12.03	20.27	24.70	32.82
Perry Creek	670.26	12.16	27.43	33.41	43.99
Royal Anne Road	314.87	7.17	12.73	15.66	20.94
Palm Creek	576.67	13.81	24.32	29.83	39.50
Unnamed Tributary	380.86	9.01	16.49	20.66	28.31
Sammamish River Tributaries					
Wayne Golf Course	361.80	9.44	17.84	22.41	31.28
South Hill	622.96	21.78	39.26	48.63	66.01
Little Swamp Creek	447.64	12.68	22.05	27.11	36.61

Differences in peak flows is attributed primarily to land use. The following table provides a comparison of land uses in terms of effective impervious and pervious functions. The percentages presented in Table 4-2 were used to convert the various land uses into pervious and impervious. The amount calculated as pervious was added to the pasture category in Table 4-5.

Table 4-5
Current Land Use Shown as Pervious and Impervious

Drainage Basin	Tributary Area	Impervious Area	Open Water	Wetland	Pasture	Forest
	Acres					
Horse Creek	952	310	19	20	420	183
North Creek Tributaries						
Queensborough Creek	283	99	0	0	144	40
Perry Creek	670	97	9	73	438	53
Royal Anne Road	315	55	0	8	208	44
Palm Creek	577	99	0	0	404	74
Unnamed Tributaries	381	24	0	17	124	216
Sammamish River Tributaries						
Wayne Golf Course	362	26	0	9	168	158
South Hill	623	168	0	16	269	170
Bloomberg	225	94	0	0	131	0
Little Swamp Creek	448	46	0	26	236	140

4.3.2 Problem Areas

Conveyance capacities of the existing system were exceeded at several locations throughout the basin when a 25-year representative storm was simulated. These problem areas were also identified by City staff as known flooding problems. Those locations are described below and are shown on Plate 2.

- 9th Avenue S.E. near 226th Street S.E.
- 96th Avenue N.E. between N.E. 198th Street and N.E. 203rd Street
- Piped conveyance of Horse Creek between Bothell Way to N.E. 195th Street
- Waynita Way near Valhalla
- N.E. 185th Street between Beardslee Boulevard and Ross Road
- 224th Street S.W. between 8th Avenue West and 4th Avenue S.E.
- North Creek and adjacent properties flood during large storm events
- Crystal Ridge Detention Pond at 6th Drive S.E. and 223rd Place S.E. is not functioning as it was designed
- Crystal Ridge Detention Pond at 226th Street S.E. and 7th Drive S.E. is not functioning as it was designed
- Crystal Ridge Detention Pond at 4th Avenue S.E. and 5th Drive S.E. no longer functions
- Detention facility on northeast corner of 228th Street S.W. and SR 527 needs maintenance and outflow control

- Canyon Crest #1 detention pond does not function and requires maintenance
- The natural channel near Richmond Road and 212th Street S.E. may be at risk for bank erosion and sedimentation problems
- The Queensborough tributary to North Creek exhibits erosion and sedimentation problems from excessive flows
- Stream reach between 228th Street S.E. and 212th Street S.E. and 39th Avenue S.E. is at risk for erosion and sedimentation
- The two stream reaches between 45th Avenue S.E. and 35th Avenue S.E. south of 228th Street S.E. are at risk under future conditions to bank erosion and sedimentation problems
- Little Swamp Creek north of 240th Street S.E. is at risk to bank erosion and sedimentation under future conditions
- Perry Creek exhibits bank erosion and sedimentation problems
- Upper reaches of Horse Creek may be at risk to bank erosion and sedimentation problems under future conditions
- The open channels of Wayne Creek and its' tributaries between 145th Street and Wayne Golf Course display bank erosion and sedimentation problems
- The natural channel between the conveyance system on 96th Avenue N.E. to discharge point in Horse Creek shows signs of bank erosion and sedimentation
- The open channel between the conveyance system on 98th Avenue N.E. and discharge point in Horse Creek show signs of bank erosion and sedimentation
- Open channel on conveyance system under 100th Avenue N.E. is at risk to bank erosion
- The open channel portion of Horse Creek near N.E. 188th Street is highly eroded
- The Horse Creek channel at its discharge point to the Sammamish River exhibits bank erosion
- The natural channel downstream of Canyon Crest #1 detention pond is highly eroded causing sedimentation problems into North Creek
- Erosion is evident on the banks of North Creek through the Canyon Park Industrial Park
- Discharge of surface water runoff from Beardslee Boulevard onto private property causes seasonal flooding

4.4 FUTURE CONDITION ANALYSIS

The model was used to simulate flows for future (full build-out) land use conditions in the drainage basins. Certain simplifying assumptions were made to simulate future hydrologic events. The future build-out condition is interpreted as the land use coverage that will exist sometime in the future when all the developable land in the basins has been urbanized to the extent allowed by the current zoning. This in itself is a fairly broad assumption in that it implies that zoning, a dynamic process, will stay constant. It also implies that all land will be developed to its maximum potential and that all undeveloped acreage will be converted. The zoning for any particular area can be obtained from the planning department of the City. Existing land use of tributary basins outside the Urban Growth Management Boundary was

not converted to higher density uses. A summary of projected land use in each basin is presented in Table 2-2.

For the purposes of simulation it was assumed that the conveyance system remained open-channel where it currently exists and existing wetland and in-channel storage would be maintained irrespective of the underlying zoning. While these assumptions will probably not hold true when the land is eventually urbanized, they are the closest approximations that can be made.

4.4.1 Recurrence Interval Peak Flows

Table 4-6 shows the peak flows for the 2-, 10-, 25-, and 100-year storm event that can be expected under future conditions. The relative increase in peak-flows is a function of changes in land cover. In addition, the magnitude of existing flooding problems increases. Those pipes, ditches, or detention facilities with existing capacity problems are unable to accommodate the increased runoff rates.

Table 4-6
Future Condition Peak Flows

Drainage Basin	Tributary Area	Future Peak Flows (cfs)			
		2-yr	10-yr	25-yr	100-yr
Horse Creek	951.68	29.73	50.01	61.02	81.07
North Creek Tributaries					
Queensborough Creek	282.78	12.03	20.27	24.70	32.82
Perry Creek	670.26	20.94	38.86	50.86	61.94
Royal Anne Road	314.87	7.17	12.73	15.66	20.94
Palm Creek	576.67	16.78	29.27	35.72	46.84
Unnamed Tributary	380.86	12.97	23.15	28.69	38.69
Sammamish River Tributaries					
Wayne Golf Course	361.80	15.43	28.11	34.96	47.57
South Hill	622.96	24.36	43.23	53.30	71.66
Little Swamp Creek	447.64	13.27	24.09	29.91	40.77

The basins demonstrating the greatest change in peak flows have relatively large percentage increases in impervious surface area and/or have forest cover removed from a relatively large percentage of the tributary area. The loss of forest cover represents a reduction in the amount of interception storage and a loss of detention or absorption provided by the organic debris that covers the forest floor. The increase in pasture represents the conversion of land surfaces to well-drained landscaped areas. Table 4-7 provides a comparison of land uses in terms of effective impervious and pervious functions. The percentages presented in

Table 4-2 were used to convert the various land uses into pervious and impervious. The amount calculated as pervious was added to the pasture category.

Table 4-7
Future Land Use Shown as Pervious and Impervious

Drainage Basin	Tributary Area	Impervious Area	Open Water	Wetland	Pasture	Forest
	Acres					
Horse Creek	952	365	19	20	380	168
North Creek Tributaries						
Queensborough Creek	283	99	0	0	144	40
Perry Creek	670	253	9	73	283	52
Royal Anne Road	315	55	0	8	238	14
Palm Creek	577	111	0	0	463	3
Unnamed Tributaries	381	40	0	17	324	0
Sammamish River Tributaries						
Wayne Golf Course	362	95	0	9	213	45
South Hill	623	200	0	16	285	122
Bloomberg	225	94	0	0	131	0
Little Swamp Creek	448	62	0	26	274	86

4.4.2 Problem Areas

The expected increase in future runoff rates intensifies existing flooding problems by increasing their frequency. Pipes, ditches, or detention facilities with existing problems are unable to accommodate the increased runoff rates. Simulations indicated that several other areas may experience capacity problems. Those additional flooding problem area locations are described below and are shown on Plate 2.

- Cross culverts under 228th Street S.E. at 31st Avenue S.E. is undersized
- Insufficient pipe capacity on Bothell Way between Ormbrek Street and N.E. 180th Street
- 3rd Avenue S.E. cross culvert near 234th Street S.E. is undersized
- Insufficent pipe capacity of cross culvert under 240th Street S.W. east of 7th Avenue S.E.

Chapter 5 - NONPOINT SOURCE POLLUTION ANALYSIS

Most pollutants originate on the land, where they are picked up by rainwater and carried into streams and rivers that empty into surface water bodies. Sources of nonpoint pollution are numerous, varied, and difficult to detect, but their cumulative effects on water quality and habitats in Puget Sound can be significant.

Nonpoint source pollution is usually associated with specific land use activities and encompasses a wide variety of possible sources such as:

- urban runoff
- agricultural runoff
- chemical spills
- septic tank and drainfield systems
- atmospheric deposition from cars and wood stoves
- improper waste handling and disposal practices

Early nonpoint source control efforts targeting on-site septic systems, agricultural practices, and forest practices were administered by different government agencies through separate programs. These programs produced some important local successes; however, overall control of nonpoint source control was inadequate. Meaningful control of nonpoint pollution is becoming more important due to the rapid population growth in the Puget Sound region. Because of their diffuse nature, nonpoint pollutant sources are difficult to characterize and control. Typical methods usually involve implementing land management and conservation practices which minimize disruptive land use activities and reduce the amount of pollutants introduced onto the land surface.

Water quality impacts from urban runoff are controlled by local conditions such as runoff characteristics, geometry, flow, and chemistry. Three primary characteristics of urban runoff, which potentially make the water quality impact different from treated point sources are 1) the random nature of the loadings, 2) the variability within and between events, and 3) the relative concentration of suspended solids in the discharges.

Loading from urban runoff can be determined by the characteristics of the urban runoff, the receiving water responses, and the water quality criteria employed to assess the impact of this type of discharge. Standard criteria allows for comparison of the data of interest to a safe or desired concentration or level. Water quality standards for freshwater quality in Washington State are established in Chapter 173-201 WAC.

The following discussion focuses on the criteria used to evaluate water quality, contaminants, and sources most common in stormwater runoff. In the next section, problems in the Bothell area are identified based on past and current investigations conducted by several agencies and research groups. Appropriate strategies for addressing problem areas and reducing adverse impacts are then summarized.

5.1 WATER QUALITY STANDARDS

Stormwater runoff constitutes the primary transport mechanism for nonpoint pollution. Pollution problems associated with land utilization and development encompass the common use of potential pollutants such as pesticides, fertilizers, petroleum products, and numerous others. A further problem from residential, commercial, and industrial land uses is the higher volume of runoff because of the higher percentage of impervious area. In developed areas, certain pollutants are more prevalent than in undeveloped areas. Pollutants accumulate in surficial soils and on paved surfaces from vehicular emissions, atmospheric deposition, spills, leaks, improper waste storage/disposal practices, and fertilizer/pesticide application. They are then washed off the land surface during subsequent storm events and transported via stormwater runoff to nearby water bodies or infiltrated to shallow groundwater supplies.

Nonpoint pollutants can also be discharged directly to surface waters via atmospheric deposition, spills, leaks, recreational boating, or improper waste disposal practices. Although these types of nonpoint pollution can be attributed to an individual source, their intermittent nature makes it difficult to identify and control these discharges. For the purposes of this report, these direct discharges have been considered nonpoint pollution sources. Parameters which define nonpoint pollution are discussed below in terms of state standards and potential sources.

5.1.1 Parameters of Concern

Water quality parameters affecting stormwater comprise a long list and are classified in many ways. Typical categories include sediment, nutrients, and metals; oxygen demanding and inert material; particulate and dissolved; chemical, biological, and physical; toxic and nontoxic; and organic and inorganic. Many specific pollutants are incorporated into one classification if their effects on receiving water are somewhat the same. Receiving water can assimilate a limited quantity of each, but there are thresholds beyond which the measured amount becomes a pollutant and results in an undesirable impact.

Human health considerations in fresh water can be monitored through the analysis of conventional water column parameters, nutrients, and oil and grease. The following section provides a brief description of contaminants, likely sources, and potential environmental effects.

Oxygen Demand or DO is necessary in water to maintain life. In the oxidation of organic matter by biological activities, oxygen from water is used. A problem from low DO results

when the rate of oxygen-demanding material exceeds the rate of replenishment. DO levels are especially important during summer when low stream flows and high temperatures make oxygen less available to aquatic life. Dissolved oxygen concentrations may also become critical when wastes that require oxygen for decomposition enter the water. In addition to diurnal variation, DO also varies with season and stream site. These natural variations are caused by differences in such things as light intensity and hydrological conditions. Natural variation can also be caused by water sources; groundwater or water draining bogs and marshes will typically have lower DO concentrations. Fish kills and reduction in aesthetic values have resulted from low-DO conditions.

pH impacts and is impacted by chemical and biological systems of natural waters. Similar to DO, pH responds to natural environmental factors. Changes in pH affect the degree of dissociation of weak acids and bases which affect the toxicity, reactivity, and solubility of many compounds. Diurnal variations in pH occur as a result of changes in production and respiration rates and different water sources such as groundwater or water draining wetlands.

Temperature extremes affect stream productivity and eventually may result in loss of aquatic life. Temperature also affects stream chemistry and varies diurnally and seasonally.

Turbidity is not a measurement of mass or concentration, it is a water quality attribute. Therefore, it can not be used as a quantitative measure to calculate loadings, but is used qualitatively to compare against a standard. Turbidity responds to physical factors such as runoff, proximity to exposed erodible soils, and stream flow.

Nutrients are chemicals that stimulate the growth of algae and water plants. Typical sources include detergents, fertilizers, septic system effluent, manure, etc. The primary nutrients of concern are nitrogen and phosphorus. Forms of nitrogen include ammonia, nitrite, and nitrate which are components of fertilizers, septic system effluent, and manure. Total phosphorus is a component of detergents, fertilizers, septic systems, and manure. The typical nutrient concentrations in runoff are usually more than sufficient to stimulate the growth of algal and plant species. The increased algal activity will cause a decrease in DO and an increase in surface algal scums, water discoloration, odors, and overgrowth of plants.

Nitrogen and phosphorus are the principal nutrients for algae and other plants in fresh water ecosystems including wetlands, streams, and lakes. Phosphorus is often the controlling nutrient for algae growth in fresh waters. A large input from nonpoint sources can result in algal blooms that can affect recreational use and reduce the overall quality of receiving waters. Nitrogen can affect the trophic status of receiving waters, but it is also an important parameter for waters used as drinking water supplies.

Pathogens/bacteria commonly refer to fecal coliform bacteria which are found in the intestinal tracts of warm-blooded animals, including humans. Fecal coliform bacteria in surface waters has historically been used as an indicator of water-borne pathogenic bacteria or viruses. Therefore, fecal coliform are used as indicators of public health concerns. High

levels can indicate failing septic systems, poor livestock management practices, poorly operated wastewater treatment systems, municipal storm and sanitary sewers, and other point or nonpoint sources.

High **oil and grease** concentrations are associated with urban and industrial stormwater runoff. In addition to representing a water quality problem they can also serve as indicators of a wide array of hydrocarbon compounds that can be toxic to aquatic life at low concentrations. Typically, oil and grease concentrations are low in receiving waters and are usually associated with runoff events.

Total suspended solids originate from erosion of urban and agricultural soils. Sediments washed off paved surfaces are transported by runoff and discharged to receiving waters. Land-clearing activities associated with urban development as well as poor livestock and crop management can accelerate soil erosion and increase sediment transport to receiving waters. The conversion of land from forest to urban increases impervious surfaces and accelerates stormwater runoff. The total volume and peak rate of stormwater is increased and can cause scouring in stream channels, thereby increasing the suspended solids loading in the stream.

Metals commonly found in stormwater runoff from road surfaces and parking areas that are of concern include lead, zinc, copper, chromium, arsenic, cadmium, and nickel. Other potential sources of metals originate from commercial car washes, auto repair facilities, and industrial operations. Most metals are adsorbed onto suspended solids present in the runoff and are probably not toxic to aquatic life.

Toxic organic compounds include a variety of contaminants such as pesticides, petroleum hydrocarbons, and volatile organic compounds. Potential nonpoint sources of these contaminants include urban and agricultural runoff, hazardous substance spills, improper disposal of waste products, and industrial discharges. Compounds that are most frequently found in runoff include phthalates, polynuclear aromatic hydrocarbons, volatile organic compounds, and some pesticides. The availability of toxic organic compounds is difficult to determine because of their adsorption to particulate matter. Particulate-bound contaminants are usually flushed out of the receiving system during high stormwater flows.

Organic material is an integral component of top soil. The organic content is mostly produced by microorganisms during the degradation of dead plant and animal material. The microbial degradation of organic matter in aerobic systems results in the consumption of oxygen. Waters high in organic matter may experience depressed oxygen concentrations relative to concentrations at saturation.

5.1.2 Criteria

Water quality standards for surface water in Washington State are established in Chapter 173-201 WAC. Standard criteria allows for comparison of the data of interest to a safe or

desired concentration or level. Management practices that violate established standards are subject to further investigation and ultimately appropriate corrective measures.

The Department of Ecology has responsibility for managing the state's water resources which are classified into five classes for surface water: Class AA (extraordinary), Class A (excellent), Class B (good), Class C (fair), and Lake. Specific surface water bodies are classified under WAC 173-201-080 or 173-201-085. All unclassified surface waters that are tributaries to Class AA waters are classified Class AA. All other unclassified surface waters within the state are classified Class A.

The WAC defines North Creek, Swamp Creek, and the Sammamish River as Class AA waters. Among the beneficial uses that a Class AA water must support are: water supply for domestic, industrial, or agricultural; stock watering; fish and shellfish rearing, spawning, and harvesting; wildlife habitat; and primary contact recreation, sport fishing, and aesthetic enjoyment. Water quality standards that apply to Class AA waters are presented in Table 5-1.

In addition to the water quality parameters listed in Table 5-1, concentrations of toxic substances, such as organic compounds and metals, must not exceed standards specified in WAC 173-201-047. These standards are based on the U.S. Environmental Protection Agency (EPA) Quality Criteria for Water (1986) which are derived from federal water quality criteria based on aquatic toxicology.

The WAC defines both acute and chronic criteria for toxic substances. Acute toxicity criteria are based on death percentages of test organisms within 24 hours. Chronic toxicity criteria are defined as the concentration that causes long-term adverse effects on an organism's functions.

Water quality criteria for nutrients are not defined in federal or state regulations for surface water. However, because of their influence on algal growth in surface waters, nitrogen and phosphorus are the nutrients of greatest interest in stormwater runoff. Phosphorus is often the limiting nutrient for growth of plants in freshwater systems. Phosphorus enrichment can, therefore, result in excessive algal blooms and associated nuisance conditions in streams and lakes. The general threshold for eutrophic conditions in lakes is 20 ug/l total phosphorus (Welch, 1980). Criteria for defining eutrophic thresholds in streams do not exist. However, Horner et al. (1983) proposed that soluble phosphorus in the range of 15 to 25 ug/l promotes nuisance conditions in streams.

Table 5-1
Water Quality Criteria for Class AA Waters*

(1)	Fecal coliform organisms	Freshwater - fecal coliform organisms shall not exceed a geometric mean value of 50 organisms/100 mL, with not more than 10 percent of samples exceeding 100 organisms/100 mL. Marine water - fecal coliform organisms shall not exceed a geometric mean value of 14 organisms/100 mL, with not more than 10 percent of samples exceeding 43 organisms/100 mL.
(2)	Dissolved oxygen	Freshwater - dissolved oxygen shall exceed 9.5 mg/L Marine water - dissolved oxygen shall exceed 7.0 mg/L. When natural conditions, such as upwelling, occur, causing the dissolved oxygen to be depressed near or below 7.0 mg/L, natural dissolved oxygen levels can be degraded by up to 0.2 mg/L by man-caused activities.
(3)	Total dissolved gas	Total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection.
(4)	Temperature	Temperature shall not exceed 16.0 degrees C (freshwater) or 13.0 degrees C (marine water) due to human activities. Temperature increases shall not, at any time, exceed $t=23/(T+5)$ (freshwater) or $t=8/(T-4)$ (marine water). ("t" represents the maximum permissible temperature increase measured at a dilution zone boundary, and "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.) When natural conditions exceed 16.0 degrees C (freshwater) and 13 degrees C (marine water), no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3 degree C. Provided that temperature increase resulting from nonpoint source activities shall not exceed 2.8 degree C, and the maximum water temperature shall not exceed 16.3 degree C.
(5)	pH	pH shall be within the range of 6.5 to 8.5 (freshwater) or 7.0 to 8.5 (marine water) with a man-caused variation within a range of less than 0.2 units.
(6)	Turbidity	Turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU.
(7)	Toxic, radioactive, or deleterious material concentrations	Toxic, radioactive, or deleterious material concentrations shall be below those which may adversely affect characteristic water uses, cause acute or chronic conditions to the aquatic biota, or adversely affect public health.
(8)	Aesthetic values	Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

* WAC 173-201-045(1)

Groundwaters in the state of Washington are established in Chapter 173-200 WAC. The standards establish criteria for maximum contaminant concentrations in terms of primary and secondary contaminants and radionuclides based on human health based criteria. Special protection areas can be designated because of wellheads and recharge areas that are vulnerable to pollution because of hydrogeologic characteristics and sole source aquifer status by federal designation. Currently, no special protection areas are recognized within the study area although the Snohomish County potion of Bothell's planning area is within the boundaries of a Groundwater Management Area study which is in progress.

5.1.3 **Sources of Nonpoint Pollutants**

The major types of nonpoint pollution sources in the Bothell area are related to urban development and agricultural activities. Other locally important sources of nonpoint pollution include transportation-related activities, illicit connections to the storm drain system, and improper waste storage and disposal practices. These nonpoint pollution sources, their associated pollutants, and impact on the study area are discussed in the following sections.

5.1.3.1 Urban Development

Urban development within the study area has changed in response to changes in population and services. Most land use changes have been the conversion of undeveloped land to residential uses. Historically, commercial and industrial activities were centered in the downtown district. However farmland in the North Creek valley has been modified to accommodate industrial and commercial activities.

Construction-related impacts occur both during and after project construction but are usually associated with land-clearing and site preparation activities. Areas that have been cleared of vegetation are more prone to erosion and can significantly increase sediment loading to nearby water bodies. Sediments can become deposited in natural and constructed channels thereby reducing the hydraulic capacity. The efficiency and capacity of associated stormwater control structures such as culverts, pipes, and detention facilities will also be affected by the deposition of sediment.

The amount of stormwater runoff also usually increases during construction as vegetative cover is removed. Leaf interception and infiltration provide a natural detention benefit while plant roots generally improve a soil's water holding capacity. When vegetation is removed from an area, the total volume and peak runoff rate increase which erode streambanks and accelerate channel scouring. This in turn can damage property, destroy riparian habitat, and degrade water quality.

Land use changes associated with construction can also result in the permanent removal of riparian zone vegetation, filling of wetlands and swales, increased impervious area, channelized creeks, and introduce other impairments to the natural drainage system. Past

and current construction practices and subsequent urban development in the Bothell area have undoubtedly lowered the retention capacity of the natural drainage system.

In addition to soil erosion, other pollutants can also be generated by building activities. These additional pollutants include pesticides, fertilizers, petroleum products, cleaning solvents, paints, asphalt by-products, acids, and salts as well as various solid wastes. These various pollutants are usually associated with chemical spills and leaks from construction equipment.

Post-development impacts from urban development continue even after construction is complete. Impacts are associated with increased runoff that occurs when forested lands are converted to residential, commercial, and industrial use, as well as the more intensive use of the land and resultant human activities that occurs after development.

The volume of stormwater runoff and peak discharge rate increases as a direct result of the increase in the amount of impervious area. Additionally, an increase in impervious surfaces decreases the infiltration and groundwater recharge. Higher flow rates accelerate bank erosion and scour in the receiving systems which result in an increase in sediment deposition further downstream. Higher flow rates can also cause localized flooding as the carrying capacity of natural streams and piped conveyance systems is exceeded.

In addition to sediment and flooding effects, urban runoff also carries contaminants such as nutrients, metals, and toxic organic compounds that can degrade water quality. Normal residential and commercial landscaping practices include application of fertilizers, pesticides, and herbicides. As a result, these contaminants are often found in urban runoff.

The elevated level of nutrients to the receiving water body can stimulate biological activity and increase the growth of nuisance aquatic plants and algae, which affect both the aesthetic quality and recreational use of the water body. Subsequently, as these plants decay and are broken down by microorganisms in the water, dissolved oxygen is depleted and aquatic life is threatened.

Urban runoff can also contain elevated concentrations of metals such as cadmium, lead, copper, and zinc. These contaminants are produced by dryfall from industrial and vehicle emissions, vehicle wear and tear, and chemical products. These metals individually or collectively can be toxic to aquatic organisms.

Other contaminants commonly found in urban runoff include toxic organic compounds such as pesticides and polynuclear aromatic hydrocarbons (PAH). Volatile organic compounds such as solvents may also be present in urban runoff and are typically associated with spills and improper waste disposal practices.

Nonpoint pollutants from urban runoff can also impact groundwater and wetlands through recharge from infiltration. Undeveloped areas are usually groundwater recharge areas while

infiltration through wetlands is not as significant. Both transport pathways are probable sources of contaminants. Recharge may be less important because of the predominance of glacial till soils which generally impede infiltration of surface water. Urban activities in the area that are known to pose a high risk to groundwater include:

- Decrease in recharge due to impervious surfaces which divert water in conveyance systems and remove runoff from the recharge areas.

- Decreased groundwater infiltration in combination with pollutant loading via the groundwater has had detrimental effects on aquifers.

Nonpoint pollution can be a significant threat to wetland quality and functions. Most wetlands sites have been disturbed to varying degrees by human or livestock practices. Urbanization of an area frequently results in clearing of vegetated areas that include the loss of wetlands. Vegetation plays a major role in regulating urban runoff by intercepting rainfall and reducing overland flow. Urbanization increases impermeable surfaces which increase stormwater transport to receiving bodies of water. Erosion and flooding problems are indicative of these land surface conversions. Urbanization often results in the invasion of nonnative plant species such as purple loosestrife, reed canary grass, and smooth cordgrass to disturbed areas. These invasive species frequently form monotypic stands which limit the wildlife value of the area.

Urbanization also generally results in more frequent instances of human intrusion into remaining forest adjacent to development resulting in:

- Garbage and debris deposition such as tires, refrigerators, shopping carts, lawn clippings, and yard waste

- Channelization and drainage or placement of fill for conversion to other land use

- Pet disruption of wildlife

- Petroleum products deposition

5.1.3.2 Agriculture Activities

Nonpoint pollution from agriculture use in the area consists primarily of small hobby farms and small ranches. The cumulative effects from these activities often result in nonpoint pollution problems. Generally agricultural activities involve crop production and animal grazing and pasturing. Animal keeping activities appear to be the most significant source of agricultural nonpoint pollution in the area. Pasturing and boarding of animals generally contribute to nonpoint pollution through waste management and poor grazing practices. Runoff from barnyard and pastureland may contaminate water supplies, destroy aquatic life

in streams, and generally degrade water quality. Nitrate, ammonia, organic carbon, and fecal coliforms are commonly elevated in runoff from land used by livestock.

Poor grazing practices that permit overgrazing contributes to soil erosion. When livestock are allowed direct access to open bodies of water, they severely damage the banks, causing erosion and bank sloughing. The direct access of animals to streams, ponds, and wetlands also promotes direct disposal of feces and urine wastes. The associated nutrients, organic loads, and pathogens are then introduced to the surface water system. Large quantities of suspended sediments generated by soil and bank erosion cause sediment deposition which contributes to the destruction of habitats of aquatic plants and animals. Sediment deposition further restricts flow through conveyance systems and may cause localized flooding.

Agricultural activities further disrupt the hydrological regime of wetlands through construction of ditches and dikes. Native plant species and communities are often invaded by exotic plants because of disturbance to the area or due to seeding and planting of the area for agriculture or livestock.

Grazing of an area can degrade wetland quality and functions through simplification of the vegetation communities. Plant species numbers are reduced and structural complexity of the habitat is also reduced.

5.1.3.3 Other Nonpoint Sources

Other sources of nonpoint pollution of concern include highway runoff, spills, uncontrolled runoff from chemical storage and waste disposal areas, improper waste disposal practices, and illegal connections to the storm drain system. These additional sources can contribute a wide variety of pollutants to adjacent surface waters. For some nonpoint sources, pollutant loadings and transport pathways are not related to stormwater runoff.

Stormwater runoff from state and county highways and city arterials are similar to runoff from residential streets because it can contain elevated concentrations of metals, suspended solids, and organic compounds such as petroleum hydrocarbons. Studies have shown that pollutant loading is directly related to the amount of vehicle traffic during the storm (Horner and Mar, 1982). Therefore, major highways with high vehicle use can be significant sources of nonpoint pollutant loading. Sanding and road deicing in the winter further contributes sediment and nutrients to the drainage system. Major thoroughfares in the study area include State Route 522, Bothell-Everett Highway, and Interstate 405.

Periodic spills into surface water conveyance systems can occur in spite of the best management efforts due to ignorance or accidents involving hazardous substances. Significant spills usually result from accidents associated with transportation, fuel storage facilities, or industrial sites. Application of pesticides for agricultural purposes and road right-of-way weed control, particularly those that occur adjacent to streams, wetlands, or stormwater conveyance structures, is also of concern.

Waste disposal facilities can contribute toxic substances to nearby surface water systems. Improper chemical storage and waste disposal practices are the common cause of contaminates migrating off-site of these facilities. Chemical storage problems are usually associated with commercial or industrial facilities. Often, storage areas are located outside without adequate cover or containment. Stormwater that comes in contact with these areas may contain elevated concentrations of contaminants such as petroleum hydrocarbons, pesticides, and solvents. Two waste disposal facilities are located in the vicinity. No reported contamination of surface water or groundwater supplies has resulted from these facilities.

Potential problems caused by improper waste disposal practices apply to residential as well as commercial and industrial operations. It is usually impossible to trace the source of contamination from residential practices. Waste oil disposal from individual car maintenance activities is a common source of nonpoint pollution. Used crankcase oil is often poured on the ground or directly into a nearby catch basins for disposal. Ignorance of the potential environmental damage and limited availability of waste oil recycling centers contribute to the problem. However, public awareness programs have helped to reduce the occurrence of waste oil discharge to storm drains.

Other practices that generate nonpoint pollution include dumping of household trash, yard clippings, and general garbage in undeveloped areas, creeks, hidden road turn-outs, construction sites, and other public access areas perhaps as a result of rising landfill costs and associated tipping fees. Isolated waste sites may not cause a problem, but the cumulative nutrient and toxic load from such practices could be significant. Problems such as decomposing yard waste and toxic or hazardous seepage from various products in household garbage can affect both surface and groundwater resources.

Nutrients, bacteria, and toxic substances may also enter drainage systems through illegal connections. Drain or outlet pipes that should be connected to a sanitary sewer or discharge to a treatment system are considered illegal connections. Because of their illicit nature, these sources are often difficult to locate. Typically, detailed field investigations and dye tracing studies are required to identify these connections.

Examples of improper connections include washwater from commercial car washes, industrial discharges, and domestic wastewater. Historically, service stations have had a higher rate of illegal connections than other types of businesses. Floor drains in maintenance areas are often incorrectly plumbed to the storm drain system. The number of illegal connections to a system is usually small. However, because a single connection can contribute a large pollutant loading, illegal connections are considered to be a potentially significant source of nonpoint pollution.

5.2 EXISTING WATER QUALITY STUDIES

This section presents an overview of existing water quality information available for the Bothell area. The discussion includes results from Watershed Management Plans completed by Snohomish County for Swamp Creek and North Creek and results from samples collected by Snohomish County and Metro.

5.2.1 North Creek Watershed Management plan

Snohomish County initiated the planning process for the development of the North Creek Watershed Management Plan in November 1990 after being awarded a Centennial Clean Water Fund Grant from Ecology. The Surface Water Management section of the County worked closely with the Watershed Management Committee which was comprised of representatives from various County departments, cities, tribes, and private and environmental interests. The City of Bothell participated on this committee. The purpose of the plan was to:

- Make County and City elected officials, County and City department, and the general public aware of the serious nonpoint pollution and flooding problems present in the North Creek watershed; and

- Set forth actions to control nonpoint pollution and flooding problems in the watershed.

Elements of the plan included a watershed characterization, water quality assessment, nonpoint source problem identification, and recommended actions. The first three elements focused on the collection and analysis of existing information to evaluate the impact of nonpoint pollution within the whole watershed. Included in the analysis was a review of existing water quality information for North Creek. Stream surveys conducted since 1972 by Metro and the current Snohomish County water quality survey initiated in July 1990 were included in the review.

Based on these existing studies, the water quality of North Creek was rated poor to fair. Problem water quality parameters include fecal coliform bacteria, dissolved oxygen, turbidity, total suspended solids, and nutrients. In addition, concentrations of several metals (lead, copper, zinc) measured by Snohomish County occasionally violated water quality standards during 1990-1991 wet-weather conditions. Low concentrations of oil and grease and total petroleum hydrocarbons were generally found on the sampling events which were not targeted for storm event analysis (Snohomish County, 1991).

The County determined the cause of water quality degradation in North Creek was attributed to nonpoint source pollution originating from urban and agricultural land uses. Specific

water quality problem areas which were identified in the North Creek Basin that are within the Bothell Growth Management Area included:

- Flooding impacts from urban development in the general location of I-405 and 228th Street Interchange area.

- The reach adjacent to the Canyon Park Industrial Park provides poor habitat for fish because it is badly channelized with little pool formation and meandering. Much of the streamside vegetation has also been removed along this reach. Periphyton growth is heavy, indicating high nutrient input, possible from fertilizers used on landscaping at the industrial park. Iron bacteria may also be present in one of the detention ponds serving the park.

Because the water quality of North Creek is poor, long-term corrective actions were recommended. Actions were grouped into ten categories and seventy-four specific watershed actions to control nonpoint pollution and flooding problems were identified. Those actions which apply to the City include:

Administration related activites such as (1) increased inspection and plan review, (2) staff workshops, (3) conservation district staff, (4) watershed keeper, and (5) emergency complaint response.

Capital Improvement Program projects for the (6) Crystal Ridge Detention Pond, (7) 9th Avenue Ditch enlargement, (8) 3rd Drive S.E. Flood Control, (9) 13th Drive S.E. Ditch Reconstruction, (10) Canyon Park Channel Restoration, (11) Crystal Ridge Development Stream Rehabilitation, and (12) Lower North Creek agriculture management.

Finance related actions include (13) financial incentives to property owners to protect water quality.

Interagency/Governmental Coordination activities to include the (14) deterrent of illegal waste disposal, (15) coordinate with Ecology on clean-up actions, and (16) interlocal agreement for watershed keeper.

Land Acquisition actions include (17) Crystal Ridge Duck Pond and (18) inventory of riparian corridors.

Monitoring strategies to (19) coordinate with NPDES efforts and ambient water quality monitoring program.

Maintenance and Operation activities such as (20) consistent drainage system maintenance, (21) maintenance standards for facilities, (22) storm response standards, and (23) waste reduction techniques.

Predesign Alternative Analysis related actions including Crystal Ridge (24) inventory, (25) flood control, and (26) ravine protection, (27) bid flood control, and (28) Soil Conservation District inventory.

Public Involvement and Education activities include (29) pumper certification training, (30) contractor training/certification, (31) voluntary ditch maintenance, (32) public relations brochure, (33) farm owner education, (34) public involvement/brochures, (35) neighborhood organic waste, (36) annual creek clean-up days, (37) citizen advocate training, (38) general BMP manual for watershed residents, and (39) catch basin stencilling.

Regulatory/Enforcement measures include (40) adopt and enforce state design criteria and (41) increase enforcement authority.

5.2.2 Swamp Creek Watershed Management Plan

The Swamp Creek planning process was initiated in April 1990 by Snohomish County Surface Water Management section after being awarded a Centennial Clean Water Fund Grant from Ecology. The Surface Water Management section of the County worked closely with the Watershed Management Committee which was comprised of representatives from various County departments, cities, tribes, and private and environmental interests. The City of Bothell did not participate on this committee. The purpose of the plan was to:

- Make County and City elected officials, County and City department, and the general public aware of the serious nonpoint pollution and flooding problems present in the North Creek watershed; and

- Set forth actions to control nonpoint pollution and flooding problems in the watershed.

Elements of the plan included a watershed characterization, water quality assessment, nonpoint source problem identification, and recommended actions. The first three elements focused on the collection and analysis of existing information to evaluate the impact of nonpoint pollution within the whole watershed. Included in the analysis was a review of existing water quality information for Swamp Creek. Stream surveys conducted since 1972 by Metro and the current Snohomish County water quality survey initiated in July 1990 were included in the review.

Water quality parameter problems included fecal coliform bacteria, dissolved oxygen, and nutrients. In addition, concentrations of several metals (lead and (1) measured by Snohomish County routinely violated water quality standards at most sampling locations in the watershed. Low concentrations of oil and grease and total petroleum hydrocarbons were generally found on the sampling events which were not targeted for storm event analysis (Snohomish County, 1992).

The County determined the cause of water quality degradation in Swamp Creek was attributed to nonpoint source pollution originating from urban and agricultural land uses. Only one specific water quality problem was identified in the Swamp Creek Basin that is within the Bothell Growth Management Area. This problem is located at 240th Street S.E. near 88th Avenue N.E. Currently, the culvert is preventing anadromous fish from migrating upstream.

Similar to findings from the North Creek Plan, long-term corrective actions were recommended. Actions were grouped into ten categories and seventy-one specific watershed actions to control nonpoint pollution and flooding problems were identified. Many of the Administrative, Finance, Maintenance and Operation, Public Involvement and Education, and Regulatory/Enforcement actions apply to the City. However, only one Capital Improvement Program project was identified for potential action by the City. The replacement of the culvert under 240th Street S.E. was identified to be implemented by several agencies including Snohomish County Department of Public Works, Adopt-A-Stream Foundation, Muckleshoot Indian Tribe, and the Washington State Department of Fisheries.

5.2.3 **Metro Studies**

The water quality of the Sammamish River has been characterized as fair to poor by a number of the parameters regularly measured by Metro since the early 1980s. The river regularly violates standards for temperature and dissolved oxygen in the summer and fecal coliform throughout the year at the sampling site near Bothell. Over the last six years it had the highest average temperature and fecal coliform levels, the second highest nutrient levels, and the second lowest oxygen levels of the rivers sampled in the Puget Sound Ambient Monitoring Program (PSAMP).

Despite these violations, the last 10 years of data indicate that a number of parameters are improving. There have been significant decreases in turbidity, fecal coliform, and nitrates, while pH has increased. However, no improvements in temperature and dissolved oxygen, two important parameters which affect fish health, are apparent.

Samples analyzed during 1991 indicate the Sammamish River violated water quality on nine sampling dates, more than any other river measured by the Puget Sound Ambient Monitoring Program. The river exceeded fecal coliform standards in six months of the year, the temperature standards in July and August, and the dissolved oxygen standard.

5.3 SURFACE WATER QUALITY MANAGEMENT STRATEGIES

The biggest challenge facing local government is the effective management of urban stormwater. Stormwater runoff is conveyed through intentional and unintentional conveyances to surface water bodies such as lakes, streams, wetlands, or to areas where it infiltrates into groundwater. Runoff picks up pollutants from the various human activities in residential, commercial, and industrial areas. In addition, the large impervious surfaces in

urban areas increase the quantity and peak flows of runoff, which in turn increase flooding and erosion of ditches and stream channels. The result is an increase in the pollutant load of the receiving water.

Pollutants in stormwater runoff can cause a wide range of impacts to the natural environment. Some pollutants such as metals, oil and grease, and organic toxins are toxic to aquatic organisms if concentrations are high enough. Sediments can cause tissue abrasion and gill clogging in fish and can smother fish spawning habitat. Nutrients accelerate eutrophication of lakes and ponds resulting in nuisance algal blooms, reduced clarity, odors, and reduced drinking water quality.

The pollution control strategy for reducing these impacts from urban development is through the implementation of Best Management Practices (BMPs). BMPs can provide a cost effective method for meeting surface water, groundwater, or sediment quality standards. Examples of urban BMPs include:

- Operation and maintenance programs for public and private stormwater facilities. Maintenance is necessary to ensure the proper function of facilities. Poorly maintained facilities can become a source of pollutants when sediments and other materials are flushed into receiving waters during storm events.

- Controlling stormwater quantity and quality from all new development and redevelopment. Design standards reduce changes to existing natural systems, detain runoff onsite as long as possible, and prevent erosion by requiring erosion and sedimentation plans.

- Education programs inform citizens about stormwater and its effect on water quality, flooding, and fish/wildlife habitat.

State programs for controlling nonpoint source pollution from agricultural activities relies upon voluntary implementation of Best Management Practices (BMPs). Agricultural BMPs are agronomic, managerial, or structural techniques which reduce impacts to water quality. Examples include:

- Waste holding ponds,

- Fencing along riparian zones,

- Better field management, and

- Crop rotation.

The use of conservation district/SCS farm management plans is the preferred approach to controlling pollution from both commercial and non-commercial farms. The Snohomish

Conservation District, the Washington State Cooperative Extension, and the USDA Soil Conservation Service all provide technical assistant to farmers and promote farm planning and the use of agricultural BMPs. The effectiveness of these programs is limited by inadequate funding and lack of technical and other assistance for non-commercial farms.

Other sources of nonpoint pollution result from improper disposal of household hazardous wastes, periodic spills, and uncontrolled runoff from state and county highways. Often the best management of these sources includes improving educational programs which stress waste reduction and recycling. Other methods include utilizing existing networks such as trade associations to educate the private sector, promote cooperation among groups and institutions, and provide hands-on education for both children and adults.

5.3.1 **Recommendations for Nonpoint Pollution Control**

Measures for controlling nonpoint pollution sources often involve alternatives for land use management, regulations, monitoring, maintenance, emergency response, enforcement, and intergovernmental cooperation. These measures encompass the use of non-structural and structural controls. Non-structural approaches embrace a wide variety of measures enacted before, during, or after a development project in order to improve the quality of stormwater runoff discharging from the project area. Some of these measures involve planning, while others concern project design, management, or specific practices in the field. Structural controls are physical changes to the conveyance system. They include detention/retention ponds, treatment facilities, erosion control measures, and constructed wetlands.
The focus of non-structural alternatives is on preventive measures to assure future development does not increase or contribute to flooding or water quality degradation. In addition, non-structural solutions compliment actions to control stormwater which do not result in a long-term physical change in the drainage system. Thus, non-structural controls may include land use management, easement dedication, regulations, monitoring, maintenance, public education, emergency response, enforcement, and intergovernmental cooperation.

Non-structural methods for improving water quality from various land uses can be divided into regulatory and non-regulatory actions. Management approaches that are regulatory in nature are characterized by their legislative mandate and governmental powers to protect the health, safety, and welfare of the general public. These measures can be implemented as individual components, together, or in combination with other measures. Non-regulatory measures include citizen volunteer programs and public education which promote awareness of water quality issues, programs such as monitoring water quality, and policy actions such as operation and maintenance. These non-structural programs will require additional administrative, engineering, and maintenance staff to ensure implementation is carried out.

The following recommendations describe methods which will reduce the frequency of flooding and provide improved water quality benefits within the Bothell area.

RECOMMENDATION #1: Adopt Water Quality Design Standards for Stormwater Management Based on the DOE Stormwater Manual

Preventive measures such as drainage and land use regulations can reduce flooding and water quality problems before they occur. Policies and ordinances regulating construction Best Management Practices (BMPs) and stormwater detention and discharge can minimize new development impacts on the existing system.

Construction activities contribute to the stormwater pollution problem because of the potential for erosion from construction sites. Local governments typically attempt to control erosion and sedimentation during construction by requiring the application of appropriate BMPs. Additionally, local governments often regulate the construction of drainage systems by requiring permits and reviewing designs. These processes are most effective in controlling erosion and the quality and quantity of runoff following development when utilized together.

RECOMMENDATION #2: Enforce Stormwater Standards through Inspector Training and Site Inspection Procedures

The increase in environmental regulations can strain existing inspection and enforcement resources. Augmenting existing code enforcement and judicial personnel should reduce erosion and sedimentation incidents. Additionally, staff from other divisions should be trained to recognize violations and notify the proper enforcing division at the City.

The Uniform Fire Code (UFC) can be used to control surface water runoff pollution. The UFC is adopted by reference in RCW 19.27A.010. Counties and cities are required to enforce the minimum provisions of the UFC which says, "Hazardous materials shall not be released into any sewer, storm drain, ditch, drainage canal, lake, river or tidal waterway, or upon the ground, sidewalk, street, highway or into the atmosphere." This section gives local fire departments wide latitude to deal with inappropriate release and control of hazardous materials. Since all fire departments conduct regular inspections of commercial/industrial facilities, they can be particularly effective at detecting and correcting potential problems.

RECOMMENDATION #3: Develop an Operation and Maintenance Program for the Stormwater Conveyance System

The objective of a stormwater system maintenance program is to assure the reliability and dependability of the stormwater infrastructure, including catch basins, pipe networks, and open ditches. Retention/detention ponds and conveyance or treatment systems that are maintained improperly may not effectively improve water quality or control flows. Discharge of untreated, poor quality water from roadways and urban impervious areas could reduce beneficial uses of surface water and the use of groundwater for domestic water supply. Uncontrolled flows can contribute to flooding, erosion, and habitat damage.

The hydrologic modeling for this drainage plan assumed that all drainage facilities, including on-site and future regional detention ponds, will be maintained on a regular schedule and will operate as designed. If adequate on-site and regional facility maintenance is not provided, the model predictions in the drainage plan may not be valid.

A regulated maintenance program must be implemented to provide the periodic actions required to maintain and assure continual operational effectiveness of the system. In addition to cleaning and repair, the program must include inventory update and record keeping, regular facility condition assessment, and resource allocation. General guidelines for Operation and Maintenance of stormwater systems can be found in the Department of Ecology Stormwater Program Guidance Manual (DOE Manual). Proper disposal of waste materials from maintenance activities may require special considerations. An overview of appropriate maintenance activities to be performed by the City is discussed below.

The procedure for maintaining the stormwater system inventory will include updating maps and facility lists on a regular basis. The condition of each portion of the drainage system should be evaluated on a regular basis. The inspection will determine if a detention or conveyance facility is in need of maintenance based on a threshold or level of service.

Scheduling of maintenance and allocation of resources will provide the City with a predictable work plan. Recommended minimum maintenance activities are shown in Table 5-2. Maintenance activities assume all open ponds are either owned or maintained by the City.

Table 5-2
Minimum Maintenance Activities

System Component	Schedule
Catch Basins, Manholes	Once every five years
Pipes, Culverts	Once every five years
Ditches Clean & Reshape Vegetation control	 Once every five years Annually during late spring
Detention Basins Clean & sediment removal Vegetation control	 Once every four years Annually during late summer
Detention Vaults	Once every five years
Detention Pipes	Once every five years

In the past, maintenance practices have been limited to removal of debris, sediment, and vegetation buildup from ditches to maintain hydraulic capacity and appearance. This timing of this activity may have resulted in increased erosion following cleaning and elimination of vegetation that could provide biofiltration.

The disposal of vactor truck wastes generated by the Maintenance program is not identified specifically in local or state regulations. Generally it is recommended that sediments be disposed of at a sanitary landfill. However, many landfills and the associated health departments do not follow a strict policy on the disposal of vactor truck wastes and their recommendations to truck operators may vary. The City is currently participating in programs with Snohomish and King Counties to evaluate the disposal practicies and locate appropriate facilities for the waste.

RECOMMENDATION #4: Develop an Ambient Water Quality Monitoring Plan

Monitoring will provide information to evaluate the effectiveness of water quality control facilities and to identify potential water quality problems before serious degradation occurs. Quality Control/Quality Assurance, sampling assessment, and data management should be consistent with "Technical Guidance for Assessing the Quality of Aquatic Environments" (DOE, 1992) and include the use of recommended Puget Sound protocols.

Different types of water quality monitoring are necessary to provide the data for evaluating improvements to the drainage system. To assess existing environmental conditions and the effects of human activities, it is necessary to collect baseline and long-term information through "ambient" monitoring. This type of monitoring can assist decision-making by characterizing spatial and temporal trends, providing an ongoing assessment of the health of the receiving waters, and identifying problem areas.

Monitoring can also be used to measure parameters which support specific program elements. The success of proposed improvements in the drainage plan can be measured by providing a permanent record of significant natural and human-caused changes in key environmental indicators over time. An example is to conduct a thorough physical and biological survey of the reach influenced by a regional project prior to construction. Water quality monitoring before, during, and after the project will help determine the effectiveness of controls and impact of the project to the system.

RECOMMENDATION #5: Develop a Public Involvement and Education Plan to Inform Area Residents on Nonpoint Pollution

Pollution prevention requires an ongoing commitment from an informed, involved public. Both education and public involvement are necessary components of a long-term management strategy for the Sound and its resources. Education is necessary to foster public recognition of the Sound as a regional and national resource, and to stimulate public, governmental, and private sector support for the changes in lifestyle and financial commitment necessary to

preserve the Sound. Education can supplement enforcement programs and is recognized as the effective resource management tool to address those problems which result from individual actions such as improper disposal of wastes from households, automobiles, or boats.

Many harmful activities such as wetland filling or disposal of used oil and household chemicals into storm drains occur because residents do not understand the consequences of their action. Public awareness is a critical aspect of environmental protection and citizen participation. The emphasis is on prevention rather than remedial action. Public involvement and education are necessary components of a long-term management plan.

The Puget Sound Water Quality Plan contains a program element for education and public involvement which focuses on strategies to inform, educate, and involve individuals, groups, businesses, and industry in the cleanup and protection of Puget Sound. By utilizing this program element to develop a long-term Public Involvement and Education Plan the City can:

- Develop a Public Information and Exchange Board at the City complex and library. Informational brochures on alternative methods for reducing pollution could be readily available for community residents.

- Organize an annual clean up day to encourage residents to responsibly dispose of unused cleaning supplies, paint, and other household hazardous waste products.

- Paint "Dump No Waste" on catch-basins.

- Establish educational programs for protecting water resources with the local school districts.

- Require local contractors, developers, and engineers be trained and certified in the use of best management practices and erosion control.

RECOMMENDATION #6: Develop a Spill Response Program which Coordinates Federal, Local, and Private Efforts

Spill response and prevention strategies ensure that the response action of state agencies are coordinated with federal, local, and private efforts. Hazardous materials can endanger human health or the environment because of quantity, concentration, or specific physical, chemical, or infectious traits. Many federal, state, and local programs exist to regulate hazardous materials. The programs are not comprehensive, and no single government or private entity is responsible for overseeing the number aspects of hazardous materials.

The large number of hazardous materials present in the Puget Sound region creates a high potential for mishaps, and large and small spills routinely occur. Such spills have obvious potential for significant water quality impacts, both short and long term.

Prevention is the best protective and cost-effective method available to minimize environmental impacts. Response to spills can be considered a form of prevention however the technology for containing and cleaning up a spill or oil or hazardous substances is in the early stages of development. A plan which adequately addresses spill prevention and anticipates spill response actions should be developed by the City.

RECOMMENDATION #7: Develop a Drainage Complaint Response Program

During storm events, citizens call City offices to complain about localized flooding. The development of a complaint response program to process these calls will provide a record for future action. Complaints can be compiled in a methodical manner for evaluation of the conveyance system or maintenance activities. For instance, a larger more regional problem may exist in areas which consistently experience local flooding problems. Other information can be used to identify future maintenance activities by City staff.

5.3.2 Effectiveness Evaluation

There are many best management practices (BMPs) available to protect the quality of receiving waters from degradation and to correct existing problems. The question of how best to use BMPs to control runoff, manage floodplains, and detect illicit connections is a difficult one.

Applying the right control measure to solve a water quality problem requires the examination of the pollutant removal characteristics of each measure as well as cost, maintenance requirements, and impacts on the environment and adjacent communities. Ranking the priority of measures to prevent or reduce nonpoint pollution can be based on the relative toxicity and the persistence of the pollution source. Purely environmental considerations must be balanced by the policy requirement of making a plan and its implementation comprehensive.

An evaluation methodology for determining the effectiveness of nonpoint source control measures should be established. The methodology will include discussions on:

- How water quality considerations are incorporated into land use decisions;
- The effectiveness of regulations for new on-site systems and the need for on-site system maintenance programs to protect both public health and water quality;
- The effectiveness of local enforcement programs for zoning, shoreline, and health regulations affecting nonpoint pollution.

In the past, drainage management focused on reducing the damages caused by flooding and inadequate flood hazard management. Now many jurisdictions are combining both quality and quantity measures in surface water management plans. These updated plans include strategies designed to control the impacts of nonpoint source pollution which impact beneficial uses of the surface and groundwaters. Water quality issues may not be directly related to quantity, such as when source control is used to prevent pollutants from entering the runoff in the first place. However, there are also situations where management strategies for water quality protection and flood hazard management will be incompatible, such as when long-residence times and quiescent conditions are needed to settle out suspended solids whereas flood detention design may create turbulent flows with short residence times.

Chapter 6 - STORMWATER MANAGEMENT ALTERNATIVES

Specific problems associated with impacts of increased stormwater runoff and their location were presented in previous chapters. Solutions to address these problems can be described in terms of nonstructural and structural activities. Structural solutions are stormwater facilities such as detention/retention ponds or pipe conveyance which require land acquisition, design, and construction activities. Nonstructural measures include code and ordinance changes, programs, and policies to address problems associated with land development. The following pages discuss structural alternatives in terms of capital improvement projects to solve existing drainage problems in the Bothell study area. These alternatives provide information for developing a Capital Improvement Plan (CIP) for the City. The proposed improvements are intended to meet the goals of the Department of Ecology's Stormwater Management Manual for conveyance and detention, the Growth Management Act to provide for future services, and the Puget Sound Water Quality Plan by working to preserve water quality as well as solve specific flooding problems.

Efforts at quantity and quality control are confronted with the same basic task: predict the amount of runoff resulting from various land use conditions and provide sufficient storage capacity to achieve control objectives. In the case of quantity control, the objective is to release storm runoff at a rate that does not exceed conveyance capacity. For quality control, sufficient holding time is necessary for the effective operation of gravity settling and other mechanisms that remove pollutants.

The recommendations presented below describe three structural alternatives for improvements to the existing system. A *status quo*, existing level of effort alternative was also included. Capital improvement alternatives for stormwater conveyance and flood control are physical changes in the system which alter flooding characteristics by delaying or rerouting runoff. Structures within the system can collect and treat the water to improve water quality. Because of the relationship of these mechanisms, strategies to achieve the desired results can satisfy both goals.

Conveyance system alternatives were based on the computer modeling and represent changes to the primary drainage system. Local improvements address neighborhood specific problems which are not resolved by improvements to the main conveyance system.

Proposed alternatives considered the 25-year and 100-year design storms as a level of protection for the analysis. Analysis indicates portions of the existing system would need replacement in order to convey a 25-year design storm. Most of the detention facilities in the drainage network need to be redesigned in order to store a 25-year design storm. Regional facilities could be constructed to complement existing facilities to provide protection to the 100-year level.

6.1 CAPITAL IMPROVEMENT PROJECT ALTERNATIVES

The three alternatives presented below describe routing and pipe replacements to the existing City system to ensure the system-wide conveyance of the 25-year design storm. Differences between alternatives relate to the acquisition and maintenance of existing detention facilities and the addition of regional detention facilities. Recommended regional detention facilities are located in Horse Creek and Perry Creek basins and will require the procurement of easements. Proposed solution locations are shown on Plate 3.

All alternatives assume new development complies with the recommended design standards and maintenance programs, and that the basins will be developed to the fullest extent as planned within the Urban Growth Boundary. New residential development designated as 2-5 du/acre was assumed to be developed at a density of 4 du/acre. Residential designations of 6-10 du/acre were assumed to be 6 du/acre. It was also assumed that only eighty percent of future development would be required to comply with new drainage regulations due to density or amount of impervious surface as described in the exemptions of the regulations. Further, all 1 du/acre residential development was assumed to be exempt from on-site detention requirements.

Existing open channels in defined stream courses were expected to remain as open channels. Minimum pipe size considered in the analysis is 12 inches. A PVC material pipe is recommended if replacement is required for pipes up to and including 24 inches. In larger pipes, concrete is the preferred material primarily due to initial cost, conveyance efficiencies, and maintenance requirements.

6.1.1 **Alternative 1 - Existing Level of Service (LOS)**

Description: This alternative provides for no additional improvements to the conveyance system beyond what the City currently has planned. Existing efforts for maintenance and system replacement would remain at similar levels. Existing interlocal agreements with Snohomish County would remain intact.

Level of Service: Provides for conveyance of a 25-year design storm through most of the drainage system. Existing levels of flooding in the problem areas will remain and may actually increase under the future scenario.

Benefits: This approach provides for no additional benefits to water quality or relief from frequent flooding of problem areas.

Cost: The total 20-year capital cost of this alternative is **$990,250** (1993) as shown in Table 6-1.

6.1.2 Alternative 2 - 25-year Conveyance with existing levels of detention

Description: This alternative provides for the structural changes necessary to convey the 25-year design storm within the pipe network. Existing detention facilities remain at their current level of protection. Projects included in this alternative include the conveyance, local proglems, natural channel enhancements, North and Swamp Creek flood control, and the North Creek Regional Facility at N.E. 188th Street as described below.

Level of Service: This alternative provides for a 25-year conveyance system. Additional protection may be provided by existing detention facilities.

Benefits: This approach provides the City with a 25-year level of protection from flooding.

Cost: The 20-year capital cost of this alternative is **$4,239,385** (1993) as shown in Table 6-1.

6.1.3 Alternative 3 - 25-year Conveyance and detention using existing detention facilities

Description: This alternative is identical to conveyance changes in Alternative 2. However, existing detention facilities will be reconstructured to ensure they can provide for storage of the 25-year design storm. The existing facilities will be redesigned to provide for a 2-year release rate which allows for water quality enhancement options and include Detention Facility projects D-1, D-2, D-3, D-6, and D-8. As in Alternative 2 Conveyance, Local, Natural Channel, North and Swamp Creek flood control, and the North Creek Regional Facility projects as described below are included in this alternative.

Level of Service: This alternative provides for a 25-year conveyance system with 25-year detention utilizing existing facilities.

Benefits: A 25-year level of protection through conveyance and detention is provided by this alternative. Detention facilities will become City responsibility allowing for consistent maintenance activities. Outflow orifices will be adjusted on the facilities to reduce the release rate which in turn provides water quality benefits for stormwater runoff entering the system.

Cost: The 20-year capital cost of this alternative is **$5,721,050** (1993).

6.1.4 Alternative 4 - 25-year Conveyance and Existing Facility Detention and 100-year Detention for New Regional Facilities

Description: This alternative uses the conveyance and detention recommendations from Alternative 3. Additional protection to a 100-year level is provided by the construction of

new regional facilities in the Canyon Park interchange area and adjacent to Horse Creek. These projects are D-4, D-5, and D-7 as described below.

Level of Service: This alternative provides for a 25-year conveyance system with 100-year detention.

Benefits: This approach provides for a 25-year level of protection in the conveyance system and additional detention to the 100-year level through regional facilities. Detention facilities will become City responsibility allowing for consistent maintenance activities. Outflow structures will be adjusted on existing facilities to reduce the release rate which in turn provides water quality benefits for stormwater runoff entering the system.

Cost: The 20-year capital cost of this alternative is **$7,055,250** (1993).

Tables 6-2 and 6-3 provide solutions and their associated costs to projects identified as conveyance/flooding, local problems, and detention facility enhancement as identified through computer modeling and staff discussions.

Table 6-1
SUMMARY OF CAPITAL IMPROVEMENT PROJECTS

	Alternative 1 **Existing Level of Service** 10-yr conveyance, 25-yr private detention No regional detention except 180th facility			**Alternative 2** **Low Level of Service** 25-yr conveyance, 25-yr private detention No additional regional detention except 180th facility			**Alternative 3** **Medium Level of Service** 25-yr conveyance 25-yr detention (enhance existing detention facilities which impact the regional system)			**Alternative 4 (Preferred)** **High Level of Service** 25-yr conveyance 25-yr detention (as in Alternative 3) 100-yr regional detention (new facilities)		
	YEARS 1-6	YEARS 7-20	20-YEAR TOTAL	YEARS 1-6	YEARS 7-20	20-YEAR TOTAL	YEARS 1-6	YEARS 7-20	20-YEAR TOTAL	YEARS 1-6	YEARS 7-20	20-YEAR TOTAL
Conveyance/Flood Control Improvements												
Project C-1				8,590		8,590	8,590	0	8,590	8,590	0	8,590
Project C-2				11,600		11,600	11,600	0	11,600	11,600	0	11,600
Project C-3				24,150		24,150	24,150	0	24,150	24,150	0	24,150
Project C-4				58,180		58,180	58,180	0	58,180	58,180	0	58,180
Project C-5				32,810		32,810	32,810	0	32,810	32,810	0	32,810
Project C-6				0	272,930	272,930	0	272,930	272,930	0	272,930	272,930
Project C-8	1)			600,000	1,400,000	2,000,000	600,000	1,400,000	2,000,000	600,000	1,400,000	2,000,000
Sub Total	252,000	588,000	840,000	735,330	1,672,930	2,408,260	735,330	1,672,930	2,408,260	735,330	1,672,930	2,408,260
Complaint Response												
Project C-9							120,000	280,000	400,000	120,000	280,000	400,000
Local problems												
Project L-1				26,460	0	26,460	26,460	0	26,460	26,460	0	26,460
Project L-2				3,615	0	3,615	3,615	0	3,615	3,615	0	3,615
Project L-3				6,900	0	6,900	6,900	0	6,900	6,900	0	6,900
Sub Total				36,975	0	36,975	36,975	0	36,975	36,975	0	36,975
Existing Detention Facility Enhancement												
Project D-1							19,030	0	19,030	19,030	0	19,030
Project D-2							13,805	0	13,805	13,805	0	13,805
Project D-3							17,450	0	17,450	17,450	0	17,450
Project D-6							12,670	0	12,670	12,670	0	12,670
Project D-8							18,710	0	18,710	18,710	0	18,710
Sub Total							81,665	0	81,665	81,665	0	81,665
Additional Regional Facilities												
Project D-4										116,145		116,145
Project D-5										57,515		57,515
Project D-7										0	160,540	160,540
Project D-9	48,000	102,250	150,250	48,000	102,250	150,250	48,000	102,250	150,250	48,000	102,250	150,250
Sub Total	48,000	102,250	150,250	48,000	102,250	150,250	48,000	102,250	150,250	221,660	262,790	484,450
North and Swamp Creeks Flood Control Projects 2) Project C-7				150,000	1,000,000	1,150,000	250,000	1,900,000	2,150,000	350,000	2,800,000	3,150,000
Natural Channel Enhancements												
Projects NC 1,2, and 4-16				390,700		390,700	390,700		390,700	390,700		390,700
Project NC3				0	103,200	103,200	0	103,200	103,200	0	103,200	103,200
Sub Total				390,700	103,200	493,900	390,700	103,200	493,900	390,700	103,200	493,900
TOTAL COST	300,000	690,250	990,250	1,361,005	2,878,380	4,239,385	1,662,670	4,058,380	5,721,050	1,936,330	5,118,920	7,055,250

1) Existing Level of Service costs are based on historical annual averages.

2) The cost shown for the North and Swamp Creeks Flood Control Projects is based on the assumption that the City will pay 20% of total improvements. The Plan is presently in a preliminary planning stage and due to be completed in 1996. Improvements are expected to range from primarily non-structural such as zoning, property purchase, and stronger development standard development (Alternative 2) to mostly structural such as dikes, overflow bypass channels, and regional detention (Alternative 4). As the Plan nears completion and a cost-sharing methodology is formulated, the cost may change.

Table 6-2
CAPITAL CONVEYANCE PROJECTS

	Pipe Size	Length	Type	Cost							
				Material	Installation	Paving	Design	Permits	Environ-mental	Land Acquisition	Project Cost
Project C-1	24 inch	70 feet	PVC	1,830	2,100	150	3,260	400	850	0	**8,590**
Location:	9th Avenue S.E. and 226th Street S.E.										
Problem:	The existing cross culvert does not have adequate capacity to convey runoff across 9th Avenue S.E. resulting in frequent flooding.										
Solution:	Replace existing cross culvert with a larger pipe.										
Project C-2	24 inch	120 feet	PVC	3,140	3,600	0	4,710	150	0	0	**11,600**
Location:	228th Street S.E. and 31th Avenue S.E.										
Problem:	The existing cross culvert does not have adequate capacity to convey runoff across 228th Street S.E. resulting in flooding.										
Solution:	Replace existing pipe with a larger diameter pipe as a component of the 228th Street S.E. improvement.										
Project C-3	24 inch	215 feet	PVC	8,000	6,450	450	8,950	300	0	0	**24,150**
Location:	Bothell Way between Ormbrek Street and N.E. 180th Street										
Problem:	Model results showed the existing conveyance does not have the capacity to convey the 25-year storm event which will result in street flooding.										
Solution:	Replace existing conveyance with a larger diameter pipe.										
Project C-4	18 inch	660 feet	PVC	14,200	19,800	1,400	17,700	700	4,380	0	**58,180**
Location:	N.E. 185th Street between Beardslee Boulevard and Ross Road										
Problem:	Model results showed the existing conveyance does not have the capacity to convey the 25-year storm event which will result in street flooding.										
Solution:	Replace existing conveyance with a larger diameter pipe.										
Project C-5	15 inch 18 inch	320 feet 65 feet	PVC	7,410	11,500	800	12,650	400	0	0	**32,810**
Location:	96th Avenue N.E. from N.E. 203rd Street to N.E. 198th Street										
Problem:	The system does not have adequate capacity to convey runoff resulting in frequent flooding.										
Solution:	Replace and upgrade the existing system.										

Table 6-2 (cont'd)

	Pipe Size	Length	Type	Cost							
				Material	Installation	Paving	Design	Permits	Environ-mental	Land Acquisition	Project Cost
Project C-6	24 inch	3200 feet	PVC	93,150	96,000	6,640	48,950	3,910	24,280	0	**272,930**
Location:	Piped conveyance of Horse Creek through downtown										
Problem:	Conveyance system does not have the capacity to convey stormwater resulting in flooding.										
Solution:	Construct an overflow bypass at the point where the open channel enters the piped system. Route the bypass down SR 527 to reconnect with the system at the intersection of SR 527 and Bothell Way.										
Project C-7											**3,150,000**
Location:	Swamp and North Creek Channels										
Problem:	Interjurisdictional study currently being prepared										
Solution:	Projected solutions may include land acquisition, bypasses, or regional facilities.										
Project C-8											**2,000,000**
Location:	Various Locations										
Problem:	Conveyance pipes exceed their life expectancy and no longer function properly.										
Solution:	Identify and replace those sections on an annual basis. (Approx. $50,000 per year for 20 years)										
Project C-9											**400,000**
Location:	Various Locaiton										
Problem:	Drainage Complaint Response										
Solution:	Identify and replace as needed.										

Table 6-3
CAPITAL DETENTION FACILITY PROJECTS

	Cost									
	Excavation	Discharge Structures	Water Quality Pretreatment	Fencing	Signs	Design Services	Permits	Environmental	Land Acquisition	Project Cost
Project D-1	3,520	2,800	4,070	0	150	7,380	210	900	0	**19,030**
Location:	Crystal Ridge Detention Pond near 6th Drive S.E. and 223rd Place S.E.									
Action:	Redesign and construct facility to include a low flow channel, wet pond, and discharge structure to provide staged releases for the 2-year and 25-year storm event.									
Project D-2	625	2,800	4,070	0	150	5,350	150	660	0	**13,805**
Location:	Crystal Ridge Detention Pond near 226th Street S.E. and 7th Drive S.E.									
Action:	Redesign and construct facility to include a low flow channel and discharge structure to provide staged releases for the 2-year and 25-year storm event.									
Project D-3	2,640	2,800	4,070	0	150	6,760	200	830	0	**17,450**
Location:	Crystal Ridge Detention Pond near 4th Avenue S.E. and 5th Drive S.E.									
Action:	Redesign facility to include a discharge structure to provide staged releases for the 2-year and 25-year storm event. Excavate sediments to provide for storage of the 25-year storm event.									
Project D-4	50,750	3,050	4,810	5,460	150	25,700	6,425	13,800	6,000	**116,145**
Location:	Crystal Ridge Regional Detention Pond west of 9th Avenue S.E.									
Action:	Acquire land necessary to construct regional facility. Reroute one section of stream to new facility. Design facility to store 100-year storm event and provide for staged releases. Include water quality features such as wet pond, low flow channels and vegetation plan into the design.									
Project D-5	8,385	3,050	4,900	5,715	150	13,320	2,220	4,775	15,000	**57,515**
Location:	Regional Detention Pond on Northwest corner of 228th Street S.W. and SR 527									
Action:	Develop regional facility to include low flow channel and wet pond for water quality enhancement. Provide for storage of the 100-year storm event.									
Project D-6	0	2,800	4,070	0	150	4,910	140	600	0	**12,670**
Location:	Canyon Park Center Detention Pond on Northeast corner of 228th Street S.W. and SR 527									
Action:	Perform maintenance on existing facility									
Project D-7	46,980	4,100	5,660	7,560	150	25,780	6,450	13,860	50,000	**160,540**
Location:	Horse Creek Regional Detention Pond adjacent to SR 527 and north of dog kennel									
Action:	Acquire land and design facility to provide for a 100-year level of protection. Include a high flow bypass and staged outflow structure in the design.									

Table 6-3 (cont'd)

	Cost									
	Excavation	Discharge Structures	Water Quality Pretreatment	Fencing	Signs	Design Services	Permits	Environmental	Land Acquisition	Project Cost
Project D-8	3,340	2,800	4,070	0	150	7,250	210	890	0	**18,710**
Location:	Canyon Crest #1 Detention Pond near 238th Place S.E. and 26th Drive S.E.									
Action:	Redesign existing facility to provide for low flow channel, and staged outflow structure. Remove inflow control structure.									
Project D-9										**150,250**
Location:	188th Street S.W.									
Action:	Interlocal agreement with Snohomish County for Regional Facility									

LOCAL IMPROVEMENTS FOR SPECIFIC PROBLEM AREAS

Flooding problems at any specific location can often be solved by increasing the capacity of the existing system, performing maintenance, or installing new conveyance to collect and channel the runoff into existing facilities. In some instances the undersized drainage system results in flooding and subsequent temporary depression storage. Reducing this storage through improved drainage may affect the downstream system by increasing peak flow rates and contributing to downstream flooding. The minimum pipe size used in installation or replacement should be 12-inch for maintenance and conveyance purposes.

The one problem not discussed below is the discharge of surface water runoff from Beardslee Boulevard onto private property. The area of discharge is identified at a wetland on the Bothell Critical Areas map. Altering the discharge may have adverse impacts upon the wetlands functions.

On the following page is a discussion of problem location and conceptual solutions for area neighborhood problems.

Table 6-4
CAPITAL LOCAL CONVEYANCE PROJECTS

	Pipe Size	Length	Type	Cost							
				Material	Installation	Paving	Design	Permits	Environmental	Land Acquisition	Project Cost
Project L-1	18 inch	250 feet	PVC	7,370	7,500	520	10,770	300	0	0	**26,460**
Location:	224th Street S.W. between 8th Avenue W. and 4th Avenue S.E.										
Problem:	Shoulders and private property flood due to inadequate storm drains.										
Solution:	Connect various components and perform regular maintenance on system including vegetation control on road shoulders.										
Project L-2	12 inch	50 feet	PVC	380	1,500	110	1,5858	40	0	0	**3,615**
Location:	3rd Avenue S.E. near 234th Street S.E.										
Problem:	Cross culvert is inadequate to convey 25-year design storm.										
Solution:	Replace existing culvert with larger pipe.										
Project L-3	24 inch	65 feet	PVC	1,700	1,950	150	3,025	75,	0	0	**6,900**
Location:	240th Street S.W. east of 7th Avenue S.E.										
Problem:	Existing culvert and pipe system will be too small under future conditions.										
Solution:	Replace existing system with a larger cross culvert and restore natural channel when area becomes more developed.										

Natural Channel Protection/Enhancement

Streambank erosion control can be accomplished by BMPs which detain runoff flows and also by those which physically stabilize eroding streambanks. The single largest source of sedimentation within a drainage basin is attributed to streambank erosion. Natural channel protection provides for policy and regulatory mechanisms to physically stabilize streambanks. Streambank erosion is largely due to increases in bankfull flow conditions which occur in urban landscapes. Bankfull conditions in undisturbed areas generally occur only about once in every two years on average.

In urbanized areas both the frequency and duration of the bankfull condition can increase due to the effect impervious surfaces have on runoff. Bankfull conditions are a highly erosive state and, as the frequency and duration of their occurrence increases, the greater the amount of erosion results. While it may be impossible to totally recreate the frequency and duration of the pre-development bankfull conditions, reconstruction and enhancement projects should be designed with that as an objective.

Conventional detention practices which control peak flow rates from large, infrequent storms for flood control purposes are only partially effective at reducing the frequency and duration of bankfull flow conditions. However, these measures used in conjunction with bank protection techniques can reduce sedimentation problems in the basin. Natural channels which are at risk for sedimentation problems are described below and include Perry Creek, Queensborough Creek, Royal Anne tributaries, North Creek, Palm Creek, Horse Creek, Little Swamp Creek, Wayne Golf Course tributary, and their tribuaries as shown on Plate 2 in the Appendix.

Project Number	Problem/ Location	Cost
NC-1	The natural channel near Richmond Road and 212th Street S.E. may be at risk for bank erosion and sedimentation problems	**
NC-2	The Queensborough tributary to North Creek exhibits erosion and sedimentation problems from excessive flows	**
NC-3	Stream reach between 228th Street S.E. and 212th Street S.E. and 39th Avenue S.E. is at risk for erosion and sedimentation	103,200
NC-4	The two stream reaches between 45th Avenue S.E. and 35th Avenue S.E. south of 228th Street S.E. are at risk under future conditions to bank erosion and sedimentation problems	57,600
NC-5	Little Swamp Creek north of 240th Street S.E. is at risk to bank erosion and sedimentation under future conditions	**
NC-6	Perry Creek exhibits bank erosion and sedimentation problems	36,500
NC-7	Perry Creek exhibits bank erosion and sedimentation problems	6,000
NC-8	Upper reaches of Horse Creek may be at risk to bank erosion and sedimentation problems under future conditions	**
NC-9	The open channels of Wayne Creek and its' tributaries between 145th Street and Wayne Golf Course display bank erosion and sedimentation problems	14,400
NC-10	The natural channel between the conveyance system on 96th Avenue N.E. to discharge point in Horse Creek shows signs of bank erosion and sedimentation	24,000

Project Number	Problem/ Location	Cost
NC-11	The open channel between the conveyance system on 98th Avenue N.E. and discharge point in Horse Creek show signs of bank erosion and sedimentation	14,400
NC-12	Open channel on conveyance system under 100th Avenue N.E. is at risk to bank erosion	12,000
NC-13	The open channel portion of Horse Creek near N.E. 188th Street is highly eroded	4,400
NC-14	The Horse Creek channel at its discharge point to the Sammamish River exhibits bank erosion	14,400
NC-15	The natural channel downstream of Canyon Crest #1 detention pond is highly eroded causing sedimentation problems into North Creek	28,800
NC-16	Erosion is evident on the banks of North Creek through the Canyon Park Industrial Park	178,200
NC-17	Various locations	**

** Projects will be initiated prior to new construction and may require new development contribution

6.2 NONSTRUCTURAL PROJECTS

Development of a comprehensive stormwater plan includes the use of nonstructural measures such as regulatory changes, water quality monitoring, conveyance system maintenance, enforcement of violations, public involvement, and interlocal agreements. These programs and administrative actions compliment structural effects to control stormwater by adding a preventive element. The following discussion summarizes the recommendations from Chapters 3 and 5 of this Plan by consolidating them into specific projects.

Public Education/Awareness Projects

A recommendation to develop a public involvement and education plan to inform area residents on nonpoint pollution was presented in Chapter 5. Education and public involvement are necessary components of a long-term stormwater management strategy. Education can supplement enforcement programs and is recognized as the effective resource management tool to address those problems which result from individual actions such as improper disposal of wastes from households, automobiles, or boats.

Public involvement and education projects identified in this Plan are:

Project PE-1 Voluntary Ditch Maintenance

Institute voluntary ditch maintenance programs which include preparation of informational materials and training workshops that address minimum maintenance requirements and maintenance that will be required of City maintenance staff.

Cost: $10,000 Annually

Project PE-2 Interagency/Governmental Coordination

The coordination of monitoring, public eduction, and other nonpoint pollutant reduction efforts can be accomplished through agreements with Snohomish and King Counties.

Cost: $2,500 Annually

Project PE-3 Public Involvement Coordinator

Establishing a position of "Public Involvement Coordinator" will ensure the implementation of education and involvement activies. Responsibilities of the position would include coordination with other agencies, development of brochures and materials, and implementation of programs for reducing nonpoint pollution in stormwater.

Cost: $50,000 Annually

Project PE-4 Annual Creek Clean-up Days

The coordination of efforts with regional and local agencies to provide general clean-up of streams and creek on an annual basis provide an opportunity to make the community aware of natural resources. In addition, the removal of debris reduces external pollutant loading thereby improving water quality.

Cost: $4,000 Annually

Project PE-5 Catch Basin Stencilling

Stencilling of catch basins with "Drains to Creek, Dump No Pollutants" either through volunteer efforts or by City maintenance staff alerts area residents of the implications of their actions. Reducing this type of nonpoint source reduces the pollutant loading of toxic substances to streams and improves water qualitiy and aquatic habitat.

Cost: $5,000 Annually

Administrative Projects

Recommendations to policy issues were considered as administrative projects or measres for this Plan. Examples include procedures for permit review, easement acquisition, and maintenance programs. Other types of policy issues such as inspection and enforcement are mandated by ordinance. The Ecology Stormwater Manual and the Puget Sound Water Quality Management Plan contain general policy considerations for stormwater management.

The following project recommendations will provide consistency with state policies for stormwater quality and quantity management.

Project A-1 Update Stormwater Standards

Design standards with development controls can reduce or prevent future flooding and water quality problems. The following recommended modifications to Bothell Municipal Code would provide consistency with Snohomish and King County's standards and meet or exceed state stormwater standards.

Require off-site analysis to evaluate drainage system problems upstream, on-site, and downstream of a proposed project. The analysis will ensure that the project does not increase the magnitude, frequency, or duration of an existing drainage problem not create a new problem.

Require detention of the 2-, 10-, and 100-year, 24-hour events. The analysis of the 2-, 10-, and 100-year, 24-hour frequency storm event allows a "performance curve" to be plotted which represents allowable peak runoff rates for a range of storm events. The curve measures the performance of peak rate runoff control facilities.

Requiring a release rate of 50% of the 2-year, 24-hour design event will decrease adverse impacts to streams. Selecting this level of release rate will provide consistency with Ecology requirements. More restrictive runoff controls may be required for a higher frequency event depending upon the significance of downstream impacts.

Establishing a minimum storm frequency event for pipe conveyance will determine the "level of service" for that conveyance system. The Ecology Manual has established a level of service for conveyance at a 25-year, 24-hour level.

Establish a minimum pipe size for conveyance systems because of maintenance needs and the constraint of equipment required to perform the maintenance.

Require new Public Works projects to include facilities for water quality treatment such as settlement and/or filtration of stormwater. Structural control measures can provide valuable water quality enhancement to surface water runoff.

Cost: **$15,000**

Project A-2 Staff Workshops on Drainage and Water Quality Issues

The enforcement of stormwater standards through inspector training and site inspection can strain existing inspection and enforcement resources. Augmenting existing code enforcement and judicial personnel should reduce erosion and sedimentation incidents.

Additionally, staff from other divisions should be trained to recognize violations and notify the proper enforcing division at the City.

Cost: **$5,000 Annually**

Project A-3 Participate in Snohomish County's Watershed Keeper Program

The Watershed Keeper's responsibility is to serve as the focal point for implementation of the North Creek Watershed Action Plan. The Keeper's time would be shared by watershed jurisdiction through interlocal agreements.

Cost: **$5,000 Annually**

Project A-4 Water Quality Monitoring/Ambient

An Ambient Water Quality Monitoring Plan will provide information to evaluate the effectiveness of water quality control facilities and to identify potential water quality problems before serious degradation occurs.

Cost: **$61,500 Annually**

Project A-5 Water Quality Monitoring/NPDES

Compliance with federal laws for nonpoint source permits will require a stormwater monitoring plan. Specific detail and schedules for compliance are not available at this time, however, it is expected that the City will be required to obtain an NPDES permit.

Cost: **$55,500**

Project A-6 Development Review/Inspection

Administrative staff to review and inspect stormwater related issues ensures compliance with construction regulations.

Cost: **$108,000 Annually**

Project A-7 Maintenance and Operation Program

A consistent Operation and Maintenance Program for the Stormwater Conveyance System must be implemented to provide the periodic actions required to maintain and assure

continual operational effectiveness of the system. In addition to cleaning and repair, the program must include inventory update and record keeping, regular facility condition assessment, and resource allocation.

Various levels of service are presented in Tables 6-6, 6-7, and 6-8 for the Maintenance and Operation Program and are defined in terms of a low, medium, or high effort. Failure to provide for consistent maintenance results in an overall reduction of the system's conveyance capacity and reduces the pollutant removal efficiency of the system. More frequent maintenance reduces these problems and increases the hydraulic efficiency of the system.

Table 6-5
ANNUAL OPERATION AND MAINTENANCE COSTS
ALTERNATIVE 2 - LOW LEVEL OF SERVICE

Facility	Activity	Units of Measure	Total Units	Frequency (units/year)	Daily Production	Crew Size	Equipment	Crew Days	Labor Cost	Equip. Cost	Total Cost
Public Detention Facility		Ponds	15								
	Vegetation Control	Ponds	15	6	1	1	Mower	6	1,080	1,200	2,280
	Sediment Removal	Ponds	15	0	1	4	Backhoe/Dump Trk	0	0	0	0
Vault	Clean Out	Each	15	3	1	4	Vactor	3	2,232	3,000	5,232
Storage Pipes	Clean Out	Each	15	3	1	4	Vactor	3	2,232	3,000	5,232
							SUBTOTAL	12	5,544	7,200	12,744
Catch Basins and Manholes		Each	6,200								
	Clean Out	Each		425	20	4	Vactor	21	15,624	21,000	36,624
	Repair and Replace	Each		25-50/year	2	4		18	13,392	18,000	31,392
							SUBTOTAL	51	29,016	39,000	68,016
Pipes		Linear Feet	24,710								
	Clean Out	Linear Feet		550	25	4	Vactor	22	16,368	22,000	38,368
							SUBTOTAL	22	16,368	22,000	38,368
Roadside Ditches		Linear Feet	443,520								
	Vegetation Control	Linear Feet		221,760	10,000	1.5	Mower	22	5,896	4,400	10,296
	Clean, Reshape	Linear Feet		14,610	600	4	Backhoe/Dump Trk	24	17,856	26,880	44,736
							SUBTOTAL	46	23,752	31,280	55,032
Vactor Waste Disposal Fees											28,000
							SUBTOTAL		74,680	99,480	202,160
Assumed supervisory and clerical personnel costs									15,000		15,000
							TOTAL ANNUAL COST		89,680	99,480	217,160
							6-YEAR TOTAL COST		538,080	596,880	1,302,960
							20-YEAR TOTAL COST		1,793,600	1,989,600	4,343,200

Table 6-6
ANNUAL OPERATION AND MAINTENANCE COSTS
ALTERNATIVE 3 - MEDIUM LEVEL OF SERVICE

Facility	Activity	Units of Measure	Total Units	Frequency (units/year)	Daily Production	Crew Size	Equipment	Crew Days	Labor Cost	Equip. Cost	Total Cost
Public Detention Facility		Ponds	15								
	Vegetation Control	Ponds	15	8	1	1	Mower	8	1,440	1,600	3,040
	Sediment Removal	Ponds	15	2	1	4	Backhoe/Dump Trk	2	1,488	2,240	3,728
Vault	Clean Out	Each	15	5	1	4	Vactor	5	3,720	5,000	8,720
Storage Pipes	Clean Out	Each	15	5	1	4	Vactor	5	3,720	5,000	8,720
							SUBTOTAL	20	10,368	13,840	24,208
Catch Basins and Manholes		Each	6,200								
	Clean Out	Each		725	20	4	Vactor	36	26,784	36,000	62,784
	Repair and Replace	Each		50-75/year	2	4		30	22,320	30,000	52,320
							SUBTOTAL	86	49,104	66,000	115,104
Pipes		Linear Feet	24,710								
	Clean Out	Linear Feet		1,725	25	4	Vactor	69	51,336	69,000	120,336
							SUBTOTAL	69	51,336	69,000	120,336
Roadside Ditches		Linear Feet	443,520								
	Vegetation Control	Linear Feet		221,760	10,000	1.5	Mower	22	5,896	4,400	10,296
	Clean, Reshape	Linear Feet		21,225	600	4	Backhoe/Dump Trk	35	26,040	39,200	65,240
							SUBTOTAL	57	31,936	43,600	75,536
Vactor Waste Disposal Fees											30,000
							SUBTOTAL		142,744	192,440	365,184
Assumed supervisory and clerical personnel costs									25,000		25,000
							TOTAL ANNUAL COST		167,744	192,440	390,184
							6-YEAR TOTAL COST		1,006,464	1,154,640	2,341,104
							20-YEAR TOTAL COST		3,354,880	3,848,800	7,803,680

Table 6-7
ANNUAL OPERATION AND MAINTENANCE COSTS
ALTERNATIVE 4 - HIGH LEVEL OF SERVICE

Facility	Activity	Units of Measure	Total Units	Frequency (units/year)	Daily Production	Crew Size	Equipment	Crew Days	Labor Cost	Equip. Cost	Total Cost
Public Detention Facility		Ponds	15								
	Vegetation Control	Ponds	15	15	1	1	Mower	15	2,700	3,000	5,700
	Sediment Removal	Ponds	15	5	1	4	Backhoe/Dump Trk	5	3,720	5,600	9,320
Vault	Clean Out	Each	15	5	1	4	Vactor	5	3,720	5,000	8,720
Storage Pipes	Clean Out	Each	15	5	1	4	Vactor	5	3,720	5,000	8,720
							SUBTOTAL	30	13,860	18,600	32,460
Catch Basins and Manholes		Each	6,200								
	Clean Out	Each		1,035	20	4	Vactor	52	38,688	52,000	90,688
	Repair and Replace	Each		75-100/year	2	4		40	29,760	40,000	69,760
							SUBTOTAL	122	68,448	92,000	160,448
Pipes		Linear Feet	24,710								
	Clean Out	Linear Feet		1,950	25	4	Vactor	78	58,032	78,000	136,032
							SUBTOTAL	78	58,032	78,000	136,032
Roadside Ditches		Linear Feet	443,520								
	Vegetation Control	Linear Feet		221,760	10,000	1.5	Mower	22	5,896	4,400	10,296
	Clean, Reshape	Linear Feet		26,610	600	4	Backhoe/Dump Trk	44	32,736	49,280	82,016
							SUBTOTAL	66	38,632	53,680	92,312
Vactor Waste Disposal Fees											32,000
							SUBTOTAL		178,972	242,280	453,252
Assumed supervisory and clerical personnel costs									50,000		50,000
							TOTAL ANNUAL COST		228,972	242,280	503,252
							6-YEAR TOTAL COST		1,373,832	1,453,680	3,019,512
							20-YEAR TOTAL COST		4,579,440	4,845,600	10,065,040

Project A-8 North Creek Flood Control Study

Snohomish County is conducting a study of North Creek to identify preferred strategies for addressing significant increases in flood flows associated with watershed urbanization. The City has agreed to participate in this study.

Cost: **$50,000**

Project A-9 Centennial Grant Match

The Centennial Grant provides funding to prepare a Comprehensive Water Quality Management Plan. The proposed water quality management plan will include elements to develop (1) Planning Based Controls such as water quality monitoring programs, source control action programs, and regular maintenance policies; (2) Education Based Controls to establish a city-wide education program on water quality protection; (3) Regulation Based Controls for water quality performance and drainage design standards; and (4) Administrative Based Controls to establish procedures for new development inspection and enforcement.

Cost: **$50,000**

Project A-10 Utility Billing Maintenance

Administrative staff to perform database system maintenance for new accounts, collection of fees, annual budget preparation, and to ensure the charges an fees are reviewed annually.

Cost: **$25,000**

Project A-11 Utility Start-Up Costs

Efforts required to develop a stormwater utility include identifying the fee structure and billing database. The appropriate ordinances must be adopted once the public hearing process has been completed.

Cost: **$50,000**

Project A-12 Stormwater Master Plan Update

Revise the Stormwater Master Plan periodically to review recommendations and projects for appropriateness, cost, and schedule.

Cost: **$300,000**

Tables 6-8, 6-9, and 6-10 present options for implementing the various programs and administrative measures.

Table 6-8
SUMMARY OF ANNUAL PROGRAMS

	Alternative 1 Existing Level of Service	Alternive 2 Low Level of Service	Alternative 3 Medium Level of Service	Alternative 4 (Preferred) High Level of Service
Public Education/Customer Service				
Project PE-1				10,000
Project PE-3			35,000	50,000
Project PE-4				4,000
Project PE-5		5,000	5,000	5,000
Sub-total		5,000[1]	40,000[2]	69,000[3]
Water Quality Monitoring				
Project A-2			5,000	5,000
Project A-4		4,810	61,500	61,500
Sub-total	2,500[4]	4,810[5]	66,500[6]	66,500[6]
Interlocal Agreements				
Project PE-2		2,500	2,500	2,500
Project A-3		5,000	5,000	5,000
Sub-total		7,500[7]	7,500[7]	7,500[7]
Development Review/Inspection				
Project A-6	61,000	61,000	88,000[8]	108,000[9]
Utility Billing Maintenance				
Project A-10		25,000[10]	25,000[10]	25,000[10]
TOTAL ANNUAL COST	63,500	103,310	227,000	276,000
TOTAL 6-YEAR COST	381,000	619,860	1,362,000	1,656,000
TOTAL 20-YEAR COST	1,270,000	2,066,200	4,540,000	5,520,000

1) Provides for some catch-basin stencilling.
2) Provides for 1 project plus approximately 1 staff working 60% of the year.
3) Provides for 3 projects plus 1 FTE (Full-Time Equivalent).
4) Interlocal with Snohomish County for limited monitoring.
5) Increases the monitoring provided by Snohomish County.
6) Provides for 1 FTE plus lab fees for increased monitoring plus training to other staff for water quality issues.
7) Implements recommendations in the North Creek Watershed Plan.
8) Provides for existing staff plus one staff working 50% of the year.
9) Provides for an equivalent FTE beyond existing staff.
10) Provides for staff time (clerical and technician) to update utility records for accurate billing.

Table 6-9
SUMMARY OF NON-ANNUAL PROJECTS

	Alternative 1 Existing Level of Service	Alternive 2 Low Level of Service	Alternative 3 Medium Level of Service	Alternative 4 (Preferred) High Level of Service
Planning/Grant Match				
Project A-1		15,000	15,000	15,000
Project A-5				55,500
Project A-8	50,000	50,000	50,000	50,000
Project A-9	50,000	50,000	50,000	50,000
Project A-12		100,000	200,000	300,000
Sub-total	100,000[1]	215,000[2]	315,000[3]	470,500[4]
Utility Start-Up Costs[5]				
Project A-11	50,000	50,000	50,000	50,000
TOTAL COST	150,000	265,000	365,000	520,500
TOTAL 6-YEAR COST	150,000	165,000	265,000	320,500
TOTAL 20-YEAR COST	150,000	265,000	365,000	520,500

1) Interlocal for North Creek Flood Control Study and Centennial Grant Match.
2) Provides for 1 update to the Stormwater Master Plan plus updating design standards.
3) Provides for 2 updates to the Stormwater Master Plan plus updating design standards.
4) Provides for 3 updates to the Stormwater Master Plan, updating design standards, and actions to obtain NPDES permit.
5) Includes efforts for Public Meetings, Notices, and Utility Rate Structure Analysis to initiate Stormwater Utility.

Table 6-10
SUMMARY OF MAINTENANCE AND OPERATION PROGRAM

	Alternative 1[1] Existing Level of Service	Alternative 2[2] Low Level of Service	Alternative 3[3] Medium Level of Service	Alternative 4[4] (Preferred) High Level of Service
Detention Facilities				
Vegetation Control	1,890	2,280	3,040	5,700
Sediment Removal		0	3,728	9,320
Vaults	4,157	5,232	8,720	8,720
Storage Pipes	4,157	5,232	8,720	8,720
Total	10,204	12,744	24,208	32,460
Catch Basins (6,200)	36,235	68,016	115,104	158,704
Pipes (46.8 Miles)	33,987	38,368	120,336	137,776
Roadside Ditches				
Vegetation Control	14,100	10,296	10,296	10,296
Reshape	13,474	44,736	65,240	82,016
Total	27,574	55,032	75,536	92,312
Vactor Waste Disposal Fees	27,008	28,000	30,000	32,000
Sub-Total	135,008	202,160	365,184	453,252
Assumed supervisory and clerical personnel cost	7,001	15,000	25,000	50,000
TOTAL ANNUAL COST	142,009	217,160	390,184	503,252
TOTAL 6-YEAR COST	852,054	1,302,960	2,341,104	3,019,512
TOTAL 20-YEAR COST	2,840,180	4,343,200	7,803,680	10,065,040

Cost of Detention Facilities, Catch Basins, Pipes, and Roadside Ditches is based on four-person crew working at following levels:

1) Existing LOS - 30% of year (4-person crew, 80 days of work)
2) Low LOS - 45% of year (4-person crew, 120 days of work)
3) Medium LOS - 80% of year (4-person crew, 213 days of work)
4) High LOS - 100% of year (4-person crew, 266 days of work)

Chapter 7 - IMPLEMENTATION STRATEGY

This section is intended to provide implementation strategies and recommendations from which the Capital Improvement Plan (CIP) was developed. The criteria for selecting the preferred alternative considered level of service, prevention against future resource degradation, and consistency with state programs. The recommended CIP contains structural and non-structural projects as presented in the previous chapters.

7.1 PREFERRED ALTERNATIVE SELECTION

The various alternatives considered for the Capital Improvement Plan were evaluated based on the following criteria:

- Level of service to the community and ability to resolve existing flooding problems and accommodate future growth;
- Technical feasibility of solutions;
- Social/political feasibility to actually implement the preferred alternative solution;
- The ability to maintain or improve water quality;
- Ability of nonstructural programs such as maintenance and public awareness to prevent future development related problems;
- Impacts on conveyance systems, water quality, surface water, and groundwater;
- Financial feasibility of cost and likelihood of funding to implement the alternative solution;
- Consistency with state requirements for growth management and water quality.

Based on these criteria, Alternative 4 was selected as the capital improvement alternative that would provide the community with the highest level of protection from flooding and water quality degradation. This alternative will reduce the frequency of flooding while providing benefits to water quality and ensuring current beneficial uses are maintained.

Recommendations for non-structural solutions such as regulatory and enforcement programs, public education, and maintenance are harder to evaluate in terms of the above criteria. These programs coupled with the following structural projects comprise a strategy for the City to achieve the goals and objectives described in Chapter 1.

7.2 CAPITAL IMPROVEMENT PLAN

The Capital Improvement Plan (CIP) contains structural and nonstructural elements of the preferred alternative. Tables 7-1 and 7-3 presents the Plan elements which are discrete projects and will only require expenditure of funds at the time of implementation. Tables 7-2, and 7-4 provide for the annual programs and policies recommended by this plan. The priority of each project illustrated in Table 7-1 is based on severity of flooding, degree of existing development, and the amount of remaining undeveloped land. Another consideration is the ability of proposed projects to coordinate with other public works projects. Scheduling projects which coincide may reduce the cost and improve efficiency for both projects. Grouping similar solutions together to take advantage of grant programs will also reduce overall CIP costs.

Table 7-1
DETAILS OF CAPITAL IMPROVEMENT PROJECTS
20-YEAR PROGRAM - ALTERNATIVE 4 (PREFERRED)

Project Number	Priority	Project Description	Location	Cost
CONVEYANCE - FLOOD CONTROL IMPROVEMENTS				
C - 1	2	9th Avenue S.E. Cross Culvert	9th Avenue S.E. and 226th Street S.E.	8,590
C - 2	3	228th Street S.W. Cross Culvert	228th Street S.W. and 31st Avenue S.E.	11,600
C - 3	3	Bothell Way Conveyance System	Bothell Way between Ormbrek Street and N.E. 180th Street	24,150
C - 4	5	N.E. 185th Street Conveyance System	N.E. 185th Street between Beardslee Boulevard and Ross Road	58,180
C - 5	1	96th Avenue N.E. Conveyance Upgrade	96th Avenue N.E. from N.E. 203rd Street to SR 527	32,810
C - 6	7	Piped conveyance of Horse Creek through downtown	Conveyance from N.E. 195th Street to N.E. 183rd Street (overflow bypass)	272,930
C - 8	1	Conveyance pipe replacement ($100,000 annually) (6 year Total = 600,000, 7-20 year Total = 1,400,000)	Various locations City-Wide	2,000,000
			SUB-TOTAL	2,408,260
COMPLAINT RESPONSE				
C - 9	1	Drainage Complaint Response ($20,000 annually) (6 year Total = 120,000, 7-20 year Total = 28,000)	Various locations City-Wide	400,000
			SUB-TOTAL	400,000
LOCAL PROBLEMS				
L - 1	2	224th Street S.W. Conveyance System	224th Street S.W. between 8th Avenue W. and 4th Avenue S.E.	26,460
L - 2	3	3rd Avenue S.E. Cross Culvert	3rd Avenue S.E. near 234th Street S.E.	3,615
L - 3	2	240th Street S.W. Cross Culvert	240th Street S.W. east of 7th Avenue S.E.	6,900
			SUB-TOTAL	36,975
EXISTING DETENTION FACILITY ENHANCEMENT				
D - 1	3	Crystal Ridge Detention Pond #1	6th Drive S.E. and 223rd Place S.E.	19,030
D - 2	3	Crystal Ridge Detention Pond #2	226th Street S.E. and 7th Drive S.E.	13,805
D - 3	4	Crystal Ridge Detention Pond #3	4th Avenue S.E. and 5th Drive S.E.	17,450
D - 6	1	Canyon Park Center Detention Pond	Northeast corner of 228th Street S.W. and SR 527	12,670
D - 8	2	Canyon Crest #1 Detention Pond	238th Place S.E. and 26th Drive S.E.	18,710
			SUB-TOTAL	81,665
ADDITIONAL REGIONAL FACILITIES				
D - 4	4	Crystal Ridge Regional Detentio Pond	West of 9th Avenue S.E.	116,145
D - 5	5	228th Regional Detention Pond	Northwest corner of 228th Street S.W. and SR 527	57,515
D - 7	7	Horse Creek Regional Detention Pond	Adjacent to Horse Creek and SR 527 north of kennel	160,540
D - 9	1	180th North Creek Regional Detention Pond (6 year Total = 48,000, 20 year Total = 102,250)	180th Street S.W.	150,250
			SUB-TOTAL	484,450

Table 7-1 (cont'd)

Project Number	Priority	Project Description	Location	Cost
NORTH AND SWAMP CREEKs FLOOD CONTROL PROJECTS				
C - 7	10	City share of flood control improvements on Sqamp and North Creeks	Swamp and North Creeks	3,150,000
			SUB-TOTAL	3,150,000
NATURAL CHANNEL ENHANCEMENTS				
NC - 1	7	Royal Anne Road Tributary	Channel in the area of Richmond Road and 212th Street S.E.	**
NC - 2	7	Queensborough Tributary	Channel between Queensborough and Crystal Ridge development	**
NC - 3	7	Unnamed North Creek Tributary	Stream reach between 228th Street S.E. and 212th Street S.E. and 39th Avenue S.E.	103,200
NC - 4	5	Unnamed North Creek Tributary	Stream reaches between 45th Avenue S.E. and 35th Avenue S.E. south of 228th Street S.E.	57,600
NC - 5	8	Little Swamp Creek	Stream reach originating near 3rd Avenue S.E. to 240th Street S.E.	**
NC - 6	3	Perry Creek - North Branch	Stream reaches between Crystal Ridge detention ponds and SR 527	36,500
NC - 7	4	Perry Creek - South Branch	Stream originating from Mobile Home Park on 19th Avenue S.E. to 228th Street S.W.	6,000
NC - 8	8	Horse Creek	Upper reaches of Horse Creek along SR 527	**
NC - 9	2	Wayne Creek	Open channel between N.E. 145th Street and Wayne Golf Course	14,400
NC - 10	2	96th Avenue N.E. tributary	Channel between 96th Avenue N.E. and N.E. 198th Street to SR 527	24,000
NC - 11	2	98th Avenue N.E. tributary	Channel between 98th Avenue N.E. and 198th Street to SR 527	14,400
NC - 12	4	100th Avenue N.E. tributary	Open channel on northwest corner of 100th Avenue N.E. and N.E. 195th Street	12,000
NC - 13	4	Horse Creek at N.E. 188th Street	Open channel of Horse Creek at N.E. 188th Street	4,400
NC - 14	4	Horse Creek at Bothell Landing	Open channel of Horse Creek at Bothell Landing	14,400
NC - 15	2	Channel reach below Canyon Crest #1 detention pond	238th Place S.E. and 26th Drive S.E.	28,800
NC - 16	6	North Creek stream rehabilitation	North Creek through Canyon Park Industrial Park	178,200
			SUB-TOTAL	493,900
			TOTAL COST	7,055,250

** Projects to be initiated and completed in conjunction with new development.

Table 7-2
DETAILS OF ANNUAL PROGRAMS
ALTERNATIVE 4 (PREFERRED)

		PROJECT DESCRIPTION	COST
Public Education/Customer Service			
	Project PE-1	Voluntary Ditch Maintenance	10,000
	Project PE-3	Public Involvement Coordinator	50,000
	Project PE-4	Annual Creek Clean-up Days	4,000
	Project PE-5	Catch Basin Stenciling	5,000
		Sub-Total	**69,000**
Water Quality Monitoring			
	Project A-2	Staff Water Quality Workshops	5,000
	Project A-4	Ambient Water Quality Monitoring	61,500
		Sub-Total	**66,500**
Interlocal Agreements			
	Project PE-2	Interagency/Governmental Coord.	2,500
	Project A-3	Sno. Co. Watershed Keeper	5,000
		Sub-Total	**7,500**
Development Review/Inspection			
	Project A-6	Development Review/Inspection	108,000
Utility Billing Maintenance			
	Project A-10	Utility Billing Maintenance	25,000
		Total Annual Cost	276,000
		6-Year Total Cost	1,656,000
		20-Year Total Cost	5,520,000

Table 7-3
SUMMARY OF MAINTENANCE AND OPERATION PROGRAM

	Alternative 1[1] Existing Level of Service	Alternative 2[2] Low Level of Service	Alternative 3[3] Medium Level of Service	Alternative 4[4] (Preferred) High Level of Service
Detention Facilities				
Vegetation Control	1,890	2,280	3,040	5,700
Sediment Removal		0	3,728	9,320
Vaults	4,157	5,232	8,720	8,720
Storage Pipes	4,157	5,232	8,720	8,720
Total	10,204	12,744	24,208	32,460
Catch Basins (6,200)	36,235	68,016	115,104	158,704
Pipes (46.8 Miles)	33,987	38,368	120,336	137,776
Roadside Ditches				
Vegetation Control	14,100	10,296	10,296	10,296
Reshape	13,474	44,736	65,240	82,016
Total	27,574	55,032	75,536	92,312
Vactor Waste Disposal Fees	27,008	28,000	30,000	32,000
Sub-Total	135,008	202,160	365,184	453,252
Assumed supervisory and clerical personnel cost	7,001	15,000	25,000	50,000
TOTAL ANNUAL COST	142,009	217,160	390,184	503,252
TOTAL 6-YEAR COST	852,054	1,302,960	2,341,104	3,019,512
TOTAL 20-YEAR COST	2,840,180	4,343,200	7,803,680	10,065,040

Cost of Detention Facilities, Catch Basins, Pipes, and Roadside Ditches is based on four-person crew working at following levels:

1) Existing LOS - 30% of year (4-person crew, 80 days of work)
2) Low LOS - 45% of year (4-person crew, 120 days of work)
3) Medium LOS - 80% of year (4-person crew, 213 days of work)
4) High LOS - 100% of year (4-person crew, 266 days of work)

7.3 EFFECTIVENESS EVALUATION

The effectiveness of projects recommended in this plan can be evaluated based on frequency of flooding, public health, and water quality. The projects are measured by the practicality of solutions, cost, and improvements to water quality and quality. Reducing the impact of flooding while improving water quality requires implementation of management strategies such as: 1) source reduction, 2) delivery reduction, or 3) the reduction of direct impacts. Source reduction measures rely upon the prevention of nonpoint source pollution and excessive runoff from impervious surfaces. Delivery reduction measures include detention basins, filter strips, constructed wetlands, and similar practices for trapping or treating stormwater runoff. Measures that reduce direct impacts include wetland and riparian area protection, the preservation of natural stream channel characteristics, and habitat protection. Management measures are systems of practices, technologies, processes, siting criteria, operating methods, or other alternatives. Pollution control and flood abatement programs generally consist of a combination of these measures. Strategies which include programs and policies elements are hard to evaluate. Therefore the following discussion primarily addresses structural management measures in terms of their practicality, cost, and water quality enhancement features.

7.3.1 **Practicality**

Managing stormwater runoff to protect people and property while also meeting water quality and resource protection is the goal of this plan. Solving the existing problems coupled with site constraints resulted in a limited number of choices. The resulting preferred alternative combines upgrades to the existing system, construction of three new detention facilities, and a high flow by-pass to meet the water quality and flood protection goals for the City. Most of these improvements are within the Horse Creek basin or the Perry Creek tributary to North Creek.

The other basins in the study area still contain large tracts of undeveloped areas. Structural recommendations for these areas consist of replacement of cross culverts, channel enhancements, and preservation of existing wetland and riparian corridors. Adoption of regulations consistent with the Ecology Manual will ensure protection from future flooding in these basins after development occurs.

7.3.2 **Effectiveness**

The effectiveness of recommended improvements is measured by a reduction of frequency of flooding and damage to property but also to the reduction of pollution entering the system. Delivery reduction measures can be evaluated by the comparison of inflow to outflow parameters. For example, increasing the size of detention facilities or increasing the conveyance capacity of the drainage system reduces the frequency of emergency flood response by City staff and property damage. Measuring the effectiveness of pollutant reduction from this type of measure requires sampling the inflow and outflow at appropriate time intervals to measure differences in the water quality between the two points.

Evaluating the effectiveness of source reduction measures is more difficult because there are usually no discrete inflow and outflow points. The effectiveness of policies and programs initiated as a preventive measure is generally determined by upstream-downstream studies. Upstream-downstream studies are generally more useful for documenting the magnitude of a problem source than for documenting the effectiveness of a source control measures. The effects of upstream point source discharge, uncontrolled nonpoint source discharges, and upstream flow regulation can be isolated with this type of design.

The effectiveness of measures intended to prevent direct impacts cannot be determined through common sampling techniques since pollutant loads are not generated. Improvements are measured in terms of reference site approaches where the conditions at the affected area are compared over time as the improvements are implemented. An example of this procedure would be to evaluate habitat or streambank erosion at a specific site before and after improvements are constructed.

A critical step in ensuring success of a management strategy is proper operation and maintenance of each practice. Once a series of practices has been designed and installed, it is crucial that the individual practices be operated and maintained to ensure that they function as intended. Construction of detention ponds and swales coupled with a regular maintenance program will reduce the amount of pollutants discharging into the City system, North and Swamp Creeks, and the Sammamish River from stormwater washoff. During the design process, an operation and maintenance plan that identifies continual procedures, schedules, and responsibility for operating and maintaining the practices should be drafted.

7.3.3 **Improvements to Water Quality and Quantity**

Pollutants from urban sources include suspended solids, nutrients, pathogens, metals, petroleum products, and various toxics and are often bound to the sediment particles. The use of structural measures such as detention facilities and swales to settle particulates can be the most effective treatment for removing pollutants. Wet pond detention facilities also provide water quality treatment benefits through biological uptake of dissolved pollutants and provide removal of total suspended solids and some heavy metals, nutrients, and oil and grease. Historically, detention facilities controlled the rate of release of water into receiving systems. This type of control can prevent flooding, minimize streambank erosion, and protect aquatic habitats.

Another effective method of treating stormwater runoff is through the use of constructed wetlands. Wetland ecosystems can be highly effective managers of stormwater runoff by removing pollutants, attenuating flows, and recharging groundwater. However, the use of natural wetlands as pollution control facilities is dependent upon several factors. Modification of the wetland to promote stormwater quality improvement should be considered only if the wetland is already highly disturbed and serves minimal ecological functions, and if opportunities exist for concurrently improving the ecological functioning of such wetlands and increasing their resource values. When restoration or enhancement of a previously degraded wetland results in the upgrading of wetland functions there will be benefits to runoff quality control.

The major pollutant removal mechanisms operating in wetlands may be divided into physical, chemical, and biological. Physical mechanisms include sedimentation, filtration, and adsorption. Chemical mechanisms include precipitation and adsorption, and biological mechanisms include plant and bacterial uptake and metabolism, and plant absorption. The combination of these removal mechanisms can result in high removal efficiencies of pollutants - up to 90 percent or higher. However, high removal efficiencies are dependent on the exact nature of the wetland and how it has been designed and constructed.

Nonstructural changes such as regulations for new development will reduce the incidence of erosion and sediment transport from job sites and require facilities to prevent increases in runoff rates and flooding. Water quality monitoring will establish "baseline" conditions to use in the evaluation of recommendations. Citizen involvement and public education encourages recognition of regional resources and provides support for the changes in lifestyle and financial commitment necessary to preserve those resources. Nonstructural practices should be reviewed periodically as guidelines are updated or to determine the level of compliance with the guidelines.

Chapter 8 - FINANCIAL ANALYSIS

This chapter addresses the financial impacts of the storm damage program alternatives and identifies potential sources of funding to meet the program needs, including status quo or establishing a citywide utility. Based on the program options in this Plan, a citywide utility is recommended as a source of stable revenue for the future. Appendix D contains a series of issue papers specifically related to the analysis of and establishing of a citywide utility.

8.1 Overview

From a financial perspective, the structural and nonstructural projects and programs presented in earlier chapters will be discussed in the manner described below. Projects are differentiated by programs in this chapter based on the nature of the expenditure--projects are typically one time or infrequent expenditures, as compared to programs that are typically ongoing annual costs to the overall storm drainage function of the City.

- One Time Projects - These include structural capital facilities and nonstructural studies or other projects that will not be incurred on an ongoing annual basis.

- Annual Program - This category of expense includes those public education/awareness and administrative programs that will be carried out on an annual ongoing basis.

- Maintenance and Operation Program - This is actually an element of the Annual Program, but is separately identified due to the significant cost and separate options available.

8.2 Historical Capital Funding

The storm drain activities are performed by the public works crews. There is a Storm Drainage Cumulative Reserve Fund to provide for capital projects. Fees in lieu of assessment and contributions from developers as a condition of development are placed in the Cumulative Reserve Fund and used for capital projects. Historically, there has been a balance carried forward from year to year in the Cumulative Reserve Fund. In 1993, the full amount of the cumulative reserve is scheduled to go toward capital improvements, the Drainage Comprehensive Plan, and North Creek studies in collaboration with Snohomish County.

Table 8-1 shows the historical storm drainage capital program. The information is taken from a combination of the City's annual financial report and the annual budget. The capital expenses in 1992 and 1993 have significantly increased, in part due to the annexation, and in part due to the development of this Drainage Comprehensive Plan.

Table 8-1
HISTORICAL STORM DRAINAGE CAPITAL PROGRAM

CITY OF BOTHELL STORM DRAINAGE CUMULATIVE RESERVE FUND	ACTUAL 1988	ACTUAL 1989	ACTUAL 1990	ACTUAL 1991	BUDGET 1992	BUDGET 1993
ESTIMATED BEGINNING FUND BALANCE	$184,629	$199,506	$238,459	$245,500	$264,300	$160,000
Fees/Mitigation/Contributions	41,688	42,222	7,255	11,154	26,100	41,000
Other Revenues	0	0	0	7,629	0	0
FUND BALANCE AVAILABLE	226,317	241,726	245,714	264,283	290,400	201,000
EXPENDITURES						
Construction Projects	(26,811)	(3,269)	0	(119)	(200,800)	(31,600)
North Creek FEMA Study						(20,000)
Storm Drain Comprehensive Plan					(90,000)	(150,000)
PROGRAMMED EXPENDITURES	(26,811)	(3,269)	0	(119)	(290,800)	(201,600)

Source: City of Bothell Annual Financial Report and Annual Budget

8.3 Historical Maintenance Funding

The maintenance activities are also carried out by the public works crews as apart of the Street Fund. The primary sources of revenue for the Street Fund have been motor vehicle fuel tax and general property taxes from a citywide basis.

In 1992, with the annexation of the Canyon Park area of Snohomish County to the City of Bothell, an interlocal agreement was signed to continue participation in the storm drainage utility. The utility service charges paid to the County by the residents are transferred to the City and reflected in the Street Fund. The interlocal agreement was extended for 1993 and there is the potential for continuance in the future. The utility is designed to provide for maintenance, study, and improvements on a watershed basis in Snohomish County. As such, the City will be working closely with the County to plan and construct appropriate improvements to reduce the potential for flooding, property damage, and water quality. In addition to working with the County on planning and construction basinwide improvements, the city has responsibility for maintenance, permitting, inspection, and complaint investigation activities in the Canyon Park area. These are handled within the Street Fund, together with the other maintenance activities.

Table 8-2 summarizes the historical storm drainage maintenance program for the City. The data is based on the City's Annual Budget.

Table 8-2
HISTORICAL STORM DRAINAGE MAINTENANCE PROGRAM

CITY OF BOTHELL STREET FUND - STORM DRAIN MAINTENANCE	BUDGET 1988	BUDGET 1989	BUDGET 1990	BUDGET 1991	BUDGET 1992	BUDGET 1993
STORM DRAINAGE	1,800	24,361	27,011	28,295	51,932	143,819
MAINTENANCE ADMIN[1)]	25.4%	22.5%	23.1%	43.0%	67.4%	22.9%
ROAD & STREET GENERAL ADMIN[2)]	12.3%	9.0%	15.4%	7.2%	3.5%	51.3%
ADMIN TO STORM DRAIN	678	7,673	10,399	14,207	36,769	106,720
TOTAL STORM DRAINAGE MAINTENANCE	2,478	32,034	37,410	42,502	88,701	250,539

Source: City of Bothell Annual Budgets (Does not reflect "Actual")
1) Maintenance Administration as a percentage of Road & Street Maintenance
2) Road & Street General Administration as a percentage of total Street Fund budget

There are two types of administrative overhead reflected in the Street Fund as shown in the annual budget: Maintenance Administration and Road and Street Administration. The table above allocates overhead to the storm drainage maintenance program based on the percentage of overhead to total costs in the expense type. In 1992 and 1993, a portion of the administration costs is for improvements, presumably spot improvements and complaint investigations within the newly annexed area.

Because storm drainage maintenance activities represent only a portion of the work carried out within the Street Fund, assumptions were made in allocating the administrative overhead on a gross basis for the table. A separate exercise was performed with the public works administrative staff and management to estimate the percentage of time spent on the various drainage maintenance activities. Staff estimated that administrative, office support, engineering, plan review/design, technical, and inspection for 1993 would be about $108,000. In addition, maintenance crew and equipment are expected to be about $142,000. The total of these two elements is $250,000 for storm drainage maintenance activities and associated administrative overhead. This built-up number for 1993 is very close to the numbers shown in Table 8-2.

8.4 Future Annual Storm Drainage Costs

Table 8-3 provides a detailed scheduling of the projects and programs recommended in Chapter 7.

The priorities refer to the year of the project funding; "7" refers to the period 7 to 10 years; "annual" refers to the costs paid on an annual basis; and "other" refers to projects or studies to be completed.

The costs identified are those anticipated to be the responsibility of the City. Those projects to not be funded by the City do not have costs shown. There is an exception to this in project NC-16 for $178,200 is identified in the North Creek Watershed Plan as being implemented jointly by Snohomish County, Department of Fisheries, and the development

Table 8-3
PROJECT AND PROGRAM COSTS BY YEAR ($1993)

Project No.	Total Cost	Type Total	Priority Year	Total Annual	1	2	3	4	5	6	7-20	Total	Total YRS 1-6	Total YRS 7-20
					1994	1995	1996	1997	1998	1999				
STRUCTURAL - CONVEYANCE - FLOOD CONTROL														
C-1	8,590		2			8,590						8,590	8,590	0
C-2	11,600		3				11,600					11,600	11,600	0
C-3	24,150		3				24,150					24,150	24,150	0
C-4	58,180		5						58,180			58,180	58,180	0
C-5	32,810		1		32,810							32,810	32,810	0
C-6	272,930		7								272,930	272,930	0	272,930
C-7	3,150,000		10								3,150,000	3,150,000	0	3,150,000
C-8	2,000,000		Annual	100,000	100,000	100,000	10,000	100,000	100,000	100,000	1,400,000	2,000,000	400,000	1,400,000
C-9	400,000		Annual	20,000	20,000	20,000	20,000	20,000	20,000	20,000	280,000	400,000	120,000	280,000
TOTAL		3,558,260		120,000										
STRUCTURAL - DETENTION - FLOOD CONTROL														
D-1	19,030		3				19,030					19,030	19,030	0
D-2	13,805		3				13,805					13,805	13,805	0
D-3	17,450		4					17,450				17,450	17,450	0
D-4	116,145		4					116,145				116,145	116,145	0
D-5	57,515		5						57,515			57,515	57,515	0
D-6	12,670		1		12,670							12,670	12,670	0
D-7	160,540		7								160,540	160,540	0	160,540
D-8	18,710		2			18,710						18,710	18,710	0
D-9	150,520		Annual	8,000	8,000	8,000	8,000	8,000	8,000	8,000	102,250	150,250	48,000	102,250
TOTAL		415,865		8,000										

Table 8-3
PROJECT AND PROGRAM COSTS BY YEAR ($1993)

Project No.	Total Cost	Type Total	Priority Year	Total Annual	1	2	3	4	5	6	7-20	Total	Total YRS 1-6	Total YRS 7-20
					1994	1995	1996	1997	1998	1999				
STRUCTURAL - LOCAL - FLOOD CONTROL														
L-1	26,460		2			26,460						26,460	26,460	0
L-2	3,615		3				3,615					3,615	3,615	0
L-3	6,900		2			6,900						6,900	6,900	0
TOTAL		36,975												
NATURAL CHANNEL ENHANCEMENT/PROTECTION														
NC-1			As Dev											
NC-2			As Dev											
NC-3	103,200		7								103,200	103,200		103,200
NC-4	57,600		5						57,600			57,600	57,600	0
NC-5			As Dev											
NC-6	36,500		3				36,500					36,500	36,500	0
NC-7	6,000		4					6,000				6,000	6,000	0
NC-8			As Dev											
NC-9	14,400		2			14,400						14,400	14,400	0
NC-10	24,000		2			24,000						24,000	24,000	0
NC-11	14,400		2			14,400						14,400	14,400	0
NC-12	12,000		4					12,000				12,000	12,000	0
NC-13	4,400		4					4,400				4,400	4,400	0
NC-14	14,400		4					14,400				14,400	14,400	0
NC-15	28,800		2			28,800						28,800	28,800	0
NC-16			Other Fund											
NC-17			As Dev											
TOTAL		315,700												

Table 8-3
PROJECT AND PROGRAM COSTS BY YEAR ($1993)

Project No.	Total Cost	Type Total	Priority Year	Total Annual	1	2	3	4	5	6	7-20	Total	Total YRS 1-6	Total YRS 7-20
					1994	1995	1996	1997	1998	1999				
NON-ANNUAL PROGRAMS														
A-1	15,000		1		15,000							15,000	15,000	0
A-5	55,500		4					55,500				55,500	55,500	0
A-8	50,000		1		50,000							50,000	50,000	0
A-9	50,000		1		50,000							50,000	50,000	0
A-11	50,000		1		50,000							50,000	50,000	0
A-12	300,000		5-10-15						100,000		200,000	300,000	100,000	200,000
TOTAL		520,500												
TOTAL 1× PROJECTS		4,847,300												
ANNUAL PROGRAMS														
PE-1	10,000		Annual	10,000	10,000	10,000	10,000	10,000	10,000	10,000	140,000	200,000	60,000	140,000
PE-2	2,500		Annual	2,500	2,500	2,500	2,500	2,500	2,500	2,500	35,000	50,000	15,000	35,000
PE-3	50,000		Annual	50,000	50,000	50,000	50,000	50,000	50,000	50,000	700,000	1,000,000	300,000	700,000
PE-4	4,000		Annual	4,000	4,000	4,000	4,000	4,000	4,000	4,000	56,000	80,000	24,000	56,000
PE-5	5,000		Annual	5,000	5,000	5,000	5,000	5,000	5,000	5,000	70,000	100,000	30,000	70,000
A-2	5,000		Annual	5,000	5,000	5,000	5,000	5,000	5,000	5,000	70,000	100,000	30,000	70,000
A-3	5,000		annual	5,000	5,000	5,000	5,000	5,000	5,000	5,000	70,000	100,000	30,000	70,000
A-4	61,500		Annual	61,500	61,500	61,500	61,500	61,500	61,500	61,500	861,000	1,230,000	369,000	861,000
A-6	108,000		Annual	108,000	108,000	108,000	108,000	108,000	108,000	108,000	1,512,000	2,160,000	648,000	1,512,000
A-7	390,184		Annual	390,184	390,184	390,184	390,184	390,184	390,184	390,184	5,462,576	7,803,680	2,341,104	5,462,576
A-10	25,000		Annual	25,000	25,000	25,000	25,000	25,000	25,000	25,000	350,000	500,000	150,000	350,000
TOTAL				666,184										
TOTAL ANNUAL BASIS				796,184	796,184	796,184	796,184	796,184	796,184	796,184	11,108,826	15,885,930	4,777,104	11,108,826
OVERALL TOTAL		**4,847,300**		**796,184**	**1,006,664**	**938,444**	**904,884**	**1,022,079**	**1,069,479**	**796,184**	**14,995,496**	**20,733,230**	**5,737,734**	**14,995,496**

community. Although this cost shows up in Table 7-1, it is not included in the total presented in this chapter.

For the 20-year program, the one-time project costs total $7,575,750. The annual costs shown are at $666,184 at the high level of service (medium for maintenance and operation).

The total revenue required for the recommended program is about $1 million. In 1993 dollars, the total over six years is $5.7 million, and $20.7 million over 20 years.

8.5 Capital Facilities Planning for Growth Management

Under the Growth Management Act, the capital facilities required for the next six years must be identified along with funding sources. Table 8-4 summarizes drainage capital projects over the next six years, along with the recommended funding source of a citywide utility. The capital costs over the six years average $160,105. Using the existing Snohomish County Utility revenue as a basis, it is estimated that on average, $1.05 per single family per month would be required to fund the capital program from a citywide utility.

Table 8-4
SIX-YEAR CAPITAL PROJECTS

STORM DRAINAGE CAPITAL PROJECTS - 6 YRS ($1993)	1 1994	2 1995	3 1996	4 1997	5 1998	6 1999	6-YR AVERAGE
TOTAL CAPITAL PROJECTS	$210,480	$142,260	$108,700	$225,895	$273,295	$0	$160,105
OPTION: CITYWIDE UTILITY							
Assume Sno. Co. approx. equals King Co. Rate Base							
Estimated Utility Revenue	$280,000	$280,000	$280,000	$280,000	$280,000	$280,000	$280,000
Apply Existing Multiplier to meet Required Revenue	0.75	0.51	0.39	0.81	0.98	0	0.57
Existing Single-Family Annual Rate	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00	$22.00
PROJECTED SINGLE-FAMILY ANNUAL RATE	$16.50	$11.22	$8.58	$17.82	$21.56	$0	$12.54
PROJECTED SINGLE-FAMILY MONTHLY RATE (CIP only)	$1.38	$0.94	$0.72	$1.49	$1.80	$0	$1.05

8.6 Additional Annual Revenue Needed

Table 8-5 summarizes the annual revenue required to support the program and shows the additional annual revenue needed to meet those requirements:

- One-Time Costs - The total one-time projects identified over the 20 years is $4,847,300 ($1993).

- Annual Program Costs - Annual ongoing program costs, except M&O is $406,000.

- Maintenance and Operation Program (M&O) - Annual M&O program costs on an ongoing basis are recommended to be $390,184 for the medium level of service.

Currently, there is $142,009 programmed to storm drainage on an annual ongoing basis. This does not include any funds from the current Storm Drainage Cumulative Reserve as they are scheduled to be used during 1993.

Snohomish County's recent estimate of utility revenue indicates $140,000 on an ongoing annual basis. This estimate is lower than previous estimates and includes adjustments for in-kind services from the schools, adjustment for state highways, and for federal property. The current funding from the Street Fund on an ongoing annual basis is about $243,000, and an estimate of $26,000 for fee in-lieu-of-assessment is estimated based on financial reports.

The recommended program is roughly twice the size of the current annual funding level. The bottom of Table 8-5 shows the "Additional Revenue Needed." Over the 20-year program of $20.7 million, additional revenue of $12.5 million is needed to complete the recommended program.

Table 8-5
ADDITIONAL REVENUE NEEDED

STORM DRAINAGE PROGRAM ($1993)	1 1994	2 1995	3 1996	4 1997	5 1998	6 1999	7-20	TOTAL
TOTAL 1× PROJECTS	210,480	142,260	108,700	225,895	273,295	0	3,886,670	4,847,300
TOTAL ANNUAL PROGRAM	406,000	406,000	406,000	406,000	406,000	406,000	5,646,250	8,082,250
TOTAL M&O PROGRAM	390,184	390,184	390,184	390,184	390,184	390,184	5,462,576	7,803,680
TOTAL ANNUAL REVENUE REQUIRED	1,006,664	938,444	904,884	1,022,079	1,069,479	796,184	14,995,496	20,733,230
EXISTING UTILITY REVENUE	140,000	140,000	140,000	140,000	140,000	140,000	1,960,000	2,800,000
EXISTING FUEL TAX/STREET FUND/GENERAL	243,000	243,000	243,000	243,000	243,000	243,000	3,402,000	4,860,000
ESTIMATED MITIGATION/CONTRIBUTIONS	26,000	26,000	26,000	26,000	26,000	26,000	364,000	520,000
EXISTING ONGOING FUNDING SOURCES	409,000	409,000	409,000	409,000	409,000	409,000	5,726,000	8,180,000
ADDITIONAL REVENUE NEEDED	597,664	529,444	495,884	613,079	660,479	387,184	9,269,496	12,553,230

8.7 Future Sources of Revenue

The City is in somewhat of a unique position in that a portion of the City is included in a watershed-based utility providing for a portion of its maintenance and somewhat towards its capital and study requirements. The other costs of the City are funding the storm drainage activities through general citywide sources of revenue. As basin plans are developed for the other areas, it is likely that a dedicated source of funding (like the utility) would be helpful in carrying out the necessary improvements to decrease the hazard of flooding and property damage and increase water quality.

Grants are good sources of revenue for capital improvements, but cannot be counted on in the long or short run. Typically, the lead time in obtaining grant or loan funds is long. The Storm Drain Comprehensive Plan will assist in planning ahead enough to be able to apply for grant funds in the future.

There are also low interest loan programs available to assist with funding of capital improvements. The Public Works Trust Fund program has low interest (1 to 3 percent) loans that would be worth pursuing.

8.8 Citywide Utility Recommended

Approximately 84 percent of the average annual costs are ongoing and not related to one-time projects (all in $1993). The principal options for funding ongoing M&O are status quo, all Street Fund with property or motor vehicle fuel taxes, or citywide utility.

A stable revenue source provides for a more reliable program. Street and General Fund taxes typical set up an atmosphere of competition on an annual basis for funding between all aspects of street maintenance and improvement. A utility provides a dedicated, stable revenue source.

Appendix D contains issue papers that consider criteria and options for ongoing funding of a storm drainage program and specifically address utility issues.

8.9 Storm Drainage Overall Program Funding

For financial planning purposes, it is easier to work with average annual costs to know what is required as an ongoing revenue stream for both ongoing and one-time projects. This also gives a more realistic view of what can be achieved with limited dollars on a repetitive basis (annually).

Table 8-6 summarizes the analysis of the overall 20-year program level of service options. Both the Annual Program and M&O Program were presented as options of low to high level of service. The one-time projects are the same in each option. The recommended program in Chapter 7 is approximately level of service medium.

The total annual revenue required averages from $690,835 (low) to $987,549 (medium) to $1,149,617 (high).

Table 8-6
OVERALL PROGRAM OPTIONS

STORM DRAINAGE 20-YR PROGRAM ($1993) AVERAGE ANNUAL COST	LEVEL OF SERVICE		
	LOW	MED	HIGH
ANNUAL COST OF PROGRAM OPTIONS			
Total 1× Projects	242,365	242,365	242,365
Total Annual Program	231,310	355,000	404,000
Total M&O Program	217,160	390,184	503,252
Total Annual Revenue Required	$690,835	$987,549	$1,149,617
ADDITIONAL REVENUE NEEDS			
Existing Utility Revenue	140,000	140,000	140,000
Existing Fuel Tax/Street Fund/General Fund	243,000	243,000	243,000
Estimated Mitigation/Contributions	26,000	26,000	26,000
Existing Ongoing Funding Sources	$409,000	$409,000	$409,000
ADDITIONAL REVENUE NEEDED	$281,835	$578,549	$740,617
REVENUE OPTION: CITYWIDE UTILITY			
Assume Sno. Co. approx equals King. Co. Rate Base			
Estimated Utility Revenue	$280,000	$280,000	$280,000
Apply Existing Rate Multiplier to meet Required Revenue	2.47	3.53	4.11
Existing Single-Family Annual Rate	22.00	22.00	22.00
PROJECTED SINGLE-FAMILY ANNUAL RATE	$54.28	$77.59	$90.33
PROJECTED SINGLE-FAMILY MONTHLY RATE	$4.52	$6.47	$7.53

Considering that the average current funding of ongoing programs is $409,000, a significant amount of revenue is needed to meet the annual costs at any level of service. The additional revenue needed is $281,835 (low), $578,549 (medium), and $740,617 (high). Without a citywide utility, this amount would likely come from motor vehicle or general property taxes.

If the City were to establish a citywide utility, an estimate of the annual and monthly impact can be made. It appears that the Snohomish County and King County areas within the City are fairly similar based on land use, zoning, population, and utility billing statistics. We know that $140,000 is the estimated revenue generated by the Snohomish County property with the rate structure based on size of property and impervious area (Appendix D, Issue Paper 8, contains Snohomish County billing statistics). If we assume that the same revenue will be generated by the remaining portion of the City, a total of $280,000 could be generated annually by Snohomish County's utility rate structure.

Table 8-6 shows that the multiplier of additional revenue needed compared to $280,000 estimated utility revenue is 2.47 (low), 3.53 (medium), and 4.11 (high). At the current annual rate of $22.00 ($1.83 monthly) for single-family property, the level of service options would result in monthly rates for single family of $4.52 (low), $6.47 (medium), and $7.53 (high) to fund the medium level of services recommended in Chapter 7.

APPENDIX B - DEFINITIONS

Anadromous - Fishes ascending rivers from the sea for breeding.

Antecedent runoff conditions - The degree of wetness of a watershed or within the soil at the beginning of a storm.

Aquifer - A geologic stratum containing groundwater that can be withdrawn and used for human purposes.

Backwater - Water upstream from an obstruction which is deeper than it would normally be without the obstruction.

Bankfull discharge - A flow condition where streamflow completely fills the stream channel up to the top of the bank. In undisturbed watersheds, the discharge conditions occurs on average every 1.5 to 2 years and controls the shape and form of natural channels.

Berm - A constructed barrier of compacted earth, rock, or gravel.

Best Management Practice (BMP) - Physical, structural, and/or managerial practices that, when used singly or in combination, prevent or reduce pollution of water, and have been approved by Ecology.

Biofiltration - The process of reducing pollutant concentrations in water by filtering the polluted water through biological materials.

Capital Improvement Program - A project prioritized and scheduled as a part of an overall construction program, or the actual construction program.

Catchbasin - A chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Conveyance system - The drainage facilities, both natural and man-made, which collect, contain, and provide for the flow of surface and stormwater from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The human-made elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities.

Design storm - A prescribed hyetograph and total precipitation amount used to estimate runoff for a hypothetical storm of interest or concern for the purposes of analyzing existing drainage, designing new drainage facilities or assessing other impacts of a proposed project of the flow of surface water.

Detention - An above or below ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system.

Erosion/sedimentation control - Any temporary or permanent measures taken to reduce erosion; control siltation and sedimentation; and ensure that sediment-laden water does not leave the site.

Eutophication - Refers to the process where nutrient over-enrichment of water leads to excessive growth of aquatic plants, especially algae.

Flood Insurance Rate Map (FIRM) - The official map on which the Federal Insurance Administration has delineated many areas of flood hazard, floodway, and the risk premium zones.

Impervious surface - A hard surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development, and/or a hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, rood tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater.

Isopluvial map - A map with lines representing constant depth of total precipitation for a given return frequency.

National Pollutant Discharge Elimination System (NPDES) - The part of the federal Clean Water Act, which requires point source dischargers to obtain permits. These permits are referred to as NPDES permits, and, in Washington State, are administered by the Washington State Department of Ecology.

Nonpoint source pollution - Pollution that enters a water body from diffuse origins on the watershed and does not result from discernible, confined, or discrete conveyances.

Retention/detention facility - A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground; or to hold surface and stormwater runoff for a short period of time and then release it to the surface and stormwater management system.

Riparian - Pertaining to the banks of streams, wetlands, lakes or tidewater.

Stormwater facility - A constructed component of a stormwater drainage system, designed or constructed to perform a particular function, or multiple functions. Stormwater facilities include, but are not limited to pipes, swales, ditches, culverts, street gutters, detention

basins, retention basins, constructed wetlands, infiltration devices, catchbasins, oil/water separators, sediment basins, and modular pavement.

Swale - A shallow drainage conveyance with relatively gentle side slopes, generally with flow depths less than one foot.

Wetponds - Drainage facilities for water quality treatment that contain permanent pools of water that are filled during the initial runoff from a storm event. They are designed to optimize water quality by providing retention time in order to settle out particles of fine sediment to which pollutants such as heavy metals absorb, and to allow biologic activity to occur that metabolizes nutrients and organic pollutants.

Canyon Basin - 2yr event
existing conditions

==========

BASIN SUMMARY

BASIN ID: cp1 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 18.21 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 6.01 Acres
TIME INTERVAL....: 10.00 min CN....: 70.78
TIME OF CONC.....: 94.40 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 12.20 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0533
TcReach - Channel L: 300.00 kc:21.00 s:0.0467
TcReach - Shallow L: 600.00 ks:14.00 s:0.0001
PEAK RATE: 2.02 cfs VOL: 1.58 Ac-ft TIME: 490 min

BASIN ID: cp10 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 58.88 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 39.95 Acres
TIME INTERVAL....: 10.00 min CN....: 78.58
TIME OF CONC.....: 2132.08 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 18.93 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0670
TcReach - Shallow L:2000.00 ks:5.00 s:0.0100
TcReach - Channel L:1300.00 kc:10.00 s:0.0100
TcReach - Shallow L:3600.00 ks:3.00 s:0.0001
PEAK RATE: 0.97 cfs VOL: 2.66 Ac-ft TIME: 1440 min

BASIN ID: cp11 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 23.29 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 22.01 Acres
TIME INTERVAL....: 10.00 min CN....: 79.73
TIME OF CONC.....: 543.14 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 1.28 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0670
TcReach - Shallow L:1200.00 ks:5.00 s:0.0670
TcReach - Channel L:1200.00 kc:10.00 s:0.0670
TcReach - Shallow L:1500.00 ks:5.00 s:0.0001
PEAK RATE: 0.57 cfs VOL: 1.25 Ac-ft TIME: 1330 min

BASIN SUMMARY

BASIN ID: cp12 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 33.71 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 21.61 Acres
TIME INTERVAL....: 10.00 min CN....: 72.14
TIME OF CONC.....: 1424.20 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 12.10 Acres
CN....: 98.00
TcReach - Sheet L: 200.00 ns:0.4000 p2yr: 1.70 s:0.0500
TcReach - Shallow L:1000.00 ks:3.00 s:0.0770
TcReach - Channel L:1250.00 kc:10.00 s:0.0770
TcReach - Shallow L:2450.00 ks:3.00 s:0.0001
PEAK RATE: 0.68 cfs VOL: 1.85 Ac-ft TIME: 1440 min

BASIN ID: cp13 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 23.88 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 18.41 Acres
TIME INTERVAL....: 10.00 min CN....: 79.80
TIME OF CONC.....: 503.25 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 5.47 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1700 p2yr: 1.70 s:0.0633
TcReach - Shallow L: 800.00 ks:5.00 s:0.0633
TcReach - Shallow L:1100.00 ks:3.90 s:0.0001
PEAK RATE: 0.75 cfs VOL: 1.65 Ac-ft TIME: 960 min

BASIN ID: cp14 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 31.96 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 23.18 Acres
TIME INTERVAL....: 10.00 min CN....: 75.27
TIME OF CONC.....: 303.57 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 8.78 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.2167
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.1200
TcReach - Shallow L: 600.00 ks:5.00 s:0.2500
TcReach - Shallow L:1200.00 ks:7.80 s:0.0001
PEAK RATE: 0.95 cfs VOL: 1.56 Ac-ft TIME: 780 min

Canyon Basin - 2yr event
existing conditions

==========

BASIN SUMMARY

BASIN ID: cp15 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 14.15 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 10.61 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 51.88 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 3.54 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0600
TcReach - Shallow L: 300.00 ks:9.00 s:0.0600
TcReach - Shallow L: 600.00 ks:11.00 s:0.0010
PEAK RATE: 1.42 cfs VOL: 0.99 Ac-ft TIME: 490 min

BASIN ID: cp16 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 11.65 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 6.76 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 259.83 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 4.89 Acres
CN....: 98.00
TcReach - Sheet L: 200.00 ns:0.1500 p2yr: 1.70 s:0.0300
TcReach - Shallow L:1300.00 ks:9.00 s:0.0362
TcReach - Shallow L:1500.00 ks:11.00 s:0.0001
PEAK RATE: 0.69 cfs VOL: 0.96 Ac-ft TIME: 660 min

BASIN ID: cp17 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 10.03 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 5.82 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 165.27 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 4.21 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0400
TcReach - Channel L: 900.00 kc:21.00 s:0.0400
TcReach - Shallow L:1000.00 ks:11.00 s:0.0001
PEAK RATE: 0.74 cfs VOL: 0.82 Ac-ft TIME: 550 min

BASIN SUMMARY

BASIN ID: cp18 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 43.71 Acres BASEFLOWS: 0.25 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 15.92 Acres
TIME INTERVAL....: 10.00 min CN....: 71.22
TIME OF CONC.....: 1190.47 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 27.79 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.1330
TcReach - Shallow L:1700.00 ks:5.00 s:0.0253
TcReach - Channel L:1700.00 kc:17.00 s:0.0253
TcReach - Shallow L:2000.00 ks:3.00 s:0.0001
PEAK RATE: 1.50 cfs VOL: 4.12 Ac-ft TIME: 1320 min

BASIN ID: cp19 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 13.52 Acres BASEFLOWS: 0.50 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 6.95 Acres
TIME INTERVAL....: 10.00 min CN....: 72.80
TIME OF CONC.....: 184.42 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 6.57 Acres
CN....: 98.00
TcReach - Sheet L: 200.00 ns:0.4000 p2yr: 1.70 s:0.1250
TcReach - Shallow L: 700.00 ks:5.00 s:0.0570
TcReach - Shallow L: 900.00 ks:10.00 s:0.0001
PEAK RATE: 1.30 cfs VOL: 2.99 Ac-ft TIME: 540 min

BASIN ID: cp2 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 12.25 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 12.07 Acres
TIME INTERVAL....: 10.00 min CN....: 81.44
TIME OF CONC.....: 851.91 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 0.18 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0500
TcReach - Shallow L:1100.00 ks:3.00 s:0.0600
TcReach - Shallow L:1400.00 ks:3.00 s:0.0001
PEAK RATE: 0.22 cfs VOL: 0.42 Ac-ft TIME: 1440 min

Canyon Basin - 2yr event
existing conditions

BASIN SUMMARY

BASIN ID: cp20 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 9.77 Acres BASEFLOWS: 0.50 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 5.67 Acres
TIME INTERVAL....: 10.00 min CN....: 81.91
TIME OF CONC.....: 173.59 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 4.10 Acres
CN....: 98.00
TcReach - Sheet L: 150.00 ns:0.4000 p2yr: 1.70 s:0.2670
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.2000
TcReach - Channel L: 750.00 kc:21.00 s:0.0690
TcReach - Shallow L:1000.00 ks:11.00 s:0.0001
PEAK RATE: 1.12 cfs VOL: 2.79 Ac-ft TIME: 550 min

BASIN ID: cp21 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 13.31 Acres BASEFLOWS: 0.25 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 7.72 Acres
TIME INTERVAL....: 10.00 min CN....: 81.83
TIME OF CONC.....: 270.85 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 5.59 Acres
CN....: 98.00
TcReach - Sheet L: 200.00 ns:0.1500 p2yr: 1.70 s:0.1900
TcReach - Channel L:1500.00 kc:21.00 s:0.1000
TcReach - Shallow L:1700.00 ks:11.00 s:0.0001
PEAK RATE: 0.93 cfs VOL: 2.01 Ac-ft TIME: 660 min

BASIN ID: cp22 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 13.35 Acres BASEFLOWS: 0.25 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 10.83 Acres
TIME INTERVAL....: 10.00 min CN....: 81.45
TIME OF CONC.....: 1087.62 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 2.52 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.0500 p2yr: 1.70 s:0.0001
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0600
TcReach - Shallow L: 800.00 ks:5.00 s:0.1000
TcReach - Channel L:2000.00 kc:21.00 s:0.0650
TcReach - Shallow L:3200.00 ks:5.60 s:0.0001
PEAK RATE: 0.52 cfs VOL: 1.64 Ac-ft TIME: 1440 min

BASIN SUMMARY

BASIN ID: cp23 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 59.14 Acres BASEFLOWS: 0.25 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 50.27 Acres
TIME INTERVAL....: 10.00 min CN....: 82.71
TIME OF CONC.....: 984.85 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 8.87 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0667
TcReach - Shallow L: 600.00 ks:3.00 s:0.2000
TcReach - Channel L:2200.00 kc:5.00 s:0.0730
TcReach - Shallow L:3100.00 ks:5.70 s:0.0001
PEAK RATE: 1.53 cfs VOL: 3.81 Ac-ft TIME: 1440 min

BASIN ID: cp23a NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 14.69 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 9.70 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 212.50 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 4.99 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0600
TcReach - Shallow L:1200.00 ks:11.00 s:0.0700
TcReach - Shallow L:1300.00 ks:11.00 s:0.0001
PEAK RATE: 0.87 cfs VOL: 1.12 Ac-ft TIME: 600 min

BASIN ID: cp24 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 33.60 Acres BASEFLOWS: 0.25 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 19.49 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 460.92 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 14.11 Acres
CN....: 98.00
TcReach - Sheet L: 200.00 ns:0.1500 p2yr: 1.70 s:0.0200
TcReach - Shallow L:1400.00 ks:9.00 s:0.0714
TcReach - Channel L:1200.00 kc:21.00 s:0.0710
TcReach - Shallow L:2800.00 ks:11.00 s:0.0001
PEAK RATE: 1.77 cfs VOL: 3.77 Ac-ft TIME: 780 min

BASIN SUMMARY

BASIN ID: cp25 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 26.77 Acres BASEFLOWS: 0.25 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 15.53 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 193.38 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 11.24 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0600
TcReach - Channel L:1100.00 kc:21.00 s:0.0909
TcReach - Shallow L:1200.00 ks:11.00 s:0.0001
PEAK RATE: 2.08 cfs VOL: 3.23 Ac-ft TIME: 550 min

BASIN ID: cp26 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 121.92 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 70.72 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 533.92 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 51.20 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0169
TcReach - Channel L:3200.00 kc:21.00 s:0.0169
TcReach - Shallow L:3300.00 ks:11.00 s:0.0001
PEAK RATE: 5.17 cfs VOL: 9.84 Ac-ft TIME: 960 min

BASIN ID: cp3 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 13.37 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 7.76 Acres
TIME INTERVAL....: 10.00 min CN....: 87.24
TIME OF CONC.....: 182.63 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 5.61 Acres
CN....: 98.00
TcReach - Sheet L: 200.00 ns:0.1500 p2yr: 1.70 s:0.0800
TcReach - Channel L: 900.00 kc:21.00 s:0.0800
TcReach - Shallow L:1100.00 ks:11.00 s:0.0001
PEAK RATE: 0.99 cfs VOL: 1.14 Ac-ft TIME: 550 min

Canyon Basin - 2yr event
existing conditions

BASIN SUMMARY

BASIN ID: cp4 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 33.36 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 19.35 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 374.58 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 14.01 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0700
TcReach - Channel L:2000.00 kc:21.00 s:0.0600
TcReach - Shallow L:2300.00 ks:11.00 s:0.0001
PEAK RATE: 1.66 cfs VOL: 2.73 Ac-ft TIME: 780 min

BASIN ID: cp5 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 38.20 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 11.75 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 123.51 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 26.45 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0100
TcReach - Channel L: 700.00 kc:21.00 s:0.0300
TcReach - Shallow L: 800.00 ks:13.00 s:0.0001
PEAK RATE: 4.29 cfs VOL: 3.87 Ac-ft TIME: 520 min

BASIN ID: cp5a NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 53.68 Acres BASEFLOWS: 0.25 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 42.43 Acres
TIME INTERVAL....: 10.00 min CN....: 86.12
TIME OF CONC.....: 365.52 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 11.25 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.2400 p2yr: 1.70 s:0.0670
TcReach - Shallow L:1100.00 ks:8.00 s:0.0860
TcReach - Shallow L:1400.00 ks:7.10 s:0.0001
PEAK RATE: 2.42 cfs VOL: 4.65 Ac-ft TIME: 780 min

Canyon Basin - 2yr event
existing conditions

BASIN SUMMARY

BASIN ID: cp6 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 84.03 Acres BASEFLOWS: 0.25 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 65.37 Acres
TIME INTERVAL....: 10.00 min CN....: 84.21
TIME OF CONC.....: 3225.97 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 18.66 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.2400 p2yr: 1.70 s:0.0067
TcReach - Shallow L:2000.00 ks:5.00 s:0.0650
TcReach - Channel L:2400.00 kc:10.00 s:0.0650
TcReach - Shallow L:5600.00 ks:3.00 s:0.0001
PEAK RATE: 1.22 cfs VOL: 3.65 Ac-ft TIME: 1450 min

BASIN ID: cp6a NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 28.99 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 21.10 Acres
TIME INTERVAL....: 10.00 min CN....: 83.70
TIME OF CONC.....: 903.95 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 7.89 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0333
TcReach - Shallow L:1900.00 ks:5.00 s:0.0410
TcReach - Shallow L:2200.00 ks:4.50 s:0.0001
PEAK RATE: 0.78 cfs VOL: 1.73 Ac-ft TIME: 1330 min

BASIN ID: cp7 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 23.61 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 5.57 Acres
TIME INTERVAL....: 10.00 min CN....: 84.29
TIME OF CONC.....: 334.91 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 18.04 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0200
TcReach - Channel L:2400.00 kc:21.00 s:0.0340
TcReach - Shallow L:2700.00 ks:15.40 s:0.0001
PEAK RATE: 1.68 cfs VOL: 2.47 Ac-ft TIME: 660 min

Canyon Basin - 2yr event
existing conditions

BASIN SUMMARY

BASIN ID: cp7a NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 25.20 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 19.12 Acres
TIME INTERVAL....: 10.00 min CN....: 72.29
TIME OF CONC.....: 971.42 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 6.08 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0067
TcReach - Shallow L:2000.00 ks:5.00 s:0.0500
TcReach - Shallow L:2300.00 ks:4.30 s:0.0001
PEAK RATE: 0.41 cfs VOL: 0.93 Ac-ft TIME: 1440 min

BASIN ID: cp8 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 42.16 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 20.23 Acres
TIME INTERVAL....: 10.00 min CN....: 73.56
TIME OF CONC.....: 999.31 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 21.93 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0533
TcReach - Shallow L:1200.00 ks:5.00 s:0.0670
TcReach - Shallow L: 800.00 ks:3.00 s:0.0100
TcReach - Shallow L:2300.00 ks:4.30 s:0.0001
PEAK RATE: 1.15 cfs VOL: 2.73 Ac-ft TIME: 1320 min

BASIN ID: cp9 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 23.34 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 2.18 Acres
TIME INTERVAL....: 10.00 min CN....: 76.77
TIME OF CONC.....: 158.52 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 21.16 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.0110 p2yr: 1.70 s:0.0100
TcReach - Shallow L: 500.00 ks:27.00 s:0.0100
TcReach - Channel L:1400.00 kc:23.00 s:0.0050
TcReach - Shallow L:2200.00 ks:27.00 s:0.0001
PEAK RATE: 2.75 cfs VOL: 2.66 Ac-ft TIME: 540 min

Horse Creek basin
Existing Conditios

BASIN SUMMARY

BASIN ID: hc1 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 8.40 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 0.84 Acres
TIME INTERVAL....: 10.00 min CN....: 68.00
TIME OF CONC.....: 37.70 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 7.56 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.0110 p2yr: 0.01 s:1.7000
TcReach - Channel L: 400.00 kc:21.00 s:0.0100
TcReach - Shallow L: 500.00 ks:27.00 s:0.0001
PEAK RATE: 4.07 cfs VOL: 2.19 Ac-ft TIME: 490 min

BASIN ID: hc10 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 17.96 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 14.50 Acres
TIME INTERVAL....: 10.00 min CN....: 76.68
TIME OF CONC.....: 873.55 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 3.46 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.1670
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.2000
TcReach - Shallow L: 800.00 ks:8.00 s:0.0750
TcReach - Channel L:1100.00 kc:21.00 s:0.0770
TcReach - Shallow L:2500.00 ks:5.20 s:0.0001
PEAK RATE: 1.15 cfs VOL: 2.53 Ac-ft TIME: 1330 min
BASIN ID: hc11 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 26.24 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 17.32 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 420.93 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 8.92 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0100
TcReach - Channel L:2500.00 kc:21.00 s:0.0460
TcReach - Shallow L:2600.00 ks:11.00 s:0.0001
PEAK RATE: 3.34 cfs VOL: 5.62 Ac-ft TIME: 670 min

BASIN SUMMARY

BASIN ID: hc12 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 3.67 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 3.12 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 278.34 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 0.55 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.1000
TcReach - Channel L: 700.00 kc:10.00 s:0.0640
TcReach - Shallow L: 800.00 ks:5.00 s:0.0001
PEAK RATE: 0.52 cfs VOL: 0.72 Ac-ft TIME: 660 min

BASIN ID: hc13 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 23.41 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 19.90 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 1365.96 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 3.51 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0670
TcReach - Shallow L:1200.00 ks:11.00 s:0.0950
TcReach - Channel L:2500.00 kc:21.00 s:0.0860
TcReach - Shallow L:4000.00 ks:5.00 s:0.0001
PEAK RATE: 1.51 cfs VOL: 3.71 Ac-ft TIME: 1440 min

BASIN ID: hc13a NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 17.01 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 14.46 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 1372.02 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 2.55 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0500
TcReach - Shallow L:1400.00 ks:11.00 s:0.0500
TcReach - Channel L:2500.00 kc:21.00 s:0.0860
TcReach - Shallow L:4000.00 ks:5.00 s:0.0001
PEAK RATE: 1.09 cfs VOL: 2.69 Ac-ft TIME: 1440 min

BASIN SUMMARY

BASIN ID: hc14 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 11.61 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 5.57 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 278.81 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 6.04 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0800
TcReach - Shallow L: 600.00 ks:11.00 s:0.0860
TcReach - Channel L:1050.00 kc:21.00 s:0.0860
TcReach - Shallow L:1750.00 ks:11.00 s:0.0001
PEAK RATE: 2.02 cfs VOL: 2.71 Ac-ft TIME: 600 min

BASIN ID: hc15 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 21.01 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 11.65 Acres
TIME INTERVAL....: 10.00 min CN....: 85.74
TIME OF CONC.....: 339.71 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 9.36 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0100
TcReach - Channel L:1700.00 kc:21.00 s:0.0677
TcReach - Shallow L:1800.00 ks:9.47 s:0.0001
PEAK RATE: 3.16 cfs VOL: 4.72 Ac-ft TIME: 660 min

BASIN ID: hc16 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 13.75 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 6.60 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 233.68 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 7.15 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0100
TcReach - Channel L:1300.00 kc:21.00 s:0.0730
TcReach - Shallow L:1400.00 ks:11.00 s:0.0001
PEAK RATE: 2.75 cfs VOL: 3.62 Ac-ft TIME: 550 min

BASIN SUMMARY

BASIN ID: hc17 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 32.78 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 23.98 Acres
TIME INTERVAL....: 10.00 min CN....: 78.47
TIME OF CONC.....: 836.12 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 8.80 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.2400 p2yr: 1.70 s:0.0830
TcReach - Shallow L: 400.00 ks:11.00 s:0.0600
TcReach - Channel L: 950.00 kc:21.00 s:0.0368
TcReach - Shallow L:2650.00 ks:5.50 s:0.0001
PEAK RATE: 2.46 cfs VOL: 5.68 Ac-ft TIME: 1320 min

BASIN ID: hc17a NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 21.93 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 10.53 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 283.09 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 11.40 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.2400 p2yr: 1.70 s:0.0830
TcReach - Shallow L: 400.00 ks:11.00 s:0.0600
TcReach - Channel L: 950.00 kc:21.00 s:0.0368
TcReach - Shallow L:1650.00 ks:11.00 s:0.0001
PEAK RATE: 3.88 cfs VOL: 5.53 Ac-ft TIME: 600 min

BASIN ID: hc18 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 4.94 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 2.87 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 204.45 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 2.07 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0100
TcReach - Channel L:1100.00 kc:21.00 s:0.0318
TcReach - Shallow L:1200.00 ks:11.00 s:0.0001
PEAK RATE: 1.07 cfs VOL: 1.52 Ac-ft TIME: 550 min

BASIN SUMMARY

BASIN ID: hc19 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 6.83 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 3.28 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 171.91 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 3.55 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0100
TcReach - Channel L: 900.00 kc:21.00 s:0.0720
TcReach - Shallow L:1000.00 ks:11.00 s:0.0001
PEAK RATE: 1.64 cfs VOL: 2.01 Ac-ft TIME: 540 min

BASIN ID: hc2 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 11.64 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 2.99 Acres
TIME INTERVAL....: 10.00 min CN....: 68.00
TIME OF CONC.....: 150.61 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 8.65 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.0110 p2yr: 1.70 s:0.0100
TcReach - Channel L:1200.00 kc:21.00 s:0.0100
TcReach - Shallow L:1300.00 ks:15.60 s:0.0001
PEAK RATE: 2.72 cfs VOL: 2.67 Ac-ft TIME: 540 min

BASIN ID: hc20 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 8.72 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 4.19 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 239.48 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 4.53 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0100
TcReach - Channel L:1300.00 kc:21.00 s:0.0115
TcReach - Shallow L:1400.00 ks:11.00 s:0.0001
PEAK RATE: 1.76 cfs VOL: 2.45 Ac-ft TIME: 550 min

BASIN SUMMARY

```
BASIN ID: hc21          NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.......:  11.75 Acres      BASEFLOWS:   0.10 cfs
RAINFALL TYPE....:    TYPE1A         PERVIOUS AREA
PRECIPITATION....:   3.60 inches       AREA..:    6.98 Acres
TIME INTERVAL....:     10.00 min       CN....:   85.63
TIME OF CONC.....:  519.23 min        IMPERVIOUS AREA
ABSTRACTION COEFF:   0.20              AREA..:    4.77 Acres
                                       CN....:   98.00
TcReach - Sheet   L: 300.00 ns:0.2400 p2yr: 1.70 s:0.0330
TcReach - Shallow L:1100.00 ks:5.00 s:0.0820
TcReach - Channel L:1050.00 kc:21.00 s:0.0476
TcReach - Shallow L:2450.00 ks:8.80 s:0.0001
PEAK RATE:   1.48 cfs  VOL:   2.97 Ac-ft  TIME:    780 min

BASIN ID: hc22          NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.......:  58.60 Acres      BASEFLOWS:   0.10 cfs
RAINFALL TYPE....:    TYPE1A         PERVIOUS AREA
PRECIPITATION....:   3.60 inches       AREA..:   37.64 Acres
TIME INTERVAL....:     10.00 min       CN....:   86.02
TIME OF CONC.....:  561.30 min        IMPERVIOUS AREA
ABSTRACTION COEFF:   0.20              AREA..:   20.96 Acres
                                       CN....:   98.00
TcReach - Sheet   L: 300.00 ns:0.8000 p2yr: 1.70 s:0.0067
TcReach - Shallow L: 200.00 ks:11.00 s:0.0380
TcReach - Channel L:1500.00 kc:21.00 s:0.0380
TcReach - Shallow L:2000.00 ks:9.20 s:0.0001
PEAK RATE:   6.61 cfs  VOL:  12.90 Ac-ft  TIME:    790 min

BASIN ID: hc22a         NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.......:  14.23 Acres      BASEFLOWS:   0.10 cfs
RAINFALL TYPE....:    TYPE1A         PERVIOUS AREA
PRECIPITATION....:   3.60 inches       AREA..:    9.12 Acres
TIME INTERVAL....:     10.00 min       CN....:   84.87
TIME OF CONC.....:  592.55 min        IMPERVIOUS AREA
ABSTRACTION COEFF:   0.20              AREA..:    5.11 Acres
                                       CN....:   98.00
TcReach - Sheet   L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0067
TcReach - Shallow L: 200.00 ks:11.00 s:0.0380
TcReach - Channel L:1200.00 kc:21.00 s:0.0380
TcReach - Channel L:1150.00 kc:5.00 s:0.0380
TcReach - Shallow L:2850.00 ks:9.20 s:0.0001
PEAK RATE:   1.60 cfs  VOL:   3.36 Ac-ft  TIME:    960 min
```

BASIN SUMMARY

BASIN ID: hc23 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 12.09 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 10.41 Acres
TIME INTERVAL....: 10.00 min CN....: 76.26
TIME OF CONC.....: 459.94 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 1.68 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.2000
TcReach - Shallow L: 300.00 ks:3.00 s:0.1670
TcReach - Channel L: 700.00 kc:17.00 s:0.0029
TcReach - Shallow L:1300.00 ks:5.50 s:0.0001
PEAK RATE: 0.95 cfs VOL: 1.72 Ac-ft TIME: 960 min

BASIN ID: hc24 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 42.93 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 42.93 Acres
TIME INTERVAL....: 10.00 min CN....: 84.61
TIME OF CONC.....: 1350.93 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 0.00 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.0067
TcReach - Shallow L: 700.00 ks:3.00 s:0.1360
TcReach - Channel L:1800.00 kc:5.00 s:0.0250
TcReach - Shallow L:2800.00 ks:4.20 s:0.0001
PEAK RATE: 2.49 cfs VOL: 5.95 Ac-ft TIME: 1440 min

BASIN ID: hc25 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 13.04 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 8.61 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 275.35 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 4.43 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0080
TcReach - Channel L:1620.00 kc:21.00 s:0.0150
TcReach - Shallow L:1620.00 ks:11.00 s:0.0001
PEAK RATE: 2.07 cfs VOL: 2.81 Ac-ft TIME: 610 min

BASIN SUMMARY

BASIN ID: hc26 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 7.61 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 5.02 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 174.87 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 2.59 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0300
TcReach - Channel L: 950.00 kc:21.00 s:0.0300
TcReach - Shallow L:1050.00 ks:11.00 s:0.0001
PEAK RATE: 1.54 cfs VOL: 1.64 Ac-ft TIME: 540 min

BASIN ID: hc27 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 77.17 Acres BASEFLOWS: 0.25 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 74.02 Acres
TIME INTERVAL....: 10.00 min CN....: 75.92
TIME OF CONC.....: 1371.43 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 3.15 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.2000
TcReach - Shallow L: 600.00 ks:5.00 s:0.1080
TcReach - Shallow L:1000.00 ks:3.00 s:0.1250
TcReach - Channel L: 700.00 kc:5.00 s:0.0014
TcReach - Shallow L:2600.00 ks:3.50 s:0.0001
PEAK RATE: 3.58 cfs VOL: 8.74 Ac-ft TIME: 1440 min
BASIN ID: hc28 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 92.80 Acres BASEFLOWS: 1.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 52.71 Acres
TIME INTERVAL....: 10.00 min CN....: 83.71
TIME OF CONC.....: 1295.99 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 40.09 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.0110 p2yr: 1.70 s:0.0200
TcReach - Shallow L: 300.00 ks:13.00 s:0.0030
TcReach - Shallow L: 200.00 ks:5.00 s:0.3000
TcReach - Channel L:2300.00 kc:5.00 s:0.0087
TcReach - Shallow L:3100.00 ks:4.30 s:0.0001
PEAK RATE: 7.62 cfs VOL: 20.63 Ac-ft TIME: 1330 min

BASIN SUMMARY

BASIN ID: hc3 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 16.46 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 7.90 Acres
TIME INTERVAL....: 10.00 min CN....: 77.19
TIME OF CONC.....: 293.22 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 8.56 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.1330
TcReach - Channel L:1500.00 kc:21.00 s:0.0500
TcReach - Shallow L:1800.00 ks:11.00 s:0.0001
PEAK RATE: 2.39 cfs VOL: 3.40 Ac-ft TIME: 610 min

BASIN ID: hc4 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 12.21 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 5.80 Acres
TIME INTERVAL....: 10.00 min CN....: 73.28
TIME OF CONC.....: 303.88 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 6.41 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.1000
TcReach - Channel L:1550.00 kc:21.00 s:0.0350
TcReach - Shallow L:1850.00 ks:11.00 s:0.0001
PEAK RATE: 1.65 cfs VOL: 2.41 Ac-ft TIME: 660 min

BASIN ID: hc5 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 25.64 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 2.56 Acres
TIME INTERVAL....: 10.00 min CN....: 79.50
TIME OF CONC.....: 186.04 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 23.08 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0100
TcReach - Shallow L: 250.00 ks:27.00 s:0.0010
TcReach - Channel L:1500.00 kc:21.00 s:0.0100
TcReach - Shallow L:2050.00 ks:27.00 s:0.0001
PEAK RATE: 6.58 cfs VOL: 6.83 Ac-ft TIME: 540 min

BASIN SUMMARY

BASIN ID: hc5a NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 16.18 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 16.18 Acres
TIME INTERVAL....: 10.00 min CN....: 77.12
TIME OF CONC.....: 886.47 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 0.00 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0830
TcReach - Shallow L:1200.00 ks:5.00 s:0.0950
TcReach - Shallow L:1500.00 ks:3.00 s:0.0001
PEAK RATE: 0.88 cfs VOL: 1.86 Ac-ft TIME: 1330 min

BASIN ID: hc6 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 9.64 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 2.01 Acres
TIME INTERVAL....: 10.00 min CN....: 69.36
TIME OF CONC.....: 132.62 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 7.63 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.0110 p2yr: 1.70 s:0.0500
TcReach - Shallow L: 900.00 ks:13.00 s:0.0500
TcReach - Channel L: 300.00 kc:21.00 s:0.0500
TcReach - Shallow L:1300.00 ks:17.30 s:0.0001
PEAK RATE: 2.53 cfs VOL: 2.31 Ac-ft TIME: 510 min

BASIN ID: hc7 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 17.45 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 10.12 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 469.70 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 7.33 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.1000
TcReach - Shallow L:1700.00 ks:11.00 s:0.0708
TcReach - Channel L: 900.00 kc:21.00 s:0.0389
TcReach - Shallow L:2900.00 ks:11.00 s:0.0001
PEAK RATE: 2.19 cfs VOL: 3.86 Ac-ft TIME: 780 min

BASIN SUMMARY

BASIN ID: hc7a NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 14.54 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 6.86 Acres
TIME INTERVAL....: 10.00 min CN....: 79.95
TIME OF CONC.....: 469.70 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 7.68 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.1000
TcReach - Shallow L:1700.00 ks:11.00 s:0.0708
TcReach - Channel L: 900.00 kc:21.00 s:0.0389
TcReach - Shallow L:2900.00 ks:11.00 s:0.0001
PEAK RATE: 1.75 cfs VOL: 3.10 Ac-ft TIME: 780 min

BASIN ID: hc8 NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 8.44 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 0.84 Acres
TIME INTERVAL....: 10.00 min CN....: 79.53
TIME OF CONC.....: 87.40 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 7.60 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0500
TcReach - Shallow L: 300.00 ks:11.00 s:0.0600
TcReach - Shallow L: 500.00 ks:27.00 s:0.0500
TcReach - Shallow L:1000.00 ks:27.00 s:0.0001
PEAK RATE: 3.08 cfs VOL: 2.25 Ac-ft TIME: 490 min

BASIN ID: hc8a NAME: 100yr
SBUH METHODOLOGY
TOTAL AREA.....: 22.71 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 3.60 inches AREA..: 17.44 Acres
TIME INTERVAL....: 10.00 min CN....: 84.74
TIME OF CONC.....: 240.62 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 5.27 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0830
TcReach - Shallow L: 600.00 ks:5.00 s:0.1250
TcReach - Shallow L: 900.00 ks:7.70 s:0.0001
PEAK RATE: 3.46 cfs VOL: 4.50 Ac-ft TIME: 600 min

BASIN SUMMARY

BASIN ID: hc9 NAME: 100yr
SBUH METHODOLOGY

TOTAL AREA.....:	13.36 Acres	BASEFLOWS:	0.00 cfs
RAINFALL TYPE....:	TYPE1A	PERVIOUS AREA	
PRECIPITATION....:	3.60 inches	AREA..:	4.65 Acres
TIME INTERVAL....:	10.00 min	CN....:	85.45
TIME OF CONC.....:	227.77 min	IMPERVIOUS AREA	
ABSTRACTION COEFF:	0.20	AREA..:	8.71 Acres
		CN....:	98.00

TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0670
TcReach - Shallow L: 950.00 ks:13.00 s:0.0790
TcReach - Channel L: 400.00 kc:21.00 s:0.0625
TcReach - Shallow L:1650.00 ks:13.60 s:0.0001
PEAK RATE: 2.78 cfs VOL: 3.27 Ac-ft TIME: 550 min

Wayne Golf Course basin
Existing Conditions

==========

BASIN SUMMARY

BASIN ID: wg1 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 39.60 Acres BASEFLOWS: 0.01 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 30.72 Acres
TIME INTERVAL....: 10.00 min CN....: 87.46
TIME OF CONC.....: 455.78 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 8.88 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0100
TcReach - Shallow L:1500.00 ks:8.00 s:0.0100
TcReach - Channel L:1200.00 kc:17.00 s:0.0100
TcReach - Shallow L: 900.00 ks:4.70 s:0.0001
PEAK RATE: 1.60 cfs VOL: 2.88 Ac-ft TIME: 960 min

BASIN ID: wg10 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 62.44 Acres BASEFLOWS: 0.01 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 57.45 Acres
TIME INTERVAL....: 10.00 min CN....: 81.84
TIME OF CONC.....: 663.08 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 4.99 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.3300
TcReach - Shallow L:1200.00 ks:3.00 s:0.1670
TcReach - Shallow L: 100.00 ks:11.00 s:0.1100
TcReach - Shallow L:1600.00 ks:4.40 s:0.0001
PEAK RATE: 1.39 cfs VOL: 2.71 Ac-ft TIME: 1330 min

BASIN ID: wg2 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 21.14 Acres BASEFLOWS: 0.01 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 17.06 Acres
TIME INTERVAL....: 10.00 min CN....: 84.59
TIME OF CONC.....: 116.92 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 4.08 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.3300
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.1167
TcReach - Channel L:1450.00 kc:21.00 s:0.1100
TcReach - Shallow L: 300.00 ks:8.74 s:0.0001
PEAK RATE: 1.23 cfs VOL: 1.33 Ac-ft TIME: 550 min

BASIN SUMMARY

BASIN ID: wg3 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 10.30 Acres BASEFLOWS: 0.01 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 10.30 Acres
TIME INTERVAL....: 10.00 min CN....: 85.00
TIME OF CONC.....: 360.19 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 0.00 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0110
TcReach - Shallow L: 600.00 ks:5.00 s:0.0110
TcReach - Shallow L: 900.00 ks:5.00 s:0.0001
PEAK RATE: 0.31 cfs VOL: 0.52 Ac-ft TIME: 960 min

BASIN ID: wg4 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 15.86 Acres BASEFLOWS: 0.01 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 12.56 Acres
TIME INTERVAL....: 10.00 min CN....: 84.95
TIME OF CONC.....: 99.36 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 3.30 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.3300
TcReach - Shallow L: 200.00 ks:11.00 s:0.1250
TcReach - Channel L:1500.00 kc:21.00 s:0.0670
TcReach - Shallow L: 300.00 ks:9.32 s:0.0001
PEAK RATE: 1.04 cfs VOL: 1.03 Ac-ft TIME: 540 min

BASIN ID: wg5 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 77.33 Acres BASEFLOWS: 0.50 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 77.33 Acres
TIME INTERVAL....: 10.00 min CN....: 85.37
TIME OF CONC.....: 1369.46 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 0.00 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.2000
TcReach - Shallow L: 800.00 ks:3.00 s:0.0110
TcReach - Channel L:3500.00 kc:5.00 s:0.0110
TcReach - Shallow L:3500.00 ks:5.00 s:0.0001
PEAK RATE: 1.86 cfs VOL: 5.11 Ac-ft TIME: 1440 min

Wayne Golf Course basin
Existing Conditions

BASIN SUMMARY

BASIN ID: wg6 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 58.04 Acres BASEFLOWS: 0.01 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 50.81 Acres
TIME INTERVAL....: 10.00 min CN....: 83.13
TIME OF CONC.....: 318.99 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 7.23 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.3300
TcReach - Shallow L: 700.00 ks:3.00 s:0.1070
TcReach - Shallow L: 400.00 ks:11.00 s:0.1000
TcReach - Channel L:1800.00 kc:21.00 s:0.1000
TcReach - Shallow L:1000.00 ks:6.40 s:0.0001
PEAK RATE: 1.88 cfs VOL: 3.06 Ac-ft TIME: 960 min
BASIN ID: wg7 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 35.70 Acres BASEFLOWS: 0.01 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 29.05 Acres
TIME INTERVAL....: 10.00 min CN....: 81.76
TIME OF CONC.....: 727.81 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 6.65 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.3300
TcReach - Shallow L:1200.00 ks:3.00 s:0.3300
TcReach - Channel L:1600.00 kc:5.00 s:0.3300
TcReach - Shallow L:1800.00 ks:4.50 s:0.0001
PEAK RATE: 0.89 cfs VOL: 1.85 Ac-ft TIME: 1330 min

BASIN ID: wg8 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 8.93 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 8.93 Acres
TIME INTERVAL....: 10.00 min CN....: 81.00
TIME OF CONC.....: 401.95 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 0.00 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.1000
TcReach - Shallow L: 300.00 ks:3.00 s:0.2000
TcReach - Shallow L: 600.00 ks:3.00 s:0.0001
PEAK RATE: 0.19 cfs VOL: 0.31 Ac-ft TIME: 1320 min

BASIN SUMMARY

BASIN ID: wg9 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 32.46 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 32.46 Acres
TIME INTERVAL....: 10.00 min CN....: 81.00
TIME OF CONC.....: 1268.89 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 0.00 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.1167
TcReach - Shallow L:1900.00 ks:3.00 s:0.1184
TcReach - Shallow L:2200.00 ks:3.00 s:0.0001
PEAK RATE: 0.44 cfs VOL: 0.92 Ac-ft TIME: 1440 min

East Basin - 2yr
Existing condtions

==========

BASIN SUMMARY

BASIN ID: eb1 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 179.83 Acres BASEFLOWS: 1.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 166.59 Acres
TIME INTERVAL....: 10.00 min CN....: 79.53
TIME OF CONC.....: 628.78 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 13.24 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.0600
TcReach - Shallow L:2400.00 ks:3.00 s:0.0420
TcReach - Shallow L:2400.00 ks:5.00 s:0.0800
TcReach - Channel L:3200.00 kc:10.00 s:0.0430
TcReach - Shallow L: 800.00 ks:3.10 s:0.0001
PEAK RATE: 4.50 cfs VOL: 10.70 Ac-ft TIME: 1330 min
BASIN ID: eb10 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 78.06 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 66.52 Acres
TIME INTERVAL....: 10.00 min CN....: 85.69
TIME OF CONC.....: 1401.51 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 11.54 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0300
TcReach - Shallow L:2400.00 ks:5.00 s:0.0208
TcReach - Shallow L:2700.00 ks:3.50 s:0.0001
PEAK RATE: 1.71 cfs VOL: 4.22 Ac-ft TIME: 1440 min

BASIN ID: eb2 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 158.99 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 142.12 Acres
TIME INTERVAL....: 10.00 min CN....: 84.01
TIME OF CONC.....: 1537.12 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 16.87 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0067
TcReach - Shallow L:3000.00 ks:5.00 s:0.0680
TcReach - Shallow L:2500.00 ks:3.00 s:0.0001
PEAK RATE: 2.81 cfs VOL: 6.80 Ac-ft TIME: 1440 min

East Basin - 2yr
Existing condtions

BASIN SUMMARY

BASIN ID: eb3 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 42.04 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 31.44 Acres
TIME INTERVAL....: 10.00 min CN....: 82.14
TIME OF CONC.....: 287.81 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 10.60 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.2400 p2yr: 1.70 s:0.0330
TcReach - Shallow L:1400.00 ks:5.00 s:0.0930
TcReach - Shallow L: 800.00 ks:5.70 s:0.0001
PEAK RATE: 1.72 cfs VOL: 2.94 Ac-ft TIME: 780 min

BASIN ID: eb4 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 62.98 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 48.99 Acres
TIME INTERVAL....: 10.00 min CN....: 85.72
TIME OF CONC.....: 550.46 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 13.99 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0670
TcReach - Shallow L:1500.00 ks:5.00 s:0.0800
TcReach - Shallow L:1200.00 ks:3.90 s:0.0001
PEAK RATE: 2.16 cfs VOL: 4.15 Ac-ft TIME: 960 min

BASIN ID: eb5 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 29.43 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 20.98 Acres
TIME INTERVAL....: 10.00 min CN....: 85.56
TIME OF CONC.....: 984.68 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 8.45 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.2400 p2yr: 1.70 s:0.0600
TcReach - Shallow L:2400.00 ks:9.00 s:0.0700
TcReach - Shallow L:2700.00 ks:4.80 s:0.0001
PEAK RATE: 0.83 cfs VOL: 1.88 Ac-ft TIME: 1330 min

East Basin - 2yr
Existing condtions

BASIN SUMMARY

BASIN ID: eb6 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 162.57 Acres BASEFLOWS: 0.25 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 134.52 Acres
TIME INTERVAL....: 10.00 min CN....: 84.33
TIME OF CONC.....: 1099.64 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 28.05 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0400
TcReach - Shallow L:4400.00 ks:5.00 s:0.0364
TcReach - Shallow L:2500.00 ks:4.30 s:0.0001
PEAK RATE: 3.94 cfs VOL: 9.34 Ac-ft TIME: 1440 min

BASIN ID: eb7 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 87.83 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 78.08 Acres
TIME INTERVAL....: 10.00 min CN....: 84.54
TIME OF CONC.....: 1767.07 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 9.75 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0330
TcReach - Shallow L:2700.00 ks:5.00 s:0.0452
TcReach - Shallow L:3000.00 ks:3.00 s:0.0001
PEAK RATE: 1.52 cfs VOL: 3.85 Ac-ft TIME: 1440 min

BASIN ID: eb8 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 78.55 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 66.81 Acres
TIME INTERVAL....: 10.00 min CN....: 85.98
TIME OF CONC.....: 1525.17 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 11.74 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.2400 p2yr: 1.70 s:0.0330
TcReach - Shallow L:2600.00 ks:5.00 s:0.0423
TcReach - Shallow L:2600.00 ks:3.00 s:0.0001
PEAK RATE: 1.67 cfs VOL: 4.17 Ac-ft TIME: 1440 min

East Basin - 2yr
Existing condtions

BASIN SUMMARY

BASIN ID: eb9 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 77.25 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 62.02 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 825.04 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 15.23 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0300
TcReach - Shallow L:1700.00 ks:5.00 s:0.0200
TcReach - Shallow L:2000.00 ks:4.60 s:0.0001
PEAK RATE: 2.31 cfs VOL: 5.17 Ac-ft TIME: 1330 min

Sammamish Basins
Existing conditions

BASIN SUMMARY

BASIN ID: se1 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 73.77 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 42.06 Acres
TIME INTERVAL....: 10.00 min CN....: 86.09
TIME OF CONC.....: 576.11 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 31.71 Acres
CN....: 98.00
TcReach - Sheet L: 200.00 ns:0.1500 p2yr: 1.70 s:0.0500
TcReach - Channel L:2800.00 kc:20.00 s:0.0500
TcReach - Shallow L:3000.00 ks:9.10 s:0.0001
PEAK RATE: 3.06 cfs VOL: 5.98 Ac-ft TIME: 960 min

BASIN ID: se2 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 53.54 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 26.20 Acres
TIME INTERVAL....: 10.00 min CN....: 84.77
TIME OF CONC.....: 399.68 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 27.34 Acres
CN....: 98.00
TcReach - Sheet L: 100.00 ns:0.1500 p2yr: 1.70 s:0.0200
TcReach - Channel L:2200.00 kc:21.00 s:0.0680
TcReach - Shallow L:2300.00 ks:10.10 s:0.0001
PEAK RATE: 2.73 cfs VOL: 4.59 Ac-ft TIME: 780 min

BASIN ID: se3 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 26.27 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 20.47 Acres
TIME INTERVAL....: 10.00 min CN....: 81.65
TIME OF CONC.....: 1580.41 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 5.80 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.0500
TcReach - Shallow L:3800.00 ks:3.00 s:0.0780
TcReach - Shallow L:3800.00 ks:4.50 s:0.0001
TcReach - Sheet L: 300.00 ns:0.0600 p2yr: 1.70 s:0.0400
PEAK RATE: 0.46 cfs VOL: 1.11 Ac-ft TIME: 1440 min

BASIN SUMMARY

BASIN ID: sm1 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 59.25 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 35.18 Acres
TIME INTERVAL....: 10.00 min CN....: 84.11
TIME OF CONC.....: 163.74 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 24.07 Acres
CN....: 98.00
TcReach - Sheet L: 200.00 ns:0.1500 p2yr: 1.70 s:0.0670
TcReach - Channel L:1100.00 kc:21.00 s:0.0630
TcReach - Shallow L: 700.00 ks:8.00 s:0.0001
PEAK RATE: 4.06 cfs VOL: 4.56 Ac-ft TIME: 550 min

BASIN ID: sm2 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 43.37 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 41.57 Acres
TIME INTERVAL....: 10.00 min CN....: 85.47
TIME OF CONC.....: 733.78 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 1.80 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.8000 p2yr: 1.70 s:0.0600
TcReach - Shallow L:1500.00 ks:3.00 s:0.0600
TcReach - Shallow L:1600.00 ks:4.30 s:0.0001
PEAK RATE: 1.09 cfs VOL: 2.18 Ac-ft TIME: 1330 min

BASIN ID: sm3 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 118.77 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 104.08 Acres
TIME INTERVAL....: 10.00 min CN....: 81.55
TIME OF CONC.....: 830.15 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 14.69 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0600
TcReach - Shallow L:1800.00 ks:5.00 s:0.1000
TcReach - Shallow L:1600.00 ks:3.00 s:0.0600
TcReach - Shallow L:2800.00 ks:6.40 s:0.0001
PEAK RATE: 2.52 cfs VOL: 5.21 Ac-ft TIME: 1440 min

BASIN SUMMARY

```
BASIN ID: sm4          NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.......: 134.82 Acres     BASEFLOWS:   0.00 cfs
RAINFALL TYPE....:    TYPE1A        PERVIOUS AREA
PRECIPITATION....:   1.70 inches      AREA..:   70.22 Acres
TIME INTERVAL....:     10.00 min      CN....:   85.02
TIME OF CONC.....:  393.83 min       IMPERVIOUS AREA
ABSTRACTION COEFF:   0.20             AREA..:   64.60 Acres
                                      CN....:   98.00
TcReach - Sheet   L: 100.00 ns:0.0110 p2yr: 1.70 s:0.0010
TcReach - Sheet   L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0600
TcReach - Shallow L: 700.00 ks:5.00 s:0.2140
TcReach - Shallow L:1600.00 ks:7.90 s:0.0001
PEAK RATE:   6.76 cfs  VOL:  11.32 Ac-ft  TIME:    780 min

BASIN ID: sw1          NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.......:  26.07 Acres     BASEFLOWS:   0.00 cfs
RAINFALL TYPE....:    TYPE1A        PERVIOUS AREA
PRECIPITATION....:   1.70 inches      AREA..:   20.87 Acres
TIME INTERVAL....:     10.00 min      CN....:   84.74
TIME OF CONC.....:  593.82 min       IMPERVIOUS AREA
ABSTRACTION COEFF:   0.20             AREA..:    5.20 Acres
                                      CN....:   98.00
TcReach - Sheet   L: 300.00 ns:0.2400 p2yr: 1.70 s:0.0500
TcReach - Shallow L: 150.00 ks:9.00 s:0.0600
TcReach - Channel L:2800.00 kc:21.00 s:0.2500
TcReach - Shallow L:3000.00 ks:9.00 s:0.0001
PEAK RATE:   0.80 cfs  VOL:   1.59 Ac-ft  TIME:    970 min

BASIN ID: sw2          NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.......:  87.10 Acres     BASEFLOWS:   0.00 cfs
RAINFALL TYPE....:    TYPE1A        PERVIOUS AREA
PRECIPITATION....:   1.70 inches      AREA..:   78.72 Acres
TIME INTERVAL....:     10.00 min      CN....:   82.66
TIME OF CONC.....:  647.14 min       IMPERVIOUS AREA
ABSTRACTION COEFF:   0.20             AREA..:    8.38 Acres
                                      CN....:   98.00
TcReach - Sheet   L: 300.00 ns:0.8000 p2yr: 1.70 s:0.2500
TcReach - Shallow L:1400.00 ks:3.00 s:0.1200
TcReach - Shallow L:1600.00 ks:4.60 s:0.0001
PEAK RATE:   2.08 cfs  VOL:   4.05 Ac-ft  TIME:   1330 min
```

Little Swamp Basin
Existing conditions

==========

BASIN SUMMARY

BASIN ID: ls1 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 161.62 Acres BASEFLOWS: 1.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 142.62 Acres
TIME INTERVAL....: 10.00 min CN....: 84.59
TIME OF CONC.....: 525.94 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 19.00 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0600
TcReach - Shallow L:2400.00 ks:5.00 s:0.0500
TcReach - Shallow L: 800.00 ks:3.00 s:0.0001
PEAK RATE: 5.69 cfs VOL: 13.02 Ac-ft TIME: 970 min

BASIN ID: ls2 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 93.01 Acres BASEFLOWS: 0.20 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 76.10 Acres
TIME INTERVAL....: 10.00 min CN....: 83.76
TIME OF CONC.....: 778.25 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 16.91 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0500
TcReach - Shallow L:1400.00 ks:5.00 s:0.0450
TcReach - Shallow L:1400.00 ks:3.30 s:0.0001
PEAK RATE: 2.63 cfs VOL: 5.92 Ac-ft TIME: 1330 min

BASIN ID: ls3 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 104.34 Acres BASEFLOWS: 0.10 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 65.86 Acres
TIME INTERVAL....: 10.00 min CN....: 81.30
TIME OF CONC.....: 1498.77 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 38.48 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.4000 p2yr: 1.70 s:0.0800
TcReach - Shallow L: 700.00 ks:5.00 s:0.0720
TcReach - Channel L:2400.00 kc:5.00 s:0.0600
TcReach - Shallow L:3400.00 ks:4.00 s:0.0001
PEAK RATE: 2.33 cfs VOL: 5.91 Ac-ft TIME: 1440 min

BASIN SUMMARY

BASIN ID: ls4 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 39.19 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 33.31 Acres
TIME INTERVAL....: 10.00 min CN....: 86.00
TIME OF CONC.....: 995.26 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 5.88 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0200
TcReach - Shallow L:1400.00 ks:5.00 s:0.0640
TcReach - Shallow L:1700.00 ks:3.00 s:0.0001
PEAK RATE: 0.99 cfs VOL: 2.19 Ac-ft TIME: 1440 min

BASIN ID: ls5 NAME: 2yr
SBUH METHODOLOGY
TOTAL AREA.....: 49.48 Acres BASEFLOWS: 0.00 cfs
RAINFALL TYPE....: TYPE1A PERVIOUS AREA
PRECIPITATION....: 1.70 inches AREA..: 42.06 Acres
TIME INTERVAL....: 10.00 min CN....: 83.81
TIME OF CONC.....: 874.44 min IMPERVIOUS AREA
ABSTRACTION COEFF: 0.20 AREA..: 7.42 Acres
CN....: 98.00
TcReach - Sheet L: 300.00 ns:0.1500 p2yr: 1.70 s:0.0330
TcReach - Shallow L:1200.00 ks:5.00 s:0.0750
TcReach - Shallow L:1500.00 ks:3.00 s:0.0001
PEAK RATE: 1.19 cfs VOL: 2.54 Ac-ft TIME: 1330 min

APPENDIX B - DEFINITIONS

Anadromous - Fishes ascending rivers from the sea for breeding.

Antecedent runoff conditions - The degree of wetness of a watershed or within the soil at the beginning of a storm.

Aquifer - A geologic stratum containing groundwater that can be withdrawn and used for human purposes.

Backwater - Water upstream from an obstruction which is deeper than it would normally be without the obstruction.

Bankfull discharge - A flow condition where streamflow completely fills the stream channel up to the top of the bank. In undisturbed watersheds, the discharge conditions occurs on average every 1.5 to 2 years and controls the shape and form of natural channels.

Berm - A constructed barrier of compacted earth, rock, or gravel.

Best Management Practice (BMP) - Physical, structural, and/or managerial practices that, when used singly or in combination, prevent or reduce pollution of water, and have been approved by Ecology.

Biofiltration - The process of reducing pollutant concentrations in water by filtering the polluted water through biological materials.

Capital Improvement Program - A project prioritized and scheduled as a part of an overall construction program, or the actual construction program.

Catchbasin - A chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Conveyance system - The drainage facilities, both natural and man-made, which collect, contain, and provide for the flow of surface and stormwater from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The human-made elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities.

Design storm - A prescribed hyetograph and total precipitation amount used to estimate runoff for a hypothetical storm of interest or concern for the purposes of analyzing existing drainage, designing new drainage facilities or assessing other impacts of a proposed project of the flow of surface water.

Detention - An above or below ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system.

Erosion/sedimentation control - Any temporary or permanent measures taken to reduce erosion; control siltation and sedimentation; and ensure that sediment-laden water does not leave the site.

Eutophication - Refers to the process where nutrient over-enrichment of water leads to excessive growth of aquatic plants, especially algae.

Flood Insurance Rate Map (FIRM) - The official map on which the Federal Insurance Administration has delineated many areas of flood hazard, floodway, and the risk premium zones.

Impervious surface - A hard surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development, and/or a hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, rood tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater.

Isopluvial map - A map with lines representing constant depth of total precipitation for a given return frequency.

National Pollutant Discharge Elimination System (NPDES) - The part of the federal Clean Water Act, which requires point source dischargers to obtain permits. These permits are referred to as NPDES permits, and, in Washington State, are administered by the Washington State Department of Ecology.

Nonpoint source pollution - Pollution that enters a water body from diffuse origins on the watershed and does not result from discernible, confined, or discrete conveyances.

Retention/detention facility - A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground; or to hold surface and stormwater runoff for a short period of time and then release it to the surface and stormwater management system.

Riparian - Pertaining to the banks of streams, wetlands, lakes or tidewater.

Stormwater facility - A constructed component of a stormwater drainage system, designed or constructed to perform a particular function, or multiple functions. Stormwater facilities include, but are not limited to pipes, swales, ditches, culverts, street gutters, detention

basins, retention basins, constructed wetlands, infiltration devices, catchbasins, oil/water separators, sediment basins, and modular pavement.

Swale - A shallow drainage conveyance with relatively gentle side slopes, generally with flow depths less than one foot.

Wetponds - Drainage facilities for water quality treatment that contain permanent pools of water that are filled during the initial runoff from a storm event. They are designed to optimize water quality by providing retention time in order to settle out particles of fine sediment to which pollutants such as heavy metals absorb, and to allow biologic activity to occur that metabolizes nutrients and organic pollutants.

APPENDIX C - REFERENCES

City of Bothell Comprehensive Plan, 1985. Department of Community Development.

City of Bothell Municipal Code
- Water and Sewers (Title 13)
- Shoreline Management (Title 18)
- Environment (Title 20)
  - Interim Critical Area Ordinance (Chapter 20.10)
  - Surface Water Runoff (Chapter 20.08)

Cowardin, Lewis M., V, Carter, F.C. Golet, and E.T. LaRoe, 1979. Classification of wetlands and deeper habitats of the United States. U.S. Fish and Wildlife Service, Washington, D.C. Publ No. FWS/OBS-79/31. 103 pp.

Dinicola, R.S., 1990. Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington. U.S. Geological Survey Water-Resources Investigations Report 89-4052, U.S. Geological Survey-WRD, Tacoma, WA.

Engenious Systems, Inc., 1992. WaterWorks Software for Hydrology. Seattle, Washington.

Federal Emergency Management Agency (FEMA), 1992. Limited Map Maintenance Study of Areas of Unincorporated King County and Bothell, Washington.

_____, 1989. Flood Insurance Study for the City of Bothell. U.S. Army Corps of Engineers, Seattle District, Washington.

_____, 1981. Flood Insurance Study for the City of Bothell. U.S. Army Corps of Engineers, Seattle District, Washington.

_____, 1981. Flood Insurance Study for Snohomish County. U.S. Army Corps of Engineers, Seattle District, Washington.

Federal Regulations
- Clean Water Act Sections 401, 402, and 404, the
- Flood Disaster Protection Act
- National Flood Insurance Act
- River and Harbor Act, Section 10

Gray and Osborne, 1977. Comprehensive Storm Water Control and Drainage Plan. Prepared for the City of Bothell.

Horner, R.R., E.B. Welch, and R.B. Veenstra, 1983. Development of nuisance periphytic algae in laboratory streams in relation to enrichment and velocity. pp. 121-131. In:

Periphyton of Freshwater Ecosystems. R.G. Wetzel (ed). Dr. W. Junk Publishers, The Hague, the Netherlands.

Horner, R.R. and B.W. Mar, 1982. Guide for Water Quality Impact Assessment of Highway Operations and Maintenance. Prepared for the Washington State Department of Transportation. University of Washington, Seattle, WA.

King County, January 1993. King County Flood Hazard Reduction Plan. King County Department of Public Works, Seattle, WA.

King County, 1990. King County, Washington Surface Water Design Manual. Surface Water Management Division, King County Department of Public Works, Seattle, WA. (revised November 1992).

King County Code, 1990. Sensitive Areas Ordinance (SAO).

Municipality of Metropolitan Seattle (METRO), 1982. North Creek Stream Resource Inventory. Technical Report WR-82-1. Metro, Water Quality Division, Seattle, Seattle, WA.

National Oceanic and Atmospheric Administration (NOAA), 1991. Climatological Data Annual Summary, Washington. Volume 95, Number 13. National Oceanic and Atmospheric Administration, Department of Commerce, Asheville, North Carolina.

Snohomish County Code

- Shoreline Management (Title 18)
- Shoreline Management Master Program (Title 21)
- Drainage Ordinance (Title 24)

Snohomish County Department of Public Works. Unpublished data. Water quality data collected on North Creek during 1990-1991. Snohomish County Department of Public Works, Everett, WA.

Snohomish County, 1992. North Creek Watershed Management Plan. Snohomish County Surface Water Management, Everett, WA.

Snohomish County, 1992. Swamp Creek Watershed Management Plan. Snohomish County Surface Water Management, Seattle, WA.

Soil Conservation Service 1983. Soil Survey of Snohomish County, Washington. U.S. Department of Agriculture, Soil Conservation Service.

Soil Conservation Service 1973. Soil Survey of King County, Washington. U.S. Department of Agriculture, Soil Conservation Service.

U.S. Environmental Protection Agency (EPA), 1986. Quality Criteria for Water. U.S. EPA, Water Planning Division, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1983. Results of the Nationwide Urban Runoff Program. Volume 1 - Final Report. U.S. EPA, Water Planning Division, Washington, D.C.

Washington Department of Ecology (DOE), 1992. Technical Guidance for Assessing the Quality of Aquatic Environments. Water Quality Financial Assistance Program, Olympia, Washington.

_____, 1992. Stormwater Management Manual for the Puget Sound. Water Quality Program. Olympia, WA.

_____, 1991. Guidelines and Specifications for Preparing Quality Assurance Project Plans. Environmental Investigations and Laboratory Services Program. Manchester, WA.

_____, 1990. Monitoring Guidance for Early Action Watershed Quality Assessments. Environmental Investigations and Laboratory Services Program. Manchester, WA.

Washington State Administrative and Revised Code

- Uniform Fire Code (UFC) (RCW 19.27A.010)
- Planning Enabling Act (RCW 36.70)
- Growth Management Act adopted in March 1991 (RCW 36.70A)
- Hydraulic Code (RCW 75.20)
- Floodplain Management Program (RCW 86.16)
- Shoreline Management Act (SMA) (RCW 90.58)
- Puget Sound Water Quality Act (RCW 90.70)
- State Surface Water Quality Standards (WAC 173-201)
- State Water Pollution Control Act (WAC 173-225)
- Highway Runoff Program Rule (WAC 173-270)

Welch, E.B. 1980. Ecological Effects of Wastewater. Cambridge University Press, New York, N.Y. 337 pp.

ISSUE 1: INSTITUTIONAL OPTIONS

The primary focus of this section is the institutional options for managing and funding a storm and surface water utility/management program. The institutional arrangement used to manage a program may determine the type and level of funding available. The institutional arrangements should seek to maximize the opportunity to fund all elements of a storm and surface water utility/management program at an adequate level. Some institutional options may only address the funding of capital improvements, while other options may address the funding of all elements of a program but may provide inadequate revenues. This institutional arrangement should meet or enhance the:

- Ability to fund the operations and maintenance (O&M);
- Ability to fund capital improvements;
- Ability to manage storm and surface water utility/management program to meet City standards for both maintenance and construction;
- Ability to minimize cost of billing, collection and administering revenue generation; and
- Ability to ensure equitable distribution of cost.

Six institutional options are discussed and evaluated. The matrix below summarizes the key criteria and how each of the six options satisfies the criteria. The formation of a storm and surface water management/utility program and the imposition of a service charge does not preclude using local improvement districts, developers contributions or King County to fund particular improvements. Once the City determines the most likely arrangement or combination of arrangements—the specific requirements for the arrangements need to be identified.

Institutional Option	O&M Fund	Capital Control	System Control	Maintenance Control	Sufficient Revenues
Developer Contributions		X			
Drainage District	X	X			X
Local Improvement District		X			
Drainage Utility	X	X	X	X	X
General Government	X	X	X	X	
King County/Snohomish County SWM	X	X			X

Background

The existing storm and surface water drainage programs have been managed by the Public Works Department. Private developers may have contributed financially by constructing facilities on both public and private property. Construction standards for drainage systems may not been consistent between public and private facilities. Facilities on private property most likely have been the maintenance responsibility of private parties. The City's ability to access facilities on private property to monitor maintenance of these facilities is questionable from both a funding and regulatory perspective.

Surface water runoff does not respect jurisdictional or political boundaries. Rather, surface water flows within natural drainage basins or sub-basins. The institutional arrangements should recognize the cross-jurisdictional nature of drainage basins.

Alternatives

Five institutional options for funding drainage are outlined and discussed in the following paragraphs. These options are not necessarily exclusive of one another.

Developer's Contribution

As land is developed, the amount and rate of flow of surface water run-off increases. This in turn increases the need for drainage facilities to handle the increased run-off. Thus by developing a piece of property, the developer is creating the need for additional drainage facilities. Developer contributions are a means of recovering a share of the cost of the drainage facilities constructed to handle the increased run-off caused by development.

Regional drainage facilities may be constructed to handle the run-off from private property within a drainage basin. A basin plan identifies the regional drainage improvements that will be needed in that basin at a projected level of development—usually the ultimate development based on the comprehensive land use plan or current zoning for the properties within the basin.

The basin plan may assume that each property owner is responsible for controlling the run-off on his/her property to a specified rate or level of flow. In addition, regional facilities may be needed. The plan would identify the type and cost of such facilities.

Developers' contributions are used by jurisdictions as a method of funding the regional "public" drainage capital improvements. While developers' contributions may fund improvements this method does not set up a mechanism to manage improvements or a storm and surface water programs. Developer contributions are handled most commonly by drainage development fees and construction in-lieu-of fees.

Drainage Development Fees

Drainage development fees are collected from a developer at the time the run-off from the property is increased, when the property is developed. The total cost of drainage improvements

may be allocated to the undeveloped property in the basin depending on the total area of land in each zoning classification and the estimated contribution to run-off potentially generated by all land at full development. This will determine the share of the ultimate capital system costs that should be paid by each land use classification. The undeveloped area divided by the total cost allocated to that land use will result in a charge per square foot (or area).

The development fees are collected as each parcel is developed. This method works well for drainage basins with undeveloped property that will need further improvements as the land is developed.

Advantages:

- An equitable fee can be calculated for each developing parcel that is determined by the size of the parcel and applicable zoning. This type of fee calculation is easily understandable to the developers and easy for the City to administer.
- The fees are determined by the estimated cost of constructing the improvements.
- New drainage improvements can be scheduled by the City as they are needed. The need is determined by the level of development in each basin.
- The fees collected from property in any drainage basin will be used to pay for the improvements in only that basin.

Disadvantages:

- Basin plans with capital cost estimates must be in place before the fee can be calculated.
- Significant changes in zoning, particularly down-zoning, may result in less than enough revenue to fund the facilities.
- Significant increases in construction costs over estimates used in the basin plan may result in less than enough revenue recovery.
- Patterns of development may require construction of more improvements than there is money in the bank for that basin.
- Funding of capital improvements is determined by basin and not city-wide. Funds must be used for improvements in the basin from which they were collected.
- The new developer may perceive an unfair burden if the majority of land in the basin is already developed and development fees have not been charged historically.
- Fees pay for capital improvements only.

Construction in-lieu-of fees

This method assumes that the developer will either construct or contribute directly to the construction of needed regional improvements in return for the ability to develop the land. This method tends to be used in developed areas with drainage facilities already in place that cannot

accommodate increased run-off created by the additional development or in areas that are developing where facilities are needed before development can take place.

The control and maintenance responsibility for drainage facilities constructed by developers needs to be defined. If the City is granted ownership or control of the facilities, the City will be able to ensure the facilities are maintained to an acceptable level.

Advantages:

- The development creating the need for the new improvements will pay for the cost of the improvements.
- The new facilities will often benefit the City and other properties in addition to the new development.
- The City does not have to fund the costs of improvements or may fund only a portion of the costs.
- The City and the developer do not have to wait for the needed improvements to be scheduled into the annual budgeting cycle before the land can be developed.

Disadvantages:

- The City may not have control over the construction and maintenance of the facilities installed by developers on private property.
- New development may pay more than its equitable share of the cost of the system.
- Private developers may be financing facilities that serve the public needs.
- This method deals only with capital improvements, not with ongoing maintenance and operating costs.

Drainage Districts

Creating a drainage district is a method of financing and potentially managing drainage capital improvements and ongoing maintenance and operations. The process of creating a drainage district and the method for setting the special assessments are specified in the Revised Code of Washington (RCW) 85.06 Drainage District and 85.38 Special District Creation and Operation.

These laws are directed at counties and provide a method of financing and operating facilities to serve specific areas of land. A city may operate as a drainage district, however the creation and assessment process is specifically tied to the county legislative authority within which the drainage district is located.

The creation of a drainage district involves a vote of the land owners and a separately elected Board of Commissioners. This requirement reduces the active involvement of the City in the operation and management of the district.

These laws also specify the method of assessing property within a district. Assessment zones must be defined to reflect the relative ratio of benefit or use that each property receives or will receive from the district operations and facilities. The assessment zones are used to determine the dollar value of benefit or use per acre.

An annual budget must be adopted each year and must demonstrate that the assessments are sufficient to cover the annual expenses. Any newly constructed improvements are not subject to special assessments until the year after they are made.

Advantages:

- Provides funding for both O&M and capital improvements.
- Assessments would be billed on property tax statements and collected with property taxes.
- Full cost of O&M and capital improvements could be recovered.
- Costs are equitably allocated to all property owners in the district based on benefit received on a district-wide basis.

Disadvantages:

- Involvement of City in management and operations of district is limited. The County has a legislative role in creation, and a separately elected Board of Commissioners runs the District.
- Property owners must approve by vote the creation of district.
- Funds for capital improvements cannot be collected until after the improvements are completed.
- District creation and benefit assessment processes defined by statute are very complicated.
- The City's flexibility in working with developers is limited.

Local Improvement Districts

Local improvement districts (LID) allow the City to issue revenue bonds for the cost of improvements and to recover the cost through assessments based on "specially benefiting" property, defined by the increased value in the property resulting from the improvements.

For water and sewer improvements, properties are "specially benefiting" from the improvements because they are physically connected or have the ability to physically connect to the sewer or water system. However, for drainage improvements, it is difficult to demonstrate "specially benefiting" property because there is generally no physical connection to a drainage system and the value of the property is not necessarily directly affected by the existence of a drainage system, unless it is subject to frequent flooding.

Further, property at the top of the hill does not "specially benefit from the drainage improvements. This property drains down the hill regardless of the drainage system in place. The property does,

however, contribute to the surface water problems. Property at the bottom of the hill see a more positive effect on their property from the drainage improvements, even though their property contributes only a portion of the runoff.

LID's have been used to finance water, sanitary water, and storm sewer when all three utilities are installed in an area.

An LID might be appropriate to support the construction of a facility that is serving several properties, where the run-off contribution and benefit are similar.

Drainage Utility

The underlying concept in a drainage utility is that all properties contribute surface water run-off to the drainage system, and therefore should pay an equitable share of the costs of O&M and capital improvements of the system as a whole.

RCW Chapter 35.67 gives the City the authority to fix, alter, regulate, and control the rates and charges for the use of the drainage system; provided that the rates charged must be uniform for the same class of customers or service. It also requires (RCW 36.67.30) that whenever a City decides to operate a utility, it shall specify and adopt a system plan.

The City would also have a combined utility that includes the storm sewer program with the sanitary sewer and possibly water program. RCW Chapter 35.67 defines a "public utility" to include sanitary sewer, storm sewer and water. The cities of Everett and Mountlake Terrace have used this approach.

The formation of a surface water management utility would give the City a continuous and reliable funding source to pay for both capital improvements and ongoing maintenance and operating costs of the city-wide drainage system. A utility also gives the City direct control over establishing the rates and charges to fit the needs of the City versus following a prescribed method set forth by statute (as in a drainage district).

A reliable source of funding is a key element in developing and continuing a successful, well managed surface water drainage system. The existence of a utility charge would provide Ferndale with the opportunity to plan and carry out their comprehensive drainage plan.

Other jurisdictions in Washington (and nationally) have already established or are in the process of establishing storm water drainage utilities, including: Kent, Auburn, Renton, King County, Bellevue, Tacoma, Issaquah and Redmond.

The primary disadvantage to establishing a drainage utility is the public perception that a new charge is being imposed.

General Government

Currently, Bothell's drainage program is funded through the Public Works Department with street and general government revenues. The City could continue to fund its drainage program through

this arrangement. However, by establishing a utility, the City can replace or supplement general government revenues with utility rates or charges.

Using general government revenues will not provide sufficient revenues to carry out the Comprehensive Drainage Plan unless other priorities are slipped or abandoned.

King County/Snohomish County SWM

Both King and Snohomish Counties have Surface Management Programs that currently charge most property in unincorporated areas for drainage services. The City could relinquish its drainage reponsibilities to the County. Under such a scenario the counties would assume reponsibility for drainage improvements in Bothell, for policies relating to future development and for maintaining facilities. For revenue, the counties would impose and collect a service charge on all property. While this would require little effort on Bothell's part the City would end up relinquishing control over the drainage system.

City of Bothell

Historically, the City storm water maintenance activities have been funded though the Street Fund, as is common in other cities without a separate storm water utility. Funding has been primarily from fuel tax and other general revenues.

Bothell has a Storm Drainage Cumulative Reserve Fund that has been used to accumulate monies for construction of a system of storm drains to control surface and run-off waters in the City. The funding has been from assessment fees, mitigation fees, interest, and other contributions.

CITY OF BOTHELL STORM DRAINAGE CUM. RESERVE FUND	ACTUAL 1988	ACTUAL 1989	ACTUAL 1990	ACTUAL 1991	BUDGET 1992	BUDGET 1993
ESTIMATED BEG. FUND BAL.	184,629	199,506	238,459	245,500	264,378	160,600
CHARGES FOR SERVICE	41,688	42,222	7,255	11,154	26,100	41,000
OTHER REVENUES	0	0	0	7,629	7,629	7,629
CONSTRUCTION PROJECTS	(26,811)	(3,269)	(0)	(119)	(20,800)	(51,600)
ENDING FUND BALANCE	199,506	238,459	245,714	264,164	277,307	157,629

ISSUE 2: FUNDING SOURCES

Potential funding sources include a wide variety of locally generated revenue, state and federal grants and loans, contributions of adjoining jurisdictions, and contributions of revenue or improvements from private parties developing in Bothell. Each of these funding sources has its own legal and institutional parameters, and equity and stability considerations. Criteria for evaluating each of these sources is suggested and a matrix displaying the sources and applicability of the criteria are included to assist in selecting an appropriate approach (Funding Matrix).

Future annexations to Bothell will require fairness and equity funding source for storm and surface water management should be evaluated as it applies to the potential annexation areas. Some preliminary discussion of these issues as it relates to annexation is contained in this section.

Funding Source Criteria

When developing funding for public programs, it is appropriate to identify criteria to be used in evaluating potential funding sources. Suggested criteria are listed below that may be applied to each potential funding source. Use of the criteria should assist the City in determining the most suitable funding sources for their storm and surface water management program:

Equity and Fairness	Does this funding source fairly and equitably collect revenue from those who contribute to drainage problems and will benefit from improvements and operations?
Stability/Reliability	Are revenues from this source reliable and predictable? Can the City plan on them over the long run?
Manageable	Can the City control the revenue source, increasing it or decreasing it as required to fund programs?
Predictability of Funding	Does this source generate sufficient revenue to fund requirements?
Relatednessto Program	Is this source of funding related to the problem that the revenue will be used to address?
Poltical/Citizen Acceptability	Is this source likely to be acceptable to the citizens of Bothell and Bothell's elected officials?
Legality	What are the legal restrictions and requirements for implementing or using this source.

Implementable	Can this revenue source be activated in sufficient time to fund the City's program?
Restrictions	What are the restrictions on using this funding source? Will it fund capital operations? Work on private property? What other restrictions are there?

Each potential funding source and the overall funding program should be evaluated against the criteria. The Funding Matrix lists the funding sources and offers a preliminary evaluation of each source against the criteria listed. To meet all the criteria, the surface water management program will probably need to tap a variety of funding sources.

Selected External Funding Sources

Centennial Clean Water Fund

This State fund collects revenue from a portion of the cigarette tax. Funds are available for prioritized projects relating to marine waters, ground water activities and facilities, freshwater lakes and rivers, and nonpoint activity.

The Department of Ecology administers this program which loans funds for up to 100 percent of the planning, design, and construction of water pollution control facilities, storm water management, combined sewer overflow reduction, nonpoint control, groundwater protection, and public education activities.

Loans (up to 100 percent of project costs) and base grants (50 to 75 percent of project costs) are at the following interest rates:

> 0-5 years repayment at 0 percent interest; 6-5 years repayment at 60 percent of market rate; and 15-20 years repayment at 75 percent of market rate.

The 1993 Program will allocate about $45 million with a very limited amount per applicant as shown below. Funding categories and limits in funding per applicant within categories is as follows:

Marine	$2 million per applicant
Ground Water	$810,000 (9 percent of total amount available)
Freshwater	$1.35 million (30 percent of total amount available)
Nonpoint	$750 per facility; $230,000 per applicant year
Discretionary	$4.5 million total; no more than $250,000 per applicant

The 1993 application period is each February for funds to be available the following year.

Public Works Trust Fund

This program funds the repair, replacement, reconstruction, rehabilitation and improvement of existing sanitary and storm sewer systems to serve existing population to current standars. Loans of up to 90 percent of project costs may be authorized. The interest rate charge on the loan is dependent upon the percent of local match funds:

10 percent local match equals a three percent interest rate loan

20 percent local match equals a two percent interest rate loan

30 percent local match equals a one percent interest rate loan

Funds may be loaned for up to twenty years. Local matching funds must be from locally generated revenues, not state-shared or federal and state grants.

State Revolving Fund

Funds are loaned for construction of storm water management, secondary treatment facilities, combined sewer overflow projects and others. Projects must comply with state and federal water pollution control regulations; protect public health and water quality; improvement and protect overall the environment; and prevent water quality deterioration.

Loans (up to 100 percent of project costs) and base grants (50 to 75 percent of project costs) are at the following interest rates:

0-5 years repayment at 0 percent interest; 6-5 years repayment at 60 percent of market rate; and 15-20 years repayment at 75 percent of market rate.

Funds may be used for local match for state grants but not for federal grants. The total funds available for 1993 was $30 million. Fund are allocated as follows: 80 percent to water pollution; 10 percent to nonpoint; and 10 percent to estuary management. The application period ends in he month of June each year.

Flood Control Assistance Account Program (FCAAP)

FCAAP program was established by the state legislature in 1984 to assist local jurisdictions in comprehensive planning and maintenance efforts to reduce flood damages. To be eligible the Department of Ecology must approve the flood plain management activities. Additionally, Ferndale would have to meet the requirements of National Flood Insurance Program (NFIP) and become a participant in the program.

$500,000 in non-emergency grant funds are available during the biennium within any one county. Any funds not spent within the biennium are lost and may not be carried over to the next biennium.

Three different types of matching grants are available:

1. Comprehensive Flood Control Management Plans (CFCMP) (Grants up to 50%)

2. Flood Control Maintenance Projects (Grants up to 50%)

3. Emergency Flood Control Maintenance Projects (Grants up to 80%)

The application period is during the summer months with a deadline in the fall. The Department of Ecology evaluates and releases a priority list for funding in December. Non-emergency grants may be effective for work six months after funding and negotiations are complete.

The funding matrix shows that utility charges meet most of the funding source criteria. Establishing a utility, however, may be somewhat difficult and assuring that revenues are adequate to fund capital, maintenance and operations will depend upon the level of initial charges set and the willingness of the City to adjust charges as necessary to fund the ongoing requirements.

Two methods of financing capital improvements are often discussed but are not listed on the matrix. These are revenue and general obligation bond issues. Issuing a bond for capital improvements allows the City to borrow the money up front and pay it back over time. The revenues used to pay back the bonds can be either utility charges (listed in the matrix) in which case the City would issue revenue bonds; or property taxes (implied under "General Government Taxes" on the matrix) in which case the City would issue limited (not specifically approved by voters) or unlimited (voter approved) general obligation debt. Depending upon the dollar amount needed to fund capital improvements and the revenue available from other sources, the City may choose to issue debt to fund improvements.

FUNDING MATRIX										
	Sources of Funding						State/Federal Grants and Loans (2)			
Criteria	General Government Taxes	Developer Contributions	Improvement in-lieu of Contribution	LateComer Fees	Utility Charges	Local Improvement Districts	Centennial Clean Water Fund	Public Works Trust Fund	State Revolving Fund	FCAAP
Equity and Fairness	NO	YES & NO	YES & NO	YES & NO	YES, based on contribution	YES based on benefit contribution	?	?	?	?
Stability/ Reliability	Compete w/other functions	Depends on new development	Depends on new development	NO	YES	NO	NO	NO	NO	NO
Manageabilty	Limited ability to increase	Only with new development	Lower design standards	NO	YES	NO	NO	NO	NO	NO
Predictability of Funding	NO	NO	NO	NO	MAYBE	NO	NO	NO	NO	NO
Relatedness to Program	Sources not related to drainage problems	YES	YES	MAYBE	YES	YES	Sources not related todrainage problem	Sources not related to drainage problem	Sources not related to drainage problem	Sources not related to drainage problem
Political/Citizen Acceptability	High	Medium	Medium	Low	Medium	Low	High	High	High	High
Legality	OK	May be issues (1)	May be issues (1)	May be issue (1)	OK	OK	OK	OK	OK	OK
Restrictions	Must fund public purpose items	On site capital only	On site capital only	Capital only	Funds public system O&M and capital	Capital only	Local match and funding limits per category	Repair & rehab. capital only	Local match and funding limits per category	Required flood plan approv. & part. in NFIP, liited funds for non-emergency

(1) Developers can be required to develop mitigation measures directly related to their projects or to contribute to projects off site directly required because of their development. Such contributions need to be in conjunction with plans that identify drainage facilities.

(2) Many state funding programs could be tapped for specific types of improvements, emergencies or programs. Several grants and loans include: Water Quality Management Planning, Emergency Water Withdrawal & Facilities, Ground Water Management Planning and Flood Control Assistance Account Program (FCAAP). Those called out in the chart, with the exception of FCAAP, are the largest and most likely. Federal Grants and Loans generally come through the state Department of Ecology except for emergency funds.

ISSUE 3: MINIMAL STEPS IN FORMING A STORM AND SURFACE WATER UTILITY

This section briefly describes the minimum steps necessary to form a storm and surface water utility.

A storm and surface water utility (sometimes referred to or named a drainage utility) may be established pursuant to Chapter 35.67 of the Revised Code of Washington which provides in part:

> "Every city and town may construct, condemn, and purchase, acquire, add to, maintain, conduct, and operate systems of sewerage... together with additions, extensions, and betterments thereto, within and without its limits, with full jurisdiction and authority to manage, regulate, and control them and to fix, alter, regulate, and control the rates and charges for the use thereof: Provided, That the rates charged must be uniform for the same class of customers or service..." (RCW 35.67.020)
>
> "A "system of sewerage" means and includes:..(2) Combined sanitary sewage disposal and storm or surface water sewers; (3) Storm or surface water sewers..."(RCW 35.67.010)

Cities and counties in Washington have either established separate utilities or have expanded the authority of their existing sewer utilities to cover storm and surface water. Two primary reasons have been used to justify the creation of storm and surface water utilities:

First, a utility provides a mechanism for consistent and predictable financial support for the construction and operation of facilities and for the management and administration of storm and surface water functions. Second, forming a utility provides broad visibility to storm and surface water issues making elected officials and the public more aware of the regulatory and facility requirements placed upon jurisdictions. In support of this second justification it is recommended that public information and opportunities for public involvement be provided throughout the utility development process.

The minimum requirements for establishing a utility and imposing fees and charges are: adoption of a comprehensive storm and surface water plan, identification of planned expenditures, adoption of a system of fees and charges, classification of rate payers, and establishing a system to bill rates, fees and charges. These steps are listed below in more detail.

Comprehensive Plan

1. Prepare a comprehensive storm and surface water plan for the City. The plan should include a statement of purpose, identification of City policies relating to storm and surface water, the physical boundaries of the utility, a description of drainage basins covered by the utility including those portions of basins that are beyond the corporate limits of the City, identification of improvements planned, cost estimates, and a financing plan.

2. Prepare an agreement with King/Snohomish County for portions of basin plans that are in the County. Agreement(s) should identify jurisdictional responsibility for construction and maintenance of facilities that are located in the County. Agreements with the County are not required for land located within the corporate limits of the City.

3. Determine if storm and surface water will be established as a separate utility or as a specific function/program within the sewer utility. (As a separate utility it will have more visibility and possibly more clout in implementing programs and building facilities. It may also be more conducive to developing a fair and equitable rate structure. As part of the sewer utility/function it may be more manageable, more realistically fit the organizational structure of the City; and a simple (although not necessarily the most equitable) rate structure might be tacked on to the sewer charge.

4. Adopt the comprehensive storm and surface water plan by ordinance. "When ever the legislative body of any city or town, shall deem it advisable that such city or town shall purchase, acquire or construct any public utility...or make any additions, betterments, or alterations thereto, or extensions thereof, such legislative body shall provide therefor by ordinance, which shall specify and adopt the system or plan proposed, and declare the estimate cost thereof as near as may be." (RCW 35.67.030)

Establish Utility

5. Adopt an ordinance establishing a storm and surface water utility; or amend the ordinance establishing the sewer utility to include storm and surface water as additional functions. In either approach the ordinance needs to refer to the comprehensive storm and surface water plan and needs to express the intent to establish and collect fair and equitable rates, fees, and charges.

6. Develop an annual budget and a six to ten year capital improvement program. This will set the revenue requirements for the utility. These will be the basis for determining the level of rates, fees and charges necessary to support the utility.

Set Rate Structure, Rates and the Method for Billing and Collecting Charges

7. The City may establish rates, fees and charges after the utility is adopted. Rates, fees and charges should be set to recover the full costs of operating the utility/program. Costs might include: maintenance and operations of storm drains, capital construction of facilities and regulations. A variety of mechanisms might be used to finance these different elements. Typically, periodic rates (usually based on some measure of the amount of contribution of runoff from land to the system) are used to recover annual revenues required to construct, operate and maintain the system. System development charges,

permitting fees, inspection fees, and other charges might be used to charge new development for the capital costs the City might incur to support the new development or the costs of the regulatory functions necessary to assure that construction is completed in compliance with regulations.

8. Determine the method of charging, billing, and collecting drainage fees and charges. The City may need to set up a new billing function, contract with another agency (the county) to bill storm and surface water charges, expand the information contained in an existing City billing system, or otherwise modify current practices. The time required to do this is often as long or longer than the time required to prepare and adopt the appropriate ordinances.

   Additionally, if a new billing method/function is developed the City will need to be sensitive to the need for supportive customer/billing services. Personnel should be on board and trained in customer service (knowledgeable about the program, able to answer specific account/bill related inquiries) prior to sending out new bills.

9. Develop account information to be used to establish rates or fees. Surface and storm water charges are typically based on some measurement of impervious surface. This measurement is a surrogate for actual measurement of runoff from land. There are several methods for determining impervious surface and there are several ways of incorporating impervious surface measurements into a rate structure. These methods may all meet the test of fair and equitable. Some of the commonly used methods include: measurement of actual impervious surface on each parcel of land; zoning as a surrogate for impervious surface coverage; and type of land use as a surrogate for impervious surface coverage. Some jurisdictions have established a flat fee chargeable to all parcels of land or a flat fee tacked on to the sewer bill. All methods have varying degrees of fairness and equity in the distribution of the utility's costs among rate payers. The costs of developing an account database and the ongoing costs of administering the billing program may be significant. Costs and fairness are usually balanced to determine the method to be used.

10. An analysis of the ability of the preferred rate structure to meet the utilities revenue requirements should be completed. With this information, recommendations for rate, fees and charges should be made to the City Council. An ordinance will be required to adopt rates, fees and charges.

Public Hearings

Public hearing(s) should be held at several critical points in this process to inform citizens of the planned program, costs and rates and to get input from the public. Key points for holding public hearings are three: 1) prior to adoption of the storm and surface water comprehensive plan; 2) prior to the adoption of an ordinance establishing the utility; and 3) prior to adoption of utility rates, fees and charges. These hearings may be held in conjunction with City budget hearings.

Suggested Utility Policies

The following are potential City policies that would support and/or suggest the need for a storm and surface water utility:

1. It is the City's policy to monitor and control drainage to avoid long term problems caused by runoff such as flooding, soil erosion, and sedimentation in natural drainage ways, and impacts to downstream water quality.

2. A fair and equitable system of charges will be implemented.

3. The amount of and flow of runoff increases as the property is developed with hard surfaces, such as rooftops, parking lots, driveways, patios. It is the City's policy to recognize the variations in runoff from different types of property in its rate structure.

4. Individual property owners are responsible for the control of runoff from their own property. The City will recognize this responsibility in its regulatory efforts.

5. The system of capital drainage facilities in each drainage basin will be designed to support existing and planned residential, commercial, agricultural, and industrial development as well as the naturally occurring storm and surface water issues.

6. The system of capital drainage facilities in each drainage basin will continue to be developed commensurate with the level of residential, commercial, and industrial development in each basin to assure that all property is protected against flooding and soil erosion, and will benefit from the long term control of runoff.

7. The system of capital drainage facilities in each basin will be designed to handle the runoff created by the highest level of development allowable under the current zoning at the time of design.

8. All new development will pay its fair share of the capital facilities required in the drainage basin to support such new development.

9. The City will recognize the contribution of existing development to runoff problems and will equitably spread the costs of solving these problems.

ISSUE 4: BILLING SYSTEM ALTERNATIVES

Introduction

An important consideration in designing a successful storm and surface water utility is the ease and cost of administration. A primary element in the administration is the system by which billing and collection are handled. A balance must be struck between the fairness and equity of a rate structure with the cost and ease of administration. This does not mean that inequitable rate structures are recommended, rather there are degrees of equity, and the cost of providing a higher degree of equity may not be worth the benefit of such higher degree.

The data to support a rate structure must be initially collected, maintained and updated. The data must be in a form that can be used by the billing system to generate fair and accurate billings to the property owners.

Background

The City has a utility billing system that currently bills residents for water, sewer, garbage and street lights. At this time, garbage is the only utility service that is billed throughout the entire City. For both sewer and water, parts of the City are served by separate Districts. For street lights, the recent Canyon Park annexation area has not been fully added.

The recently annexed residents in the Canyon Park area are currently billed for storm drainage services by Snohomish County through an interlocal agreement between the City and the County. The other residents of Bothell have not been billed directly for storm water management.

Optional Billing and Collection Systems

Four alternatives are evaluated for billing and collection systems: Snohomish County, King County, Counties combined, and the City of Bothell. Customer service and management control issues are also discussed. A key decision for Bothell will be whether all customers will be billed from a single billing system or more than one.

1. Snohomish County

Snohomish County has a surface water billing and collection system that operates together with the real property tax collections. The County has the advantage of having updated property information on a billing system available to contain a storm drainage charge. The recent Canyon Park annexation property owners are currently receiving bills from this system. The City must notify the County by November if they intend to continue with Snohomish County.

Advantages:

- The property owners in the Snohomish County area are used to receiving bills together with their property tax statements;
- the billing system is operating and needs no changes, eliminating set up costs;
- customer service could be provided by the County to eliminate the burden on City staff.

Disadvantages:

- Many single family owners may not be fully aware of the charge because the mortgage companies pay the property taxes;
- the City has limited control over the rate structure;
- the City has no control over the customer service provided to its citizens;
- the County may not be able to add Bothell property owners from King County, or could do so at great expense.

2. King County

King County also has a surface water billing system together with the real property tax collections. King County contracts with a number of cities (Lake Forest Park, Sea-Tac, Federal Way) to provide billing and collection services. King County has never billed the residents within Bothell for surface water and would need to add property owners to the billing system. It is probably too late in the year to be able to contract for startup in 1994. Current estimates of the cost of contracting with King County include:

- one time setup charge of $0.93 per account for the first two years;
- billing, customer service, account maintenance charge of $2.81 per account annually;
- and finance costs for collecting and handling revenue charge of one percent of revenue.

Advantages:

- The cost of a new utility bill would not be as noticeable on the property tax statement as on bimonthly utility bill;
- many single family owners may not be fully aware of the charge because the mortgage companies pay the property taxes;
- the billing system is already in place and the King County property owners could easily be added (timing may be an issue);
- customer service could be provided by the county to eliminate the burden on City staff.

Disadvantages:

- The City has limited control over the rate structure;
- the City has no control over the customer service provided to its citizens;
- the timing for the City may not be able to be accommodated by King County;
- the County may not be able to add Bothell property owners from Snohomish County, or could do so at great expense.

3. Snohomish and King County Combination

The third option would be to contract with both Snohomish and King counties for billing and collection services. This option would likely require the least account development costs because the Snohomish county accounts are set and only the non-single family accounts in King County would have to be classified.

Advantages:

- The cost of a new utility bill would not be as noticeable on the property tax statement as on bimonthly utility bill;
- many single family owners may not be fully aware of the charge because the mortgage companies pay the property taxes;
- the billing systems are already in place and could likely accommodate Bothell;
- customer service could be provided by counties to eliminate the burden on City staff.

Disadvantages:

- The City would have limited control over the rate structure and may result in two different structures;
- the City has no control over the customer service provided to its citizens and the situation may be confusing over who actually provides service;
- the timing for the City may not be able to be accommodated by King County;

4. City of Bothell Utility Billing System

The City of Bothell currently has a utility billing system that can accommodate a storm drainage charge to customers. The City currently bills the whole city for garbage. Portions of the City are billed for water, sewer and street lights. It is anticipated that the Canyon Park area will be added to the street lighting system.

Advantages:

- The City has a utility billing system in place for the whole city;
- the billing system will accommodate a surface water utility charge;

- the City has utility billing and customer service staff in place;
- the Snohomish County Bothell property owners would notice the billing switch to the City, consistent with their desire to join the City.

Disadvantages:

- The City may have to increase its utility billing/customer service staff;
- all property owners are not currently billed, only those with garbage service (i.e. undeveloped property);
- rate structure options that work best on utility billing system is different than used by Snohomish County--this could result in varying charges for property owners;
- accounts would have to be developed for all properties.

Conclusion

There are several alternative billing systems that could work for the City. The options come with varying

- costs of administration;
- management control; and
- appearance to the property owners.

ISSUE 5: DRAINAGE COST ALLOCATION METHODOLOGIES AND RATE STRUCTURES

Introduction

Many jurisdictions in the Northwest have chosen to implement a service charge for surface water programs to provide a consistent predictable source of funding. As with most charges for public services, it is more acceptable to tie a charge or fee directly to the service provided. This requires allocating costs among various customers based as closely as possible on the services provided to those customers. Once a basis for allocating costs to various customers is determined, the rate structure is developed.

The costs in a surface water management program can be generally categorized as capital planning and development, system maintenance, system operation, regulation and program administration. Other categories of costs may include public education, intergovernmental coordination, billing and collection of revenues and other miscellaneous functions. The largest cost components are generally improvement planning and implementation and system maintenance. Cost allocation methodologies generally focus on these two components. Cost for surface water management programs are usually assumed to be incurred and allocated by unit of run-off. Allocation methodologies and rate structures should be evaluated on the basis of:

- Equity--are costs equitably distributed among those contributing to the problem and receiving benefit from the system?
- Clarity--is the basis for cost allocation easy for customers and decision-makers to understand?
- Ease of implementation--can the allocation methodology be cost effectively implemented?

Background

All properties, including undeveloped properties, generate storm water run-off -- rainfall that is not absorbed into the ground. When properties are developed and hard surfaces such as rooftops or pavement are added, the amount and rate of run-off increases. This run-off is the major problem that surface water management programs have attempted to address. As quantity problems have been corrected and as new regulations have come out. Programs are also focusing on water quality issues. Programs deal with run-off problems in three basic ways:

- by limiting or eliminating run-off from individual properties;
- by channelling, collecting or otherwise controlling run-off that does occur;
- and by regulating or otherwise controlling the quality of run-off.

When rates and charges for storm and surface water management programs are established, it is generally accepted that surface water management program costs will be allocated to customers or customer classes based on the customer's contribution or potential contribution of run-off to

the drainage system.

A fully developed drainage system will be designed and built to handle the maximum run-off that would be contributed to the system if all properties were developed to their highest (most intense) planned use. "The maximum run-off" actually would be based on a "design storm event". Thus the system might be designed to handle the run-off created during a storm that might occur every 25 years (or 10 to 100 years).

For rate purposes, the customers should be grouped into classes based on the run-off characteristics of their property (either as it is currently or at maximum development). All customers within a class should be treated equally. There are a number of common ways to classify properties when a system of charges for drainage is established.

State law provides (RCW 35.67.020)

> *"...That the rates charged must be uniform for the same class of customers or service. In classifying customers served or service furnished by such system of sewerage (storm or surface water sewers), the city or town legislative body may in its own discretion consider any or all of the following factors: The difference in cost of service to the various customers; the location of the various customers within and without the city or town; the difference in cost of maintenance, operation, repair, and replacement of the various parts of the system; the different character of service furnished various customers; the quantity and quality of the sewage delivered and the time of its delivery; capital contributions made to the system, including but not limited to, assessments; and any other matters which present a reasonable difference as a ground for distinction.*

A different kind of system charges is required for Local Improvement Districts (LIDs) and Drainage Districts. Under State law, costs are distributed in these districts based on the benefits received. And the benefits received are strictly measured by the increase in value of the property resulting from the improvement. This presents certain inequities from a strict utility rate setting perspective. As an example, a development at top of a hill may not increase in value due to a drainage system installed at the bottom of the hill. The downstream drainage system, however, might be developed specifically to handle the run-off created by that development. Similarly the home at the bottom of the hill may contribute very little run-off but may greatly benefit by not having its property flood because of run-off from the top of the hill.

Many jurisdictions have implemented drainage utilities and are using a variety of methods for allocating costs and determining charges.

Classification of Properties Into Rate Categories

Four basic methods for classifying property into rate categories are used by jurisdictions around the country—impervious surface, land use, zoning and other utilities. There is much more variation in the methods used to determine the rate differential between categories of customers once they are classified.

1. Run-off Coefficient

The run-off coefficient is a measurement of the depth or rate of run-off from a particular type of property compared to the rate and duration of rainfall. The higher the run-off coefficient, the more run-off can be expected to flow from a parcel. The run-off coefficient is determined by a variety

of factors relating to the intensity and duration of rainfall but more importantly related to characteristics of the property itself such as slope of the ground, type of soil, ground cover or amount of impervious surface, and saturation of the ground from previous rainfall.

Standard engineering texts identify run-off coefficients ranging from:

0.70 to 0.95 for downtown, intensely developed type ares;

0.30 to 0.50 for single family residential developed areas;

0.10 to 0.30 for undeveloped land.

Theoretically, a run-off coefficient could be calculated for each parcel. However, it would be extremely costly to do so. No jurisdiction actually measures the run-off coefficient of each parcel.

Standard run-off coefficients are often used to distinguish between customer classifications in a drainage rate structure. Properties can be grouped into rate categories based on their run-off coefficients as estimated by current land use, zoning, or as measured by the amount of impervious surface.

2. Impervious Surface Measurements

While run-off coefficients are used to determine the broad classifications/categories of customers, some measurements of impervious surface is the method most frequently used to assign each parcel into a customer class. Impervious surfaces are those which do not absorb water or absorb water at such a slow rate that any rainfall will run-off. Roofs, drives, hardpan, parking lots, streets and roads are all impervious surfaces. Some surfaces, such as gravel, might be considered impervious or pervious. Specific definitions of impervious surfaces are determined by each jurisdiction using this method.

Jurisdictions attempting to set up equitable rate structures typically have some method for measuring impervious surfaces. Their rate structures then generally classify property into categories depending upon the percent of each parcel that is impervious, or the total amount of impervious surface on each parcel.

Many techniques have been developed to measure or estimate the percent of impervious surface on each parcel. The technique used by any jurisdiction will depend upon many factors including:

- information about property already available,
- the costs of developing additional information,
- the likelihood of legal challenges,
- the billing system capability and the perception of accuracy.

Three examples illustrate these alternatives:

1. Issaquah had aerial photographs taken to the same scale as King County assessors maps. The assessors maps were copied to mylar and overlaid on the aerial photos. The total impervious area for each parcel was then outlined directly into the City's automated computer aided drafting (CAD) computer. Puyallup used a similar approach. Issaquah

and Puyallup both charge rates that are based on total impervious area on each parcel.

2. King County contracted to have aerial photographs made of all property in the entire County. Aerial photographs were then overlaid with assessors maps that marked parcel boundaries. From the shading of the photograph impervious surfaces were picked out, measured and compared to the overall size of the parcel. All single family residential parcels were assigned to the same rate category and did not have to be measured. King County charges property that has no development the same flat rate as single family regardless of the size of the parcel. Other property is charged based on their percent impervious and total parcel area. King County tracks building permits and changes the rate category if a parcel's development (as measured by the site plan submitted in the permitting process) has caused it to go into a higher percent impervious category.

3. Seattle and Tukwilla identified five rate categories (range of percent impervious) based on assumed development levels and run-off coefficients. Sample measurements were made of the percent of impervious surface of single family residences and all single family residences were assigned to one rate category. Because of the high density and coverage of commercial and industrial development it was initially determined that all commercial development would fall into the highest category (85 to 100 percent impervious). A windshield survey was then performed of the entire City. Commercial, industrial and multifamily parcels that did not fall into the highest category were identified. An estimate of their percent impervious was made to classify the parcel into the correct range. An assumption was made that the parcel size contained in the King County Assessors files was correct.

3. Land Use

Several jurisdictions use actual land use to classify property into rate categories. Information on actual land use is usually available to a jurisdiction or less expensive than impervious surface measurements to gather, since it does not require any field measuring. If this method is used, some special sampling of land uses in a particular jurisdiction should be conducted to verify that parcels in that jurisdiction are developed to the same densities as those parcels from which 'standard' run-off coefficients are derived.

To assure fairness and equity, it is critical that the source of information on land use be reliable and up to date. It is also important that the land use classifications be fine tuned enough to distinguish between properties with different lot coverage.

This method is clear to explain but may not fairly classify property. For example two 10-unit apartment buildings would be put in the same land use category. However, one parcel may have 35 percent of its land in landscaping while the other may fully cover the lot with building and parking lot. Under the percent impervious method they would be assigned to different rate categories. If their run-off coefficients were measured they would be quite different

Snohomish County's utility customers are billed based on the use of classification of their property.

The advantage of this method is its clarity. For the most part the land use is apparent, the methodology is easy to explain to the public and decision makers, and current land use is often

readily available in an automated form. Ultimately, land use or zoning maybe an appropriate way to classify property because the actual costs of a surface water management program, designed to deal with units of run-off tied to full build out under zoning, may be related more to land use or zoning than to percent of impervious area.

4. Zoning

Zoning is not a common basis for classifying property for storm and surface water charges. However there is logic in using zoning.

The most costly portion of storm and surface water management programs are often the development and implementation of capital improvements. These improvements are usually designed to serve property at its ultimate or zoned development potential. Thus, there is a clear tie between the zoning of a parcel and the cost of the capital improvements. Similarly, management of the maintenance costs of a surface water system are related to the size of the pipes, detention basins or other capital improvements. Thus, on a traditional utility cost allocation planning basis, costs ar more appropriately assigned to customers based on the customers zoning or actual land use.

Using zoning has the same problem as using land use. Any two parcels developed or planned for the same "land use" may develop with very different configurations of impervious surface.

The zoning method relies on an existing classification of land that is accepted by developers and the public. This method would be easy to explain and understand. Because zoning information sis readily available in a central place it may be one of the least expensive methods of classifying parcels.

5. Other Methods

Some jurisdictions tack a drainage charge onto another utility bill. In these cases the property is "classified" by something not directly related to contribution or benefit. In some cases one could imply some connection between the charge and drainage--but such a connection is not obvious. For example, prior to establishing a specific surface water management charge, Seattle provided storm drain maintenance partially through their Sewer Utility. The cost of such maintenance were folded into the over all cost of the sewer utility and passed on to customers based on customers usage of the sewer system.

This is not an unusual occurrence. State law (RCW 35.67.010) provides that a system of sewerage includes storm or surface water sewers. Everett and Mountlake Terrace in Washington and Sacramento in California include charges for surface water management programs in the sewer bills.

While this method of assigning costs to customers does not meet the equity criteria, it is relatively inexpensive and does not require that properties be classified for surface water management purposes.

Ultimate Allocation of Costs

Once the methodology for classifying customers is determined and each property is assigned to a class, actual rates have to be determined. The 'science' of developing cost allocation plans and assigning costs to classifications of customers is much less sophisticated with surface water management utilities than with electric, water, sewer, and solid waste utilities. Generally the total customer base of the utility are divided into equivalent units--usually an equivalent unit is a single family residential parcel and the implied units of run-off expected from such a parcel. Total costs are divided by total equivalent units to determine the equivalent unit charge. For example, Lynnwood assumes that the average single family residential parcel has 2,900 square feet of impervious surface. Lynnwood charges $2.50 for each 2,900 square feet or ERU of impervious surface.

A more sophisticated cost allocation plan would assign specific system costs to customers based on the service unity for which the cost was incurred. See the discussion in the second paragraph under *4. Zoning*.

Translation into Rate Structure

Once a basis for allocating costs and assigning property to rate classes has been determined, a rate must be applied. When impervious surface is a factor in customer classification there are two ways rates may be calculated.

1. A parcel is assigned to a rate category based on some surrogate for run-off coefficient (percent impervious, land use, zoning). That rate category has a flat rate that is multiplied times the total parcel size to determine the charge. Actual rates charged generally follow a pattern as illustrated by this table.

Rate Structure Based on Run-Off Coefficent			
PERCENT IMPERVIOUS	**MIDPOINT**	**RUN-OFF COEFFICIENT**	**RATE FACTOR**
86-100 %	95	90.75	1.60
66-85%	75	73.75	1.30
36-65%	55	56.75	1.00
16-35%	25	31.25	0.55
0-15%	10	18.50	0.33

2. A parcel is assigned to a rate category based on some surrogate for the run-off coefficient. That rate category has a flat rate that is multiplied times the impervious surface area of the parcel to determine the rate. The City of Lynnwood calculates its stormwater rates based on an Equivalent Residential Unit (ERU) of 2,900 square feet. The single family equals one ERU and a non-single family is calculated by measured impervious area/one ERU.

Rate Category	Rate Calculation	Monthly Rate
1. Single Family	1 ERU	$2.50 flat rate
2. Multifamily, Commercial and Industrial	Sq.Ft. of Impervious/1 ERU (2,900 sq.ft.) =ERU's	$2.50 per ERU

The following table summarizes the rates from five representative jurisdictions. The second table details the sample properties used in calculating the utility rates from the various jurisdictions. More detail on these rate structures and the basis and assumptions made from the summarization are included in the following pages.

Comparison of Utility Rates: Comparative Monthly Amounts for Sample Properties					
CustomerClass	**KingCounty**	**Issaquah***	**Lake Forest Park****	**Snohomish County**	**Lynnwood**
Single Family	7.09	7.09	2.81	1.83	2.50
Multi Family I	12.08	12.08	4.02	2.42	3.93
Multi Family II	13.42	13.42	4.43	2.67	4.06
Convenience Store	18.67	18.67	6.04	3.74	6.07
Office Park	31.51	31.51	9.98	6.75	8.21
School	76.05	76.05	23.64	19.17	24.64
Park	7.09	7.09	2.81	0.54	2.50
Shopping Center	62.60	62.60	32.72	12.54	20.36
*Adopted King County's rate formula and rates.					
** Adopted King County's formula with different rates & an annual flat billing fee for all customers of $3.82.					

Sample Properties				
Customer Class	**Total Lot Size (Square Feet)**	**Impervious Area (Square Feet)**	**Percent Impervious**	**Notes**
Single Family	-	-	-	Average single family lot varies by jurisdiction
Multi Family I	5,000	5,000	100%	Building and parking cover entire lot
Multi Family II	7,000	5,000	71%	Building, parking and landscaping
Convenience Store	7,500	7,500	100%	Building with parking, fully paved
Office Park	40,000	10,000	25%	Building, parking (25%), landscaping (25%), natural wetland (25%)
School	50,000	30,000	60%	Building, pavement and park
Park	10,000	500	5%	Grassy park with paved alley
Shopping Center	25,000	25,000	100%	About 1/2 acre shopping center with parking

The following tables are the individual rate calculations for each of the storm and surface water management programs. In all cases the single family is charged a flat rate regardless of parcel size.

King County and Issaquah

King County calculates its rates by the following rate formula:

Total lot size * rate for range of impervious area percentage

The City of Issaquah and Lake Forest Park adopted King County's rate structure which is illustrated in the following table:

Rate Category	Percent of Impervious	Annual Service Charge (One acre=43,560 sq.ft)
1. Residential: Single Family	N/A	$ 85.02/parcel
2. Very Light	less than 10%	$ 85.02/parcel
3. Light	10-20 %	$ 198.40/acre
4. Moderate	20-45%	$ 410.98/acre
5. Moderately Heavy	45-65%	$ 793.60/acre
6. Heavy	65-85%	$1,006.16/acre
7. Very Heavy	85-100%	$1,317.94/acre

The following table shows the monthly amount that would be billed by King County and the City of Issaquah for each of the sample customers:

Sample Rates for King County and Issaquah		
Customer Class	**Monthly Rate**	**Monthly Amount**
Single Family	$7.09 flat rate	$7.09
Multi Family I	$109.83	$12.08
Multi Family II	$83.85	$13.42
Convenience Store	$109.83	$18.67
Office Park	$34.25	$31.51
School	$66.13	$76.05
Park	$7.09	$7.09
Shopping Center	$109.83	$62.60

Lake Forest Park

Unlike Issaquah, Lake Forest Park did not adopt King County's rates, only the county's rate structure. Lake Forest Park also charges an annual flat billing fee of $3.82 in addition to the rate. The flat billing rate is included in the following sample rates:

Rate Category	Percent of Impervious	Annual Service Charge (One acre=43,560 sq.ft)
1. Residential: Single Family	N/A	$ 29.89/parcel
2. Very Light	less than 10%	$ 29.89/parcel
3. Light	10-20 %	$ 60.83/acre
4. Moderate	20-45%	$ 126.01/acre
5. Moderately Heavy	45-65%	$ 243.33/acre
6. Heavy	65-85%	$ 308.51/acre
7. Very Heavy	85-100%	$ 404.10/acre

Sample Rates for Lake Forest Park		
Customer Class	**Monthly Rate**	**Monthly Amount (w/billing fee)**
Single Family	$2.49 flat rate	$2.81
Multi Family I	$33.68	$4.02
Multi Family II	$25.71	$4.43
Convenience Store	$33.68	$6.04
Office Park	$10.50	$9.98
School	$20.28	$23.64
Park	$2.49	$2.81
Shopping Center	$50.70	$32.72

Snohomish County

Snohomish County calculates its rates by the same method as King County:

Total lot size * rate for range of impervious area percentage

In addition to the single family flate rate, Snohomish County has a flat rate for Condominiums and Farms. Its rates are based on a 1/4 acre parcel instead of one acre.

Rate Category	Percent of Impervious	Annual Service Charge (One acre=43,560 sq.ft)
1. Single Family	N/A	$22/parcel
2. Condominium	N/A	$20/parcel
3. Farm	N/A	$22 per 1/4 acre;one acre maximum charge
4. Exempt	less than 1%	No charge
5. Very Light	1-19 %	$7 per 1/4 acre
6. Light	20-39%	$22 per 1/4 acre
7. Moderate	40-59%	$36 per 1/4 acre
8. Heavy	60-79%	$50 per 1/4 acre
9. Very Heavy	80-100%	$66 per 1/4 acre

Sample Rates for Snohomish County		
Customer Class	**Monthly Rate**	**Monthly Amount**
Single Family	$1.83	$1.83
Multi Family I	$22.00	$2.42
Multi Family II	$16.67	$2.67
Convenience Store	$22.00	$3.74
Office Park	$7.33	$6.75
School	$16.67	$19.17
Park	$2.33	$0.54
Shopping Center	$22.00	$12.54

Lynnwood

The City of Lynnwood calculates its stormwater rates based on an Equivalent Residential Unit (ERU) of 2,900 square feet. The single family is charged a flat rate of $2.50 which is equal to one ERU.

Measure square feet of impervious areas/one ERU = # of ERU's

Rate Category	Rate Calculation	Monthly Rate
1. Single Family	1 ERU	$2.50 flat rate
2. Multifamily,Commercial and Industrial	Sq.Ft. of Impervious/ 1 ERU (2,900 sq.ft.) =ERU's	$2.50 per ERU
3. Senior single family	1 ERU * 0.5	$1.25 flat rate

Sample Rates for City of Lynnwood		
Customer Class	**Monthly Rate**	**Monthly Amount** (*minimal billing rate of $2.50)
Single Family	$2.50 flat rate	$2.50
Multi Family I	$3.93	$3.93
Multi Family II	$5.71	$4.06
Convenience Store	$6.07	$6.07
Office Park	$32.86	$8.21
School	$41.07	$24.64
Park	$8.21	$2.50*
Shopping Center	$20.36	$20.36

Conclusion

- The 'best' cost allocation methodology for Bothell will depend on several critical factors including:
- The billing system;
- The availability of information about property in Bothell and the accessibility of that information;
- Cost effectiveness of collecting additional information about properties; and
- Identification of the cost components (e.g., capital in commercial areas, maintenance and operation in residential areas, regional detention facilities, water quality monitoring, etc.) that would be allocated to customer classes.

31-Aug-93 *CCAinc*

BOTHELL STORM WATER PLAN
MEASURED IMPERVIOUS AREA
SAMPLE RESIDENTIAL PARCELS

Qtrsection	no. of parcels	impervious sq. ft.		imperv x parcels
SINGLE FAMILY PARCELS				
NE 1/4 sec 25	27	2,586		69,820
SE 1/4 sec 20	33	2,669		88,065
SE 1/4 sec 20	28	3,207		89,809
NW 1/4 sec 32	23	2,775		63,833
SW 1/4 sec 5	52	2,774		144,223
SW 1/4 sec 6	44	2,900		127,587
TOTAL	207	16,911		583,336
AVERAGE		2,818	sq. ft.	2,818

WITHIN MOBILE HOME PARK			
SE 1/4 sec 31	27	1,278	Mobile Home Park
SE 1/4 sec 29	33	1,148	Mobile Home Park
AVERAGE		1,213	sq. ft.

MOBILE HOME AS % OF SINGLE FAMIL 43%

Impervious area measured by Barrett Consulting Group on sample quarter sections.

ISSUE 6: MANAGEMENT OPTIONS AND IMPLEMENTATION ISSUES

Introduction

There are a number of management options and other implementation issues that should be addressed and resolved up front to ensure a successful storm and surface water management program/utility.

- separate utility or combined;
- timing of bills;
- property owners;
- rate issues—single family customer class, undeveloped property, wetlands, direct discharge, streets and highways, on-site detention systems, senior/disabled low income discount;

These issues commonly arise in designing a new utility and rate structure. They are presented briefly for the City's consideration.

Separate Utility or Combined

The question of a separate utility for storm drainage is a management option that depends largely on how the City currently operates. For those cities with water or sewer utilities, it is often better to combine the storm drainage utility for legal purposes only. It is recommended to account for the storm drainage funds entirely separately from other utility funds on an internal basis. One reason for establishing a drainage utility is to provide a dependable source of funding. To demonstrate that the funds are being accumulated and used appropriately, it is helpful to have separate accounting.

A benefit of a combined utility can be seen if the jurisdiction will require revenue bond financing. Legally, with a combined utility, the revenue bond issues are backed by the revenues and credit of the entire utility. Again, it is recommended that separate internal accounting is essential to eliminate subsidies between utilities.

In the past, storm water utilities have often been separate utilities. This trend seems to be reversing itself as water quality regulations bring the sewer and storm operations closer together. The largest benefit of a combined utility is reportedly flexibility on the part of the City as it faces the challenges that arise. A drawback of a separate utility is the appearance of another layer of bureaucracy, whether or not it exists.

Timing of Bills

The revenue stream from a utility service charge warrants consideration prior to beginning. Depending on the financial needs of the City, the timing and billing period for a new utility charge can be designed to the City's advantage.

On one hand, the bills will serve to remind the citizens of the service provided by the City. The bills also serve as a reminder of growing costs of operations. Finally, the timely and dependable revenue to carry out the maintenance and capital programs is the primary reason for the new charge.

Given the City's utility billing system, the options appear to be bi-monthly billing in advance or arrears of the billing period, (i.e. billing in January for January and February or billing in March for January and February). Snohomish and King County bill annually on the property tax statements. Some cities bill bimonthly, quarterly, semi-annually or annually.

Property Owners vs. Tenants

Although a storm drainage utility is much alike a sewer or water utility, the actual user/contributor or benefitor is different. For water or sewer, the user is the one that turns on the water or flushes the toilet. Often, tenants are billed for such services and property owners may or may not be actually responsible.

For storm water utilities, the property itself is the contributor of run-off and benefits from a properly constructed and maintained system. In addition, as the property owner travels through the city, it benefits from the drainage system. If the rate structure is based on some measure of impervious surface, this relates to the property. An example would be a shopping center, one owner, with six businesses occupied different businesses. Each of the businesses has a water meter and garbage collection, and the parking lot is shared by all. The process of developing the account database will address such instances. A typical solution is to have a "dummy" account (or calculate the total drainage charge off the database) and divide the charge among the tenants.

Rate Issues

There are a number of issues that should be addressed in connection with refining a rate structure.

- *single family customer class*—most utilities treat single family as a flat rate versus measuring each individual single family parcel. This has been challenged in court and found to be equitably based. The excess cost of developing and administering the accounts does not typically justify any increased level of equity.
- *undeveloped property*—will undeveloped property be charged? There are nearly as many answers to this question as utilities in operation. Undeveloped property, as does all property,

benefits from the existence of a properly constructed and maintained drainage system. On the other hand, truly undeveloped property may benefit the system overall by not contributing as much runoff to the system as developed properties.

- Some rate structures do not charge undeveloped property at all, some charge a minimum charge equal to the single family rate, and some charge undeveloped for all the property but at a reduced rate than developed. Snohomish and King County do not charge for undeveloped parcels.

- *wetlands* - due to the sensitive areas ordinances and restrictions on development in wetland areas, many utilities are going to an exemption or credit for wetland areas.

- *direct discharge* - properties that discharge directly into a receiving body of water have argued that they should not have to pay a service charge. One school of thought insists that all properties benefit from the existence of the City's drainage system whether or not their property discharges directly into the system. Some utilities have given credits, some treat all property alike--everyone benefits.

- *streets and highways* - there is a statute that addresses highway property stating that they supply and maintain part of the drainage system and that they must pay a maximum of 30% of other properties. Thus, in order to charge State highways for the 30%, the City must bill itself for its streets and roads. For Bothell, the City is currently paying for the maintenance of the drainage system with fuel and other general taxes. If the rates calculated to be within this amount, the street fund would not realize an increase. Issue Paper 7 addresses this issue in detail.

- *on-site detention systems/development regulations* - the City's development regulations should be reviewed to determine the requirements property owners have had in order to develop. Property owners often argue that they had an expense to meet the requirements that all property owners have not had, and feel they should receive a credit for some or all of the service charge. Many jurisdictions do not give any credits. With regulations increasing, there may be more pressure in the future to do so.

- *senior/disabled low income discount* - depending on Bothell's existing policy for other utilities, the existence of a low income discount should be consistent.

ISSUE 7: CITY STREETS AND STATE HIGHWAYS

This issue paper addresses two primary issues:

- The degree to which streets are part of or contribute runoff to the drainage system because they convey and channel runoff; and
- Whether the City streets and State highways should be charged for drainage if a storm and surface water utility were to be formed.

Background

Properties are generally charged for drainage on the basis of such factors as land area, impervious area and land use. However, the roadways have certain drainage features that distinguish them from other properties. The citywide network of streets intercepts and collects stromwater that runs off other properties, conveying it to storm drains. Likewise, curbs, inlets, and catch basins are built into the roadway surface and are an integral part of the City's overall drainage system. The City's street program provides certain services such as mowing (rather than using herbicides), street cleaning and landscaping that are beneficial to the drainage system. In addition to these special drainage aspects of roads, there are State laws that govern the manner in which city streets and State highways may be charged for drainage.

In 1986, in the wake of mounting local activity to form drainage utilities, the State Legislature revised the statutes governing drainage charges for roads. These revisions accomplished two purposes:

- Established stricter rules regarding local drainage charges levied against State highways (RCW 90.03.525) including a cap of 30 percent of that charged to comparable properties; and
- changed legislation to allow local utilities more flexibility in drainage rate setting, in particular RCW 90.03.510 allows a local utility to give consideration to in-kind services in setting drainage rates and charges.

RCW 90.03.525 states that *"the rate charged by a local government utility to the department of transportation with respect to state highway right of way or any section of state highway right of way for the construction, operation and maintenance of storm water control facilities under chapters 35.67, 35.92, 36.89, 36.94, 56.08, and 86.15 RCW,* ***shall be thirty percent of the rate for comparable real property****, except as otherwise provided in this section. The rate charged to the department with respect to state highway right of way or any section of state highway right of way within a local government utility's jurisdiction shall not, however, exceed the rate charged for comparable city street or county road right of way within the same jurisdiction. ...utility imposing the charge and the department of transportation may, however, agree to either higher or lower rates with respect to the construction, operation, or maintenance of any specific storm water control facilities based upon the extent and adequacy of storm water control facilities constructed by the department and upon the actual benefits to state highway right of way from the storm water control facilities constructed by the local government utility..."*

RCW 90.03.510 states that *"whenever a county, city, town, sewer district, or flood control zone district imposes rates or charges to fund storm water control facilities or improvements and the operation and maintenance of such facilities or improvements..., it may provide a credit for the value of storm water control facilities or improvements that a person or entity has installed or located to mitigate or lessen the impact of storm water which would occur."*

A futher distinction is drawn on highway right-of-way depending on whether it is limited access or not. The limited access portions of State highway right-of-way are the responsibility of the State. The unlimited access areas, however, are under the control of Bothell and as such, any associated stormwater utility bill would be the responsibility of the City.

City of Bothell

State Routes 522, 524, 527 and Interstate 405 comprise approximately 79,000 square feet of the City's roadway system (CCAinc estimated the square footage of these roadways from Kroll maps measuring with a Planimeter). Of the 79,000 square feet, 63,000 square feet is limited access and the responsibility of the Washington State Department of Transportation (DOT). If a local utility charged DOT for drainage the charge would be thirty percent the rate for comparable real property. Thirty percent of DOT's right of way (63,000 square feet) is 19,000 square feet. The City's responsibility for unlimited access highway right-of-way is approximately 16,000 square feet for State Routes 522, 524 and 527.

Interstate 405 is about seventy percent of DOT's right of way. It is estimated that I-405 has between 20 to 50 percent impervious surface. If the rate structure accounts for intensity of development the drainage charge would be at a low or moderate level which may result in a lower drainage charge.

The percentage of impervious surface is higher on the State Routes compared with Interstate 405. The City would pay rates in the moderate to high categories if the rate structure has a component for intensity of development.

Summary of Roadway Square Footage

Department of Transportation *(Interstate 405 and SR522)*	62,860 sq. ft.	30% of DOT's square footage is 18,858
City of Bothell *(SR 522,524 &527)*	15,780 sq.ft.	
Total Square Footage	78,640 sq.ft.	

1. Square Footage is estimated by Planimeter on Kroll map.

Problem Statement

If the City of Bothell forms a storm and surface water utility should the City streets and State highways be charged for drainage?

Alternatives

Three alternatives are summarized and evaluated below.

1. Exempt City streets and State highways from drainage charges.
2. Charge City streets and State highways in same manner as other property.
3. Charge City Streets and State highways and provide a credit for in-kind services.

1. Exempt City streets and State highways from drainage charge

This alternative assumes that City streets and State highways are exempt from drainage charges. The rationale for exempting them is that the City's roadway system also functions as an integral part of the overall drainage system. For example, the streets are laid out in a grid pattern throughout most of the City, which allows the roadway system to intercept and collect storm water from adjacent properties and convey it to storm drains via inlets and catch basins.

Advantage

The exemption of the roadway system from drainage charges may reduce the administrative time spent preparing the accounts for billing, negotiating rates with State Department of Transportation and measuring percentage of impervious surface.

Disadvantage

Whether or not the streets are charged for drainage the utility's total cost does not change. If the streets were exempt from the charge it could result in higher drainage rates for other customers to cover the utility's total cost.

Right-of-way

The role of City streets as part of the overall surface water collection system does not extend to the undeveloped portion of City right-of-way and consequently this portion of City roads should be charged, though some credit should be granted to the roads program for the in-kind services (i.e., mowing and landscaping). If the undeveloped right-of-way was charged it could slightly lower the drainage rates charged to other customers.

2. Charge City streets and State highways

The second alternative would charge the City streets and State highways in the same manner as other property. For example, a street with 40% impervious surface would pay the same drainage rate per square foot as a business with similar impervious surface area or 4,000 square feet of

impervious. However, the State highways would pay 30% of that drainage charge as stated in RCW 90.03.52.

Advantage

Charging the streets for drainage could reduce the amount of total utility cost to be carried by other rate payers.

Disadvantage

The main disadvantage of this alternative is that it makes no adjustment for the important drainage characteristics of roadways. For example, curbs, catch basins and street cleaning. Another disadvantage would be if the rate structure developed included a component for intensity of development, 70 percent of DOT's portion of roadway would be in a lower rate category than the City's due to the higher intensity of development of City streets.

3. Charge City Streets and State highways and provide a credit for in-kind services

Alternative three has the same rationale stated in alternative one—that the roadway system is an integral part of the overall drainage system. This alternative also recognizes that the impervious surface of roadways is a source of drainage problems. Providing an in-kind credit for catch basins, detention basins, etc. recognizes that certain aspects of the roadway system contribute to the solution of drainage problems.

Advantage

The main advantage of this alternative is that it would have lower drainage rates compared to the option of fully exempting streets from drainage charges, while at the same time taking some account of the special drainage characteristics of roads. The current level of expense, in the street fund for maintaining the drainage ways would be considered in-kind and would take the place of additional utility charges.

Disadvantage

This alternative does not fully recognize the integral role that the City's roadway system plays in collecting and conveying storm water runoff. Instead, the focus in on certain pieces of the system, e.g., detention basins. Another disadvantage is the difficulty in determining the value of the various drainage benefits provided by the roadway program (e.g., mowing and landscaping instead of herbicides).

Recommendations

Selection of a recommended alternative is based on the following criteria:

1. Equity, and
2. Cost and feasibility of implementation

As a general rule, equity requires that all properties be charged in the same manner unless there are significant differences among them. In this regard, City streets are fundamentally different than other properties in that the City streets are an integral part of the City's overall drainage system.

Snohomish County currently bills State Highway Right-of-Way at the allowable 30 percent of similar property.

Summary of Square Footage by Roadway

County	Kroll Map Number	*Square inches as measured by Planimeter on Kroll Maps* City SR522	DOT SR522	DOT HWY405	City SR524	City SR527
KING	402E					7.2
KING	402W					
KING	403E			46.5		
KING	403W					
KING	404E					
KING	404W			5		
KING	407E	13.5	14.5			
KING	407W	0.2				
KING	408E		34	25		
KING	408W		19			
KING	409E					
KING	409W		26.6	4.75		
KING	412E					
KING	412W					
KING	413E			3.5		
KING	413W					
SNO	125E					
SNO	125W					
SNO	126E	2				
SNO	126W	10.5				
SNO	127E			41		
SNO	127W			30.9		
SNO	129E			1.7		
SNO	129W					
SNO	130E			42		25
SNO	130W			3.85		
SNO	131E					
SNO	131W			1.5		
SNO	133E			10.5		
SNO	133W					
SNO	134E			4	5	
SNO	134W				2.5	
SNO	135E				5	
SNO	135W				8	
Total Inches		26.2	94.1	220.2	20.5	32.2
Total Square Feet		5,240	18,820	44,040	4,100	6,440

Department of Transportation	62,860	18,858	(30% of DOT's square footage)
City of Bothell	15,780		
Total Square Feet	78,640		

ISSUE 8: SUMMARY OF ACCOUNTS BILLED BY SNOHOMISH COUNTY

This section summarizes the accounts currently billed by Snohomish County in the following watershed management areas:

9301 - Swamp Creek/Puget Sound Tributaries

9302 - North Creek

9303 - Marshland

9304 - Sunnyside

9305 - Lake Stevens

9306 - Smokey Point

9307 - City of Lake Stevens

9308 - Quilceda/Allen Creek

The following chart is the current Rate Schedule used by Snohomish County:

Rate Category	Impervious Surface	Annual Service Charge
Single Family	Flat Rate	$22 per parcel
Condominium	Flat Rate	$20 per unit
Farm	Flat Rate	$22 per 1/4 acre (one acre maximum charge)

Other Properties:		Rate per 1/4 Acre
Exempt	Less than 1%	no charge
Very Light	1-19%	$7
Light	20-39%	$22
Moderate	40-59%	$36
Heavy	60-79%	$50
Very Heavy	80-100%	$66

The following table summarizes the average drainage charge per account in Snohomish County for Single Family (SF), Very Light (VL), Moderate (ME), Heavy (HE) and Farm (FA).

Summary of Accounts

Rate	Accounts	Acres	Billed	Adjusted	Average Billed Per Account	Average Adjusted Per Account
SF	3,094	8	$67,826	$67,826	$22	$22
VL	3	2	$65	$65	$22	$22
ME	12	130	$18,463	$2,627	$1,539	$219
HE	81	472	$86,364	$68,069	$1,066	$840
FA	1	39	$88	$88	$88	$88

The previous table used the following data to calculate the average billing charge per account.

Rate	Accounts	Acres	Billed	Adjusted	Comments
FA	1	39	$88	$88	
HE	1	17	$3,406	$3,406	
HE	1	5	$1,066	$1,066	
HE	1	29	$5,800	$5,800	
HE	1	45	$9,074	$9,074	
HE	1	3	$646	$646	
HE	1	0	$72	$72	
HE	1	2	$400	$400	
HE	1	1	$114	$114	
HE	1	10	$1,946	$1,946	
HE	1	1	$252	$252	
HE	1	0	$80	$80	
HE	1	1	$106	$106	
HE	1	1	$104	$104	
HE	1	4	$880	$880	
HE	1	9	$1,830	$1,830	
HE	1	2	$362	$362	
HE	1	1	$186	$186	
HE	1	6	$1,264	$1,264	
HE	1	0	$92	$92	
HE	1	6	$1,100	$0	USA General Services
HE	1	1	$124	$124	
HE	1	2	$58	$58	
HE	1	1	$200	$200	
HE	1	4	$714	$714	
HE	1	43	$1,220	$1,220	
HE	2	7	$1,380	$1,380	
HE	2	34	$6,700	$6,700	
HE	2	7	$1,474	$1,474	
HE	2	5	$944	$944	
HE	2	2	$388	$388	
HE	2	6	$1,208	$1,208	
HE	2	1	$144	$144	
HE	2	22	$4,444	$4,444	
HE	2	5	$1,010	$1,010	
HE	2	6	$1,208	$1,208	
HE	3	2	$350	$350	
HE	3	26	$5,244	$5,244	
HE	4	10	$1,916	$1,916	
HE	5	17	$3,322	$3,322	
HE	9	62	$12,368	$3,593	3593 Canyon Park–Large Adjus
HE	6	17	$3,318	$3,318	Mostly Roads in Canyon Park
HE 47120	2	1	$124	$124	
HE 51600	1	4	$826	$826	
HE 53910	1	2	$442	$442	
HE 54111	1	0	$38	$38	
HE 67500	1	42	$8,420	$0	Army Corps of Engineers
ME	1	1	$73	$73	
ME	1	0	$42	$42	
ME	1	5	$658	$658	
ME	1	39	$5,597	$0	Schools–In Kind Credit
ME	1	9	$1,233	$0	Schools–In Kind Credit
ME	1	6	$896	$896	
ME	2	7	$958	$958	

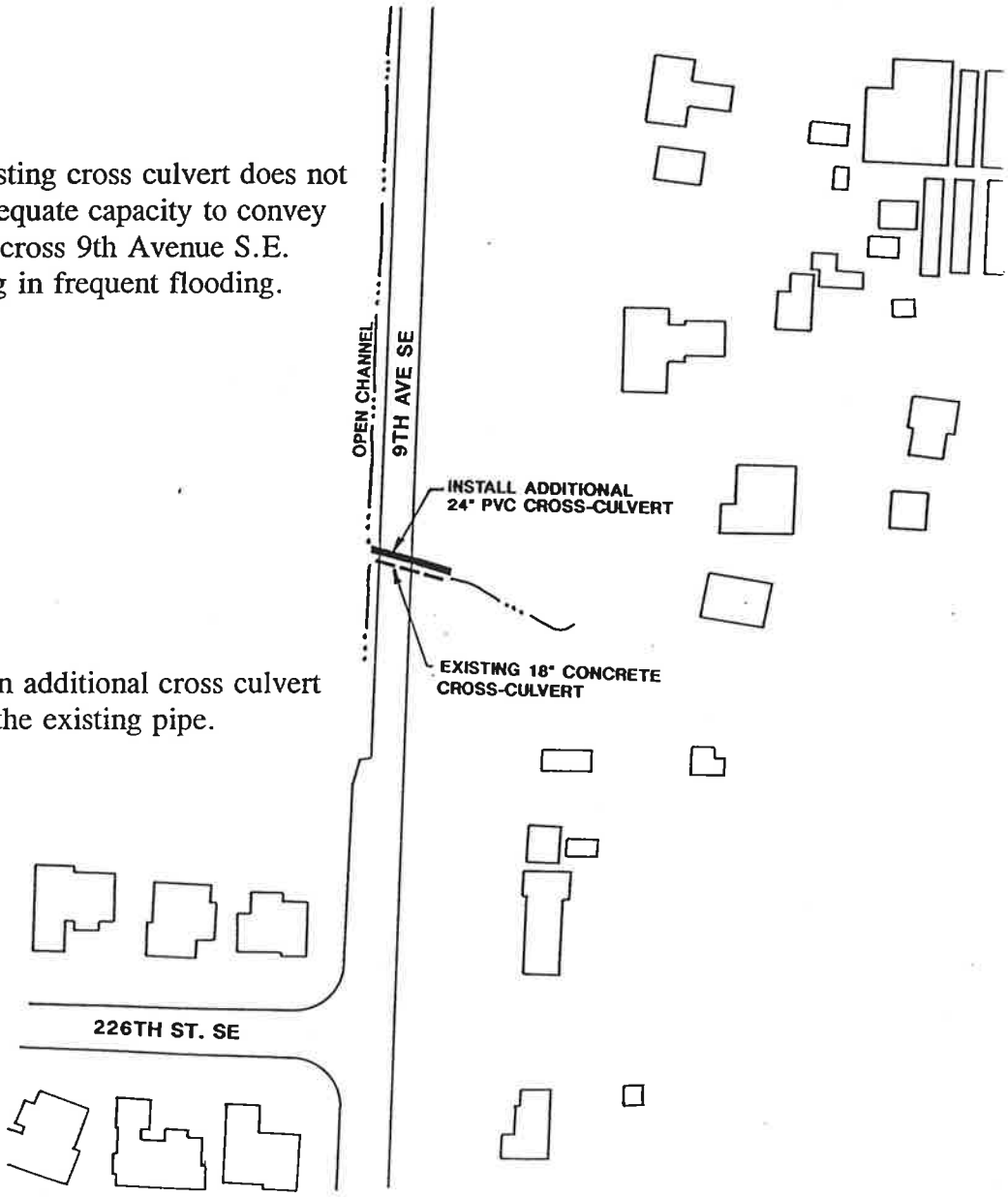
ME	3	44	$6,322	$0	Schools–In Kind Credit
ME 48301	1	19	$2,684	$0	Army Corps of Engineers
SF	1	3	$22	$22	
SF	1	1	$22	$22	
SF	1	4	$22	$22	
SF	11		$0	$0	
SF	11		$242	$242	
SF	15		$330	$330	
SF	16		$352	$352	
SF	16		$352	$352	
SF	21		$462	$462	
SF	86		$1,892	$1,892	
SF	2,915		$64,130	$64,130	
VL	1	0	$14	$14	
VL	1	2	$43	$43	
VL	1	0	$8	$8	
	3,191	651	$172,806	$138,675	

Project C-1

Location: 9th Avenue S.E. and 226th Street S.E.

Problem: The existing cross culvert does not have adequate capacity to convey runoff across 9th Avenue S.E. resulting in frequent flooding.

Solution: Install an additional cross culvert next to the existing pipe.

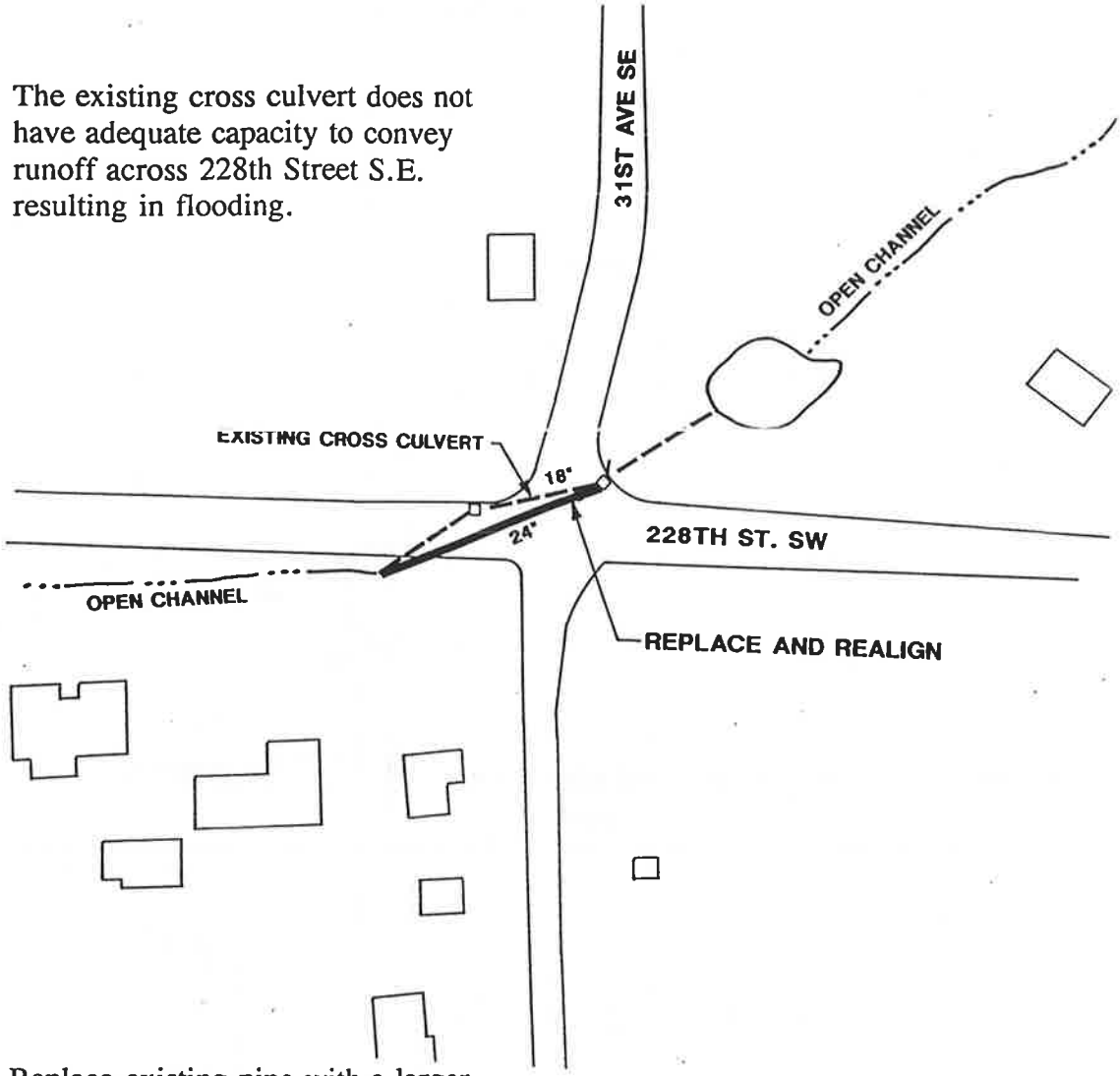


Cost: **$5,000**

Project C-2

Location: 228th Street S.E. and 31st Avenue S.E.

Problem: The existing cross culvert does not have adequate capacity to convey runoff across 228th Street S.E. resulting in flooding.



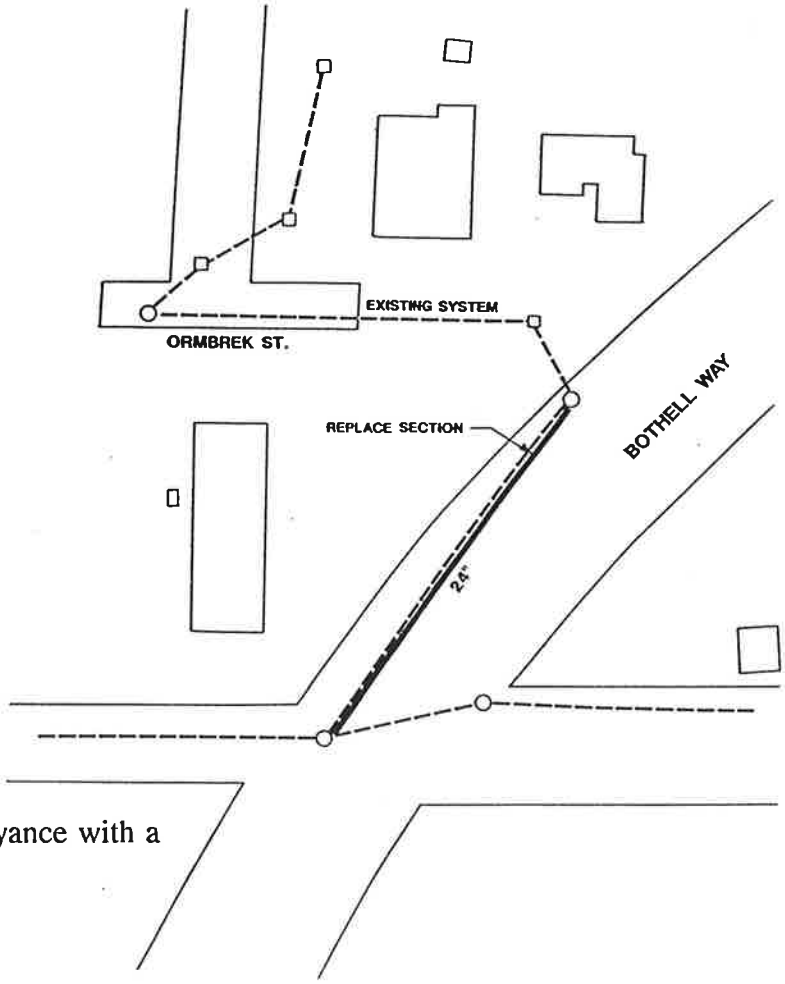
Solution: Replace existing pipe with a larger diameter pipe as a component of the 228th Street S.E. improvement.

Cost: **$6,000**

Project C-3

Location: Bothell Way between Ormbrek Street and N.E. 180th Street

Problem: Model results showed the existing conveyance does not have the capacity to convey the 25-year storm event which will result in street flooding.



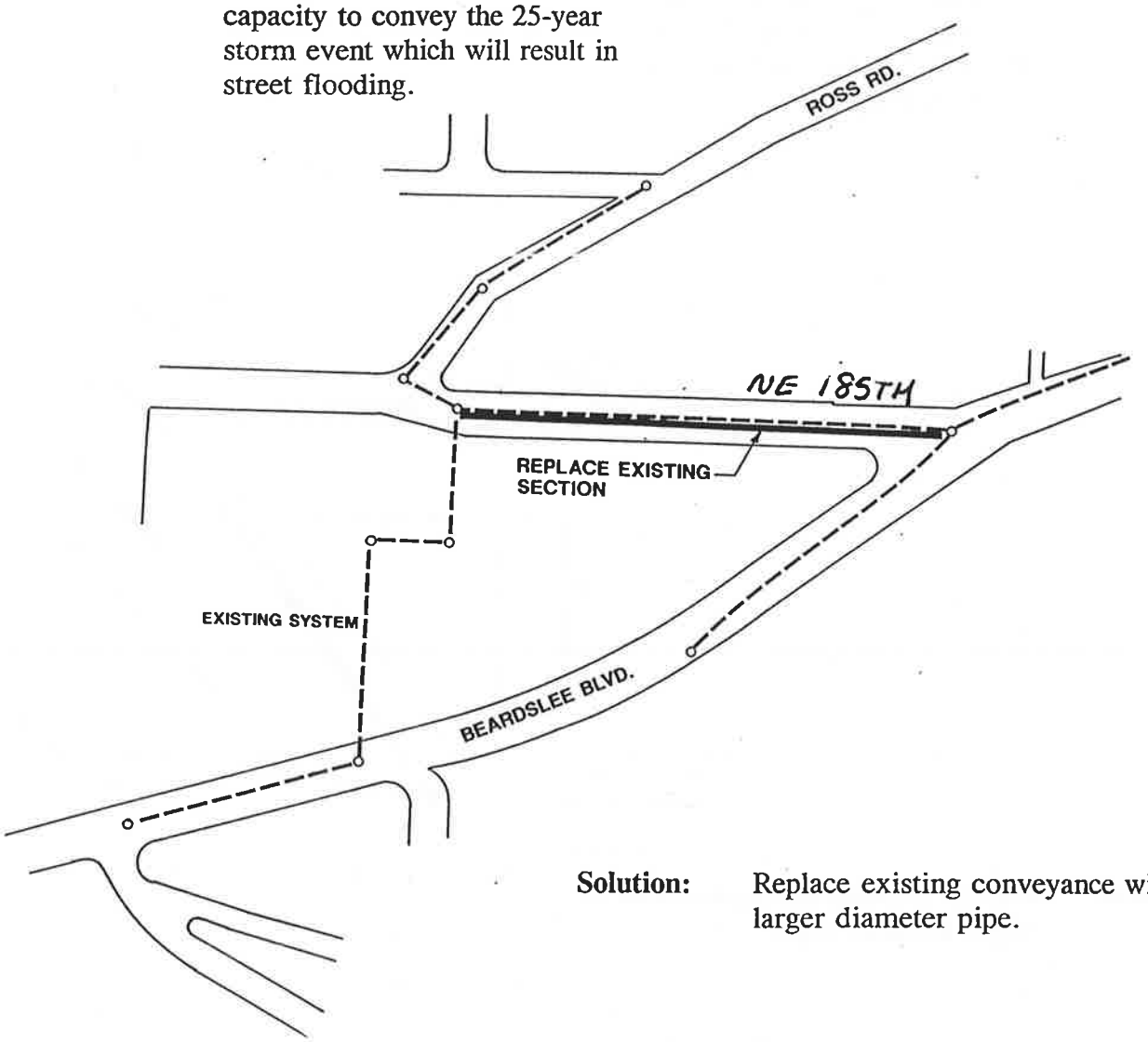
Solution: Replace existing conveyance with a larger diameter pipe.

Cost: **$16,800**

Project C-4

Location: NE 185TH between Beardslee Boulevard and Ross Road

Problem: Model results showed the existing conveyance does not have the capacity to convey the 25-year storm event which will result in street flooding.



Solution: Replace existing conveyance with a larger diameter pipe.

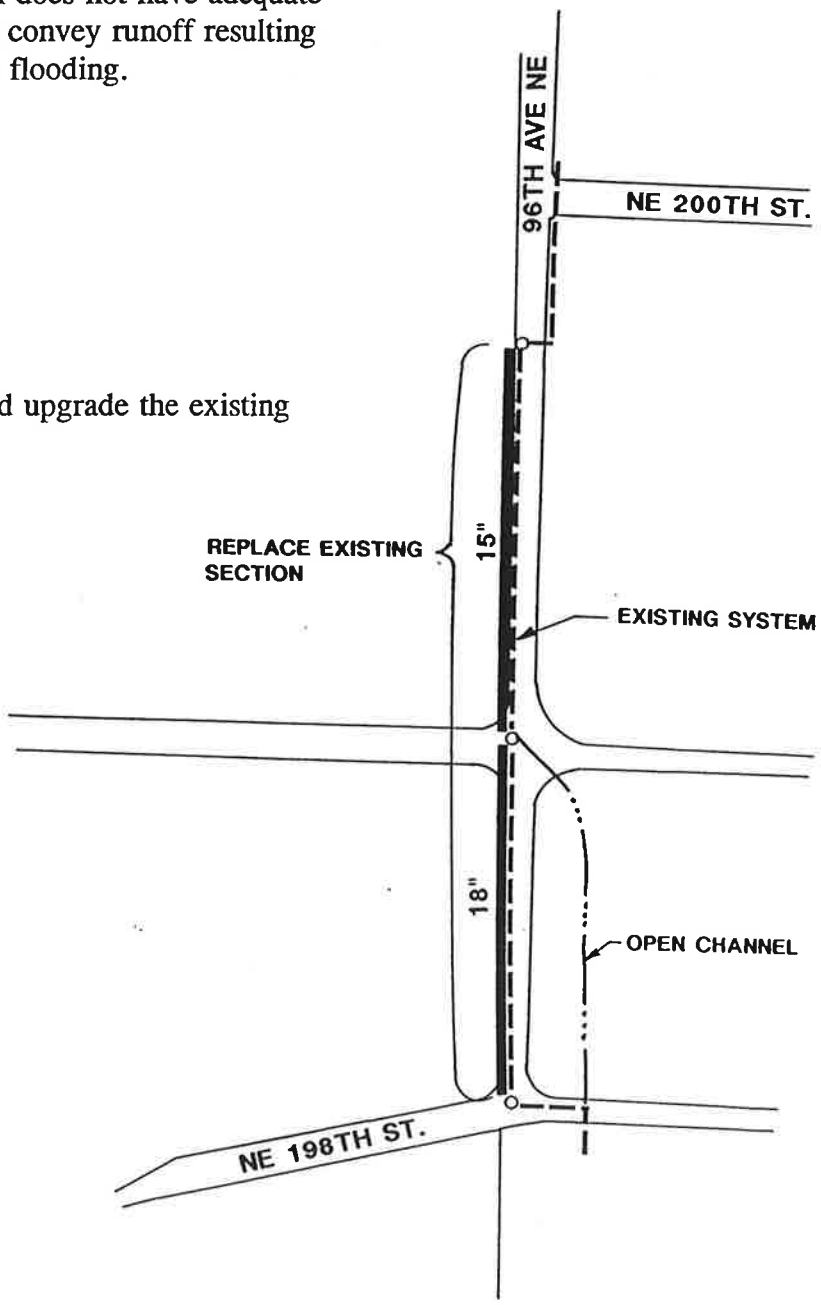
Cost: **$32,500**

Project C-5

Location: 96th Avenue N.E. from N.E. 203rd Street to N.E. 198th Street

Problem: The system does not have adequate capacity to convey runoff resulting in frequent flooding.

Solution: Replace and upgrade the existing system.



Cost: **$20,000**

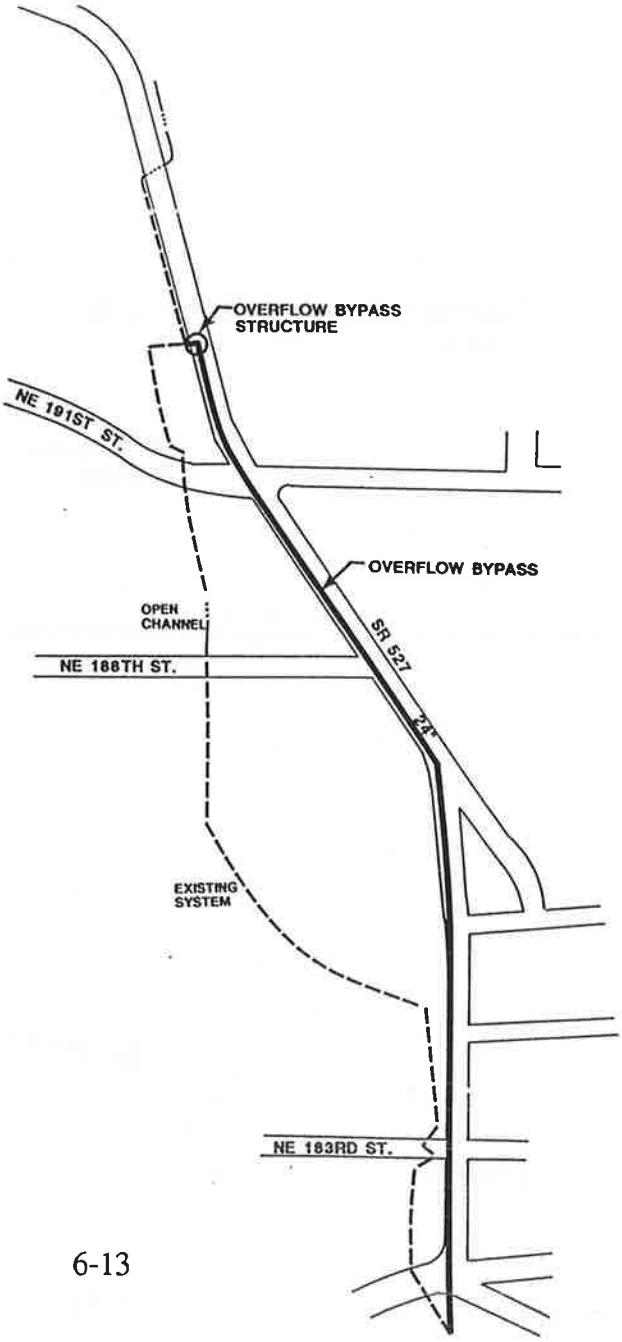
Project C-6

Location: Piped conveyance of Horse Creek through downtown

Problem: Conveyance system does not have the capacity to convey stormwater resulting in flooding.

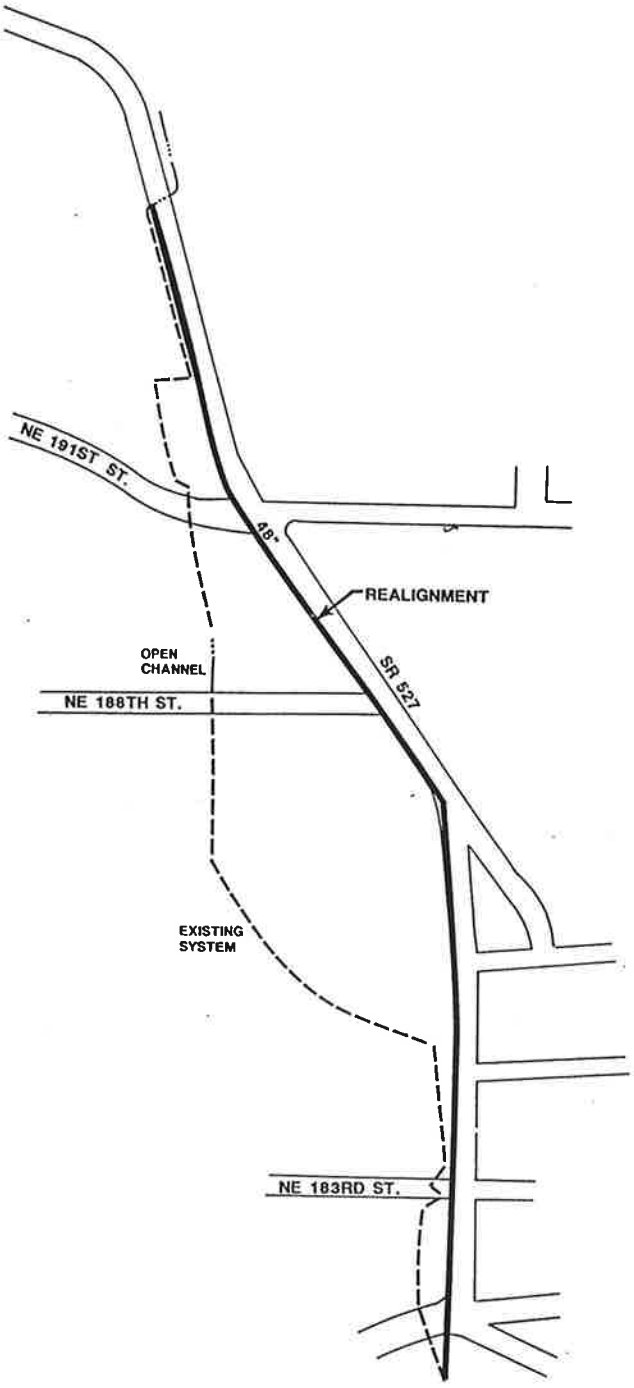
Solution: Three alternatives were investigated to determine a solution to this problem. They are presented below as Option A, B, and C.

Option A: Construct an overflow bypass at the point where the open channel enters the piped system. Route the bypass down SR 527 to reconnect with the system at the intersection of SR 527 and Bothell Way.



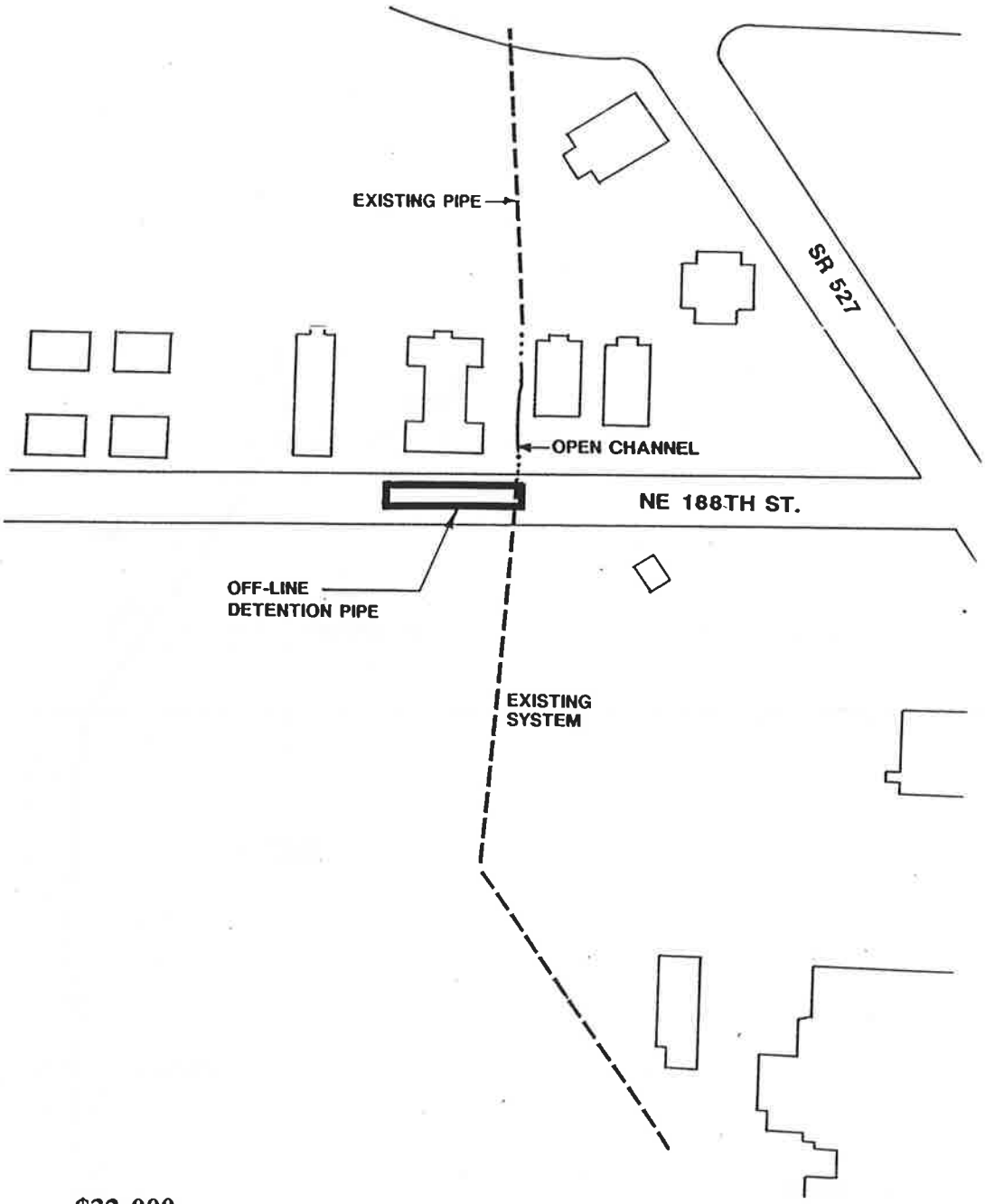
Cost: **$70,000**

Solution: B Realign the piped segment along SR 527 starting where the open channel enters the system adjacent to SR 527. Reconnect to the existing system at the intersection of SR 527 and Bothell Way.



Cost: **$166,000**

Solution: C Install an off-line detention pipe under N.E. 188th Street to provide temporarily storage of excess stormwater which has surcharged in the downstream system.

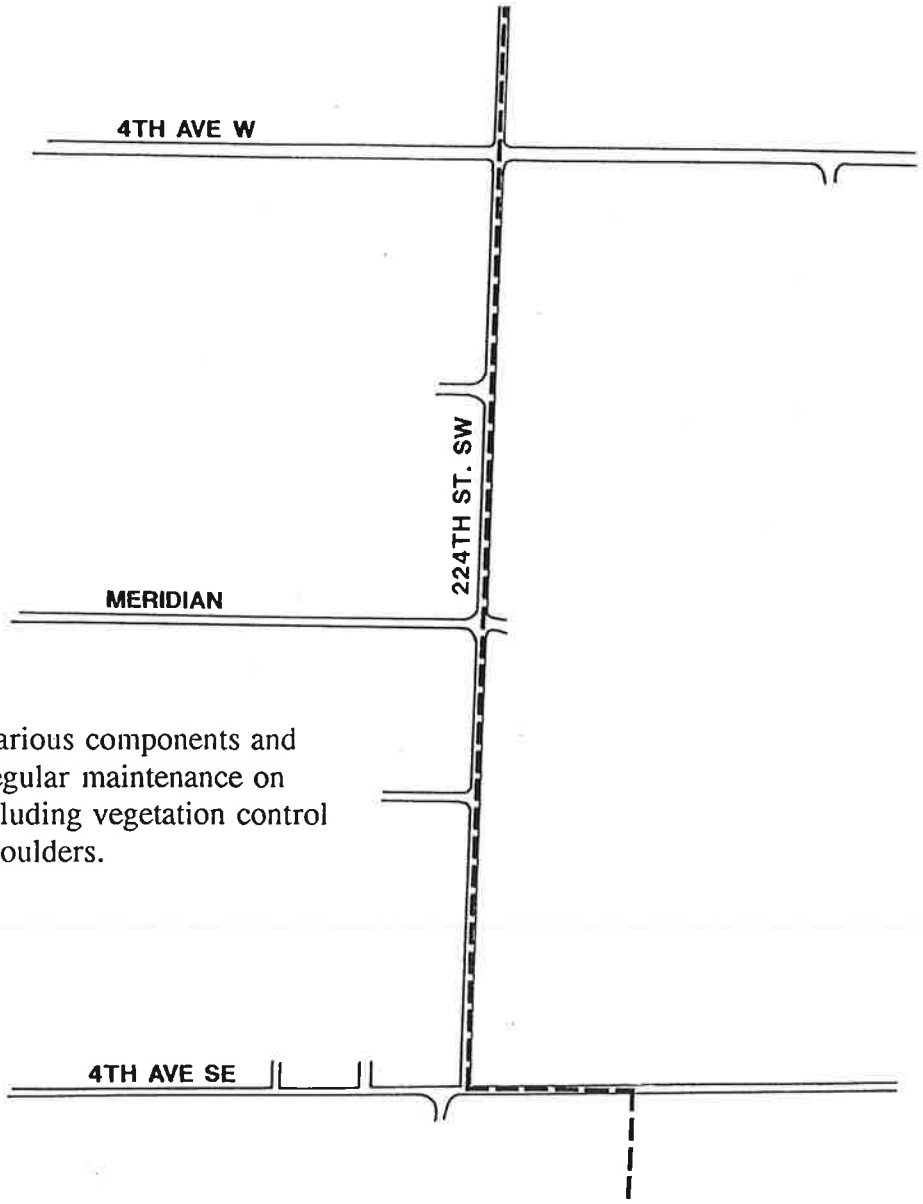


Cost: **$32,000**

Project L-1

Location: 224th Street S.W. between 8th Avenue W. and 4th Avenue S.E.

Problem: Shoulders and private property flood due to inadequate storm drains.



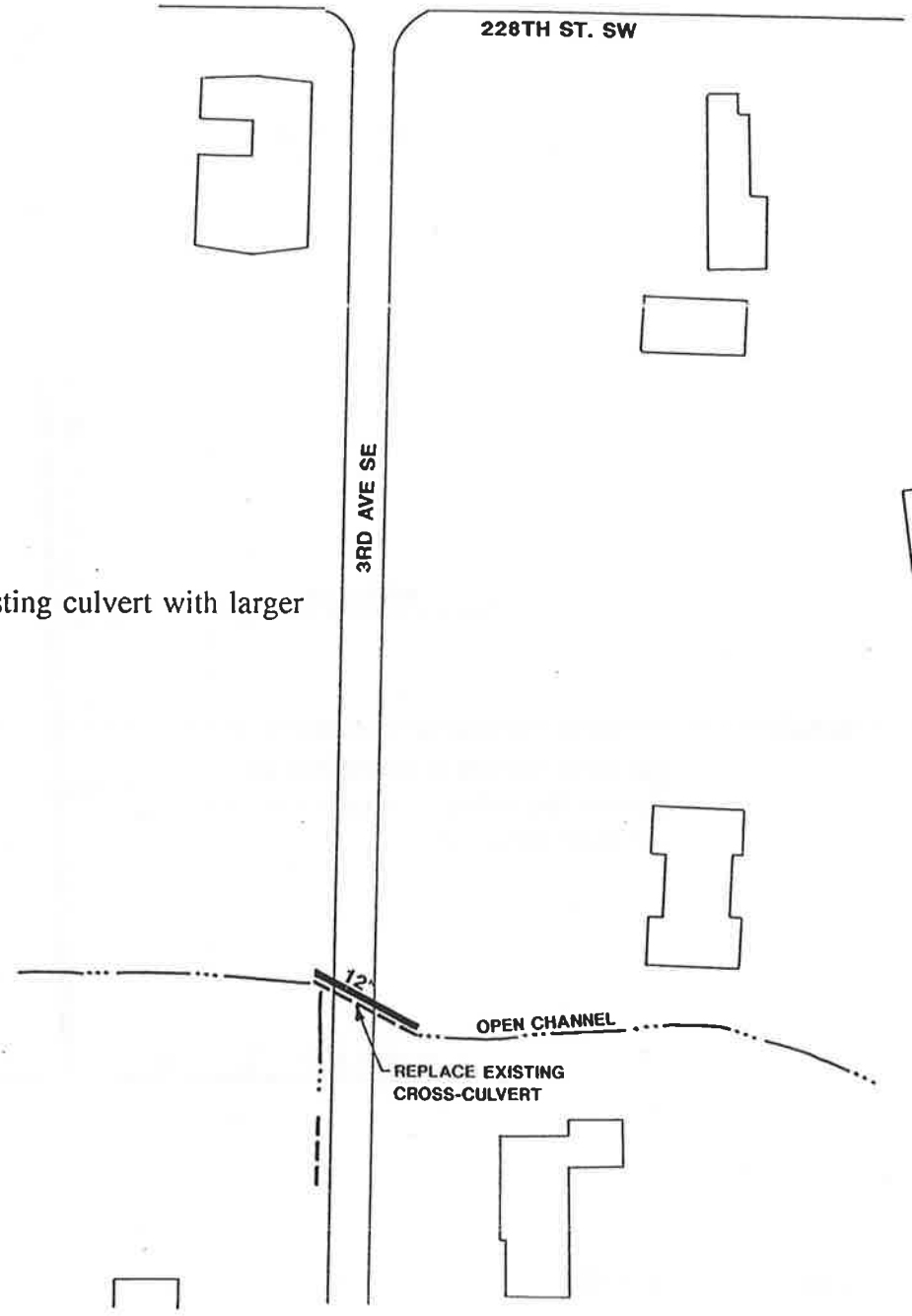
Solution: Connect various components and perform regular maintenance on system including vegetation control on road shoulders.

Cost: **$19,600**

Project L-2

Location: 3rd Avenue S.E. near 234th Street S.E.

Problem: Cross culvert is inadequate to convey 25-year design storm.



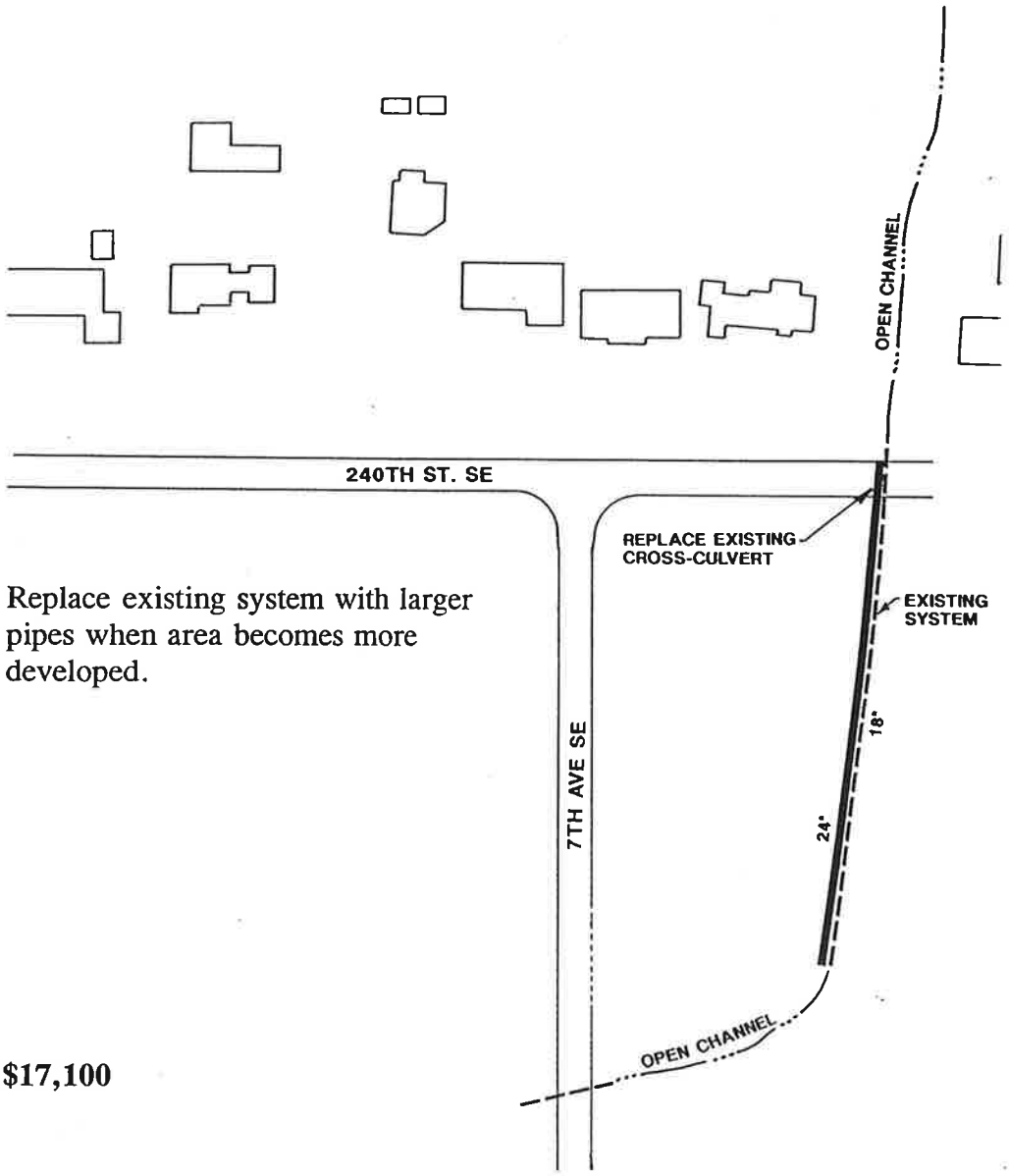
Solution: Replace existing culvert with larger pipe.

Cost: **$2,800**

Project L-3

Location: 240th Street S.W. east of 7th Avenue S.E.

Problem: Existing culvert and pipe system will be too small under future conditions.



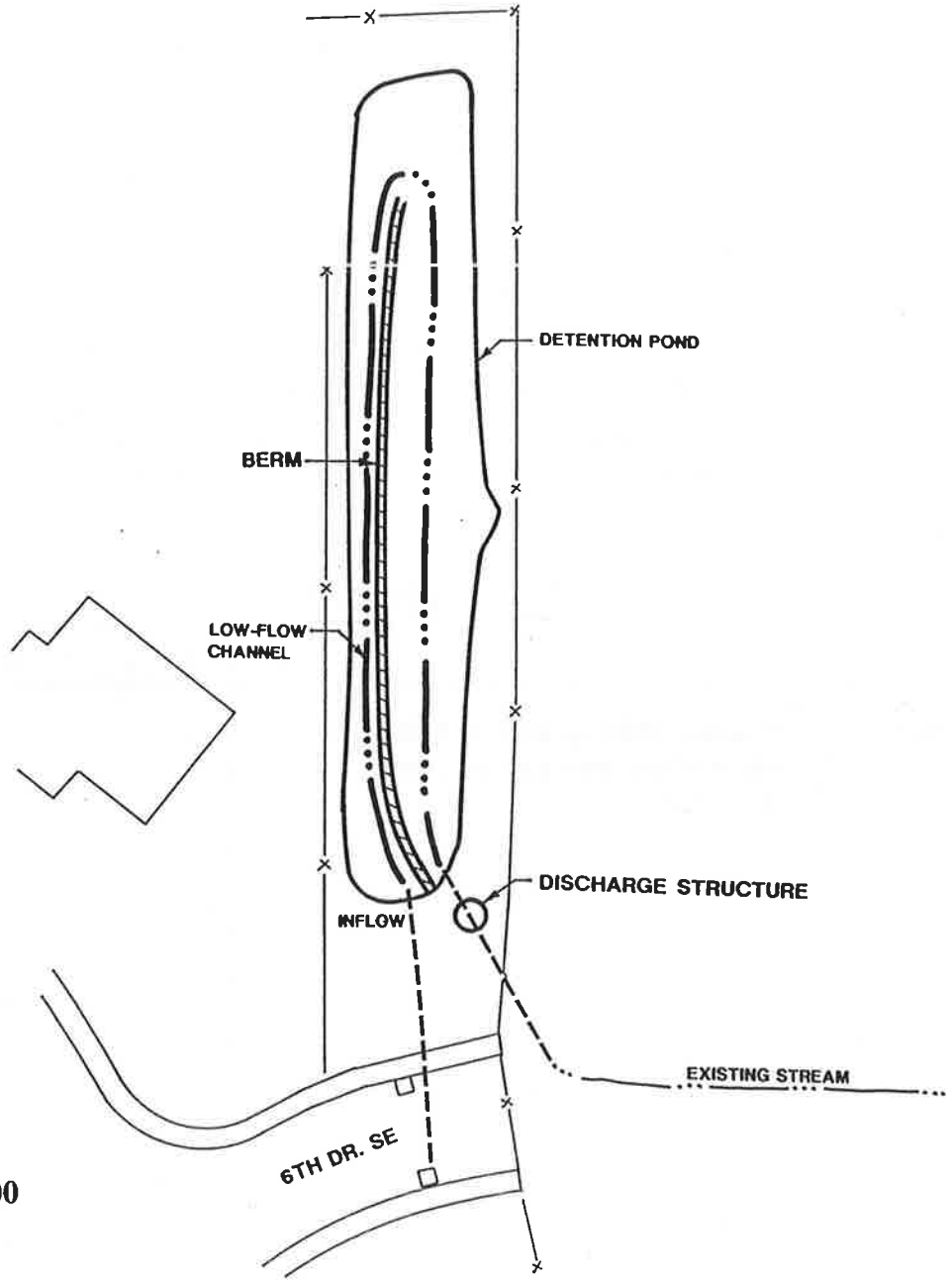
Solution: Replace existing system with larger pipes when area becomes more developed.

Cost: **$17,100**

Project D-1

Location: Crystal Ridge Detention Pond near 6th Drive S.E. and 223rd Place S.E.

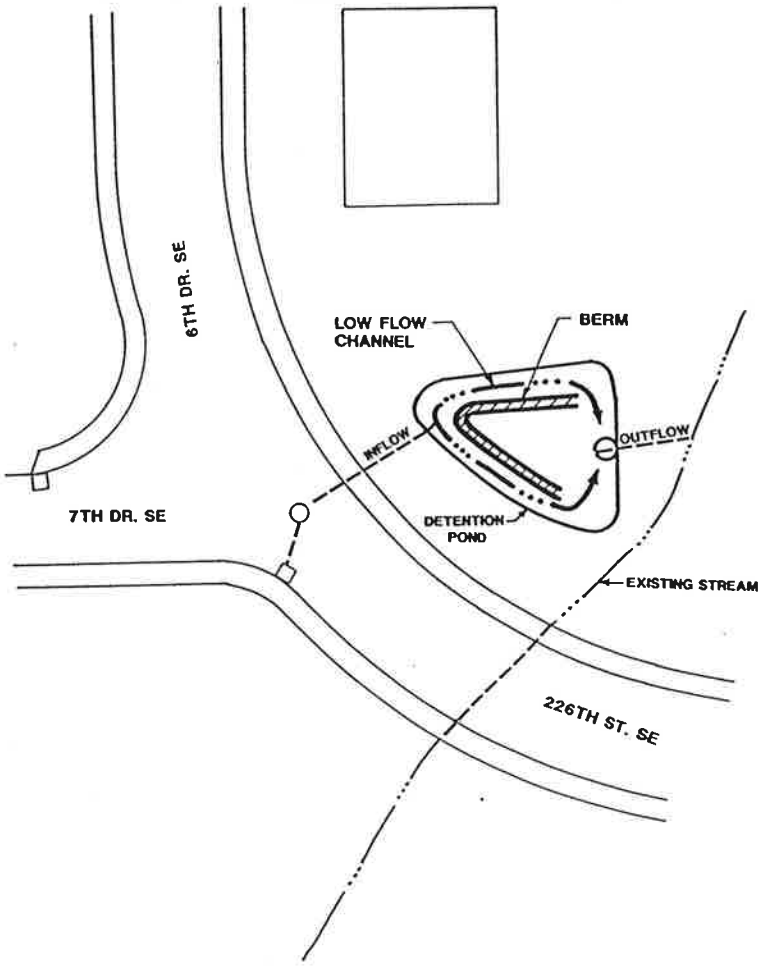
Action: Redesign and construct facility to include a low flow channel, wet pond, and discharge structure to provide staged releases for the 2-year and 25-year storm event.



Cost: **$7,800**

Project D-2

Location: Crystal Ridge Detention Pond near 226th Street S.E. and 7th Drive S.E.



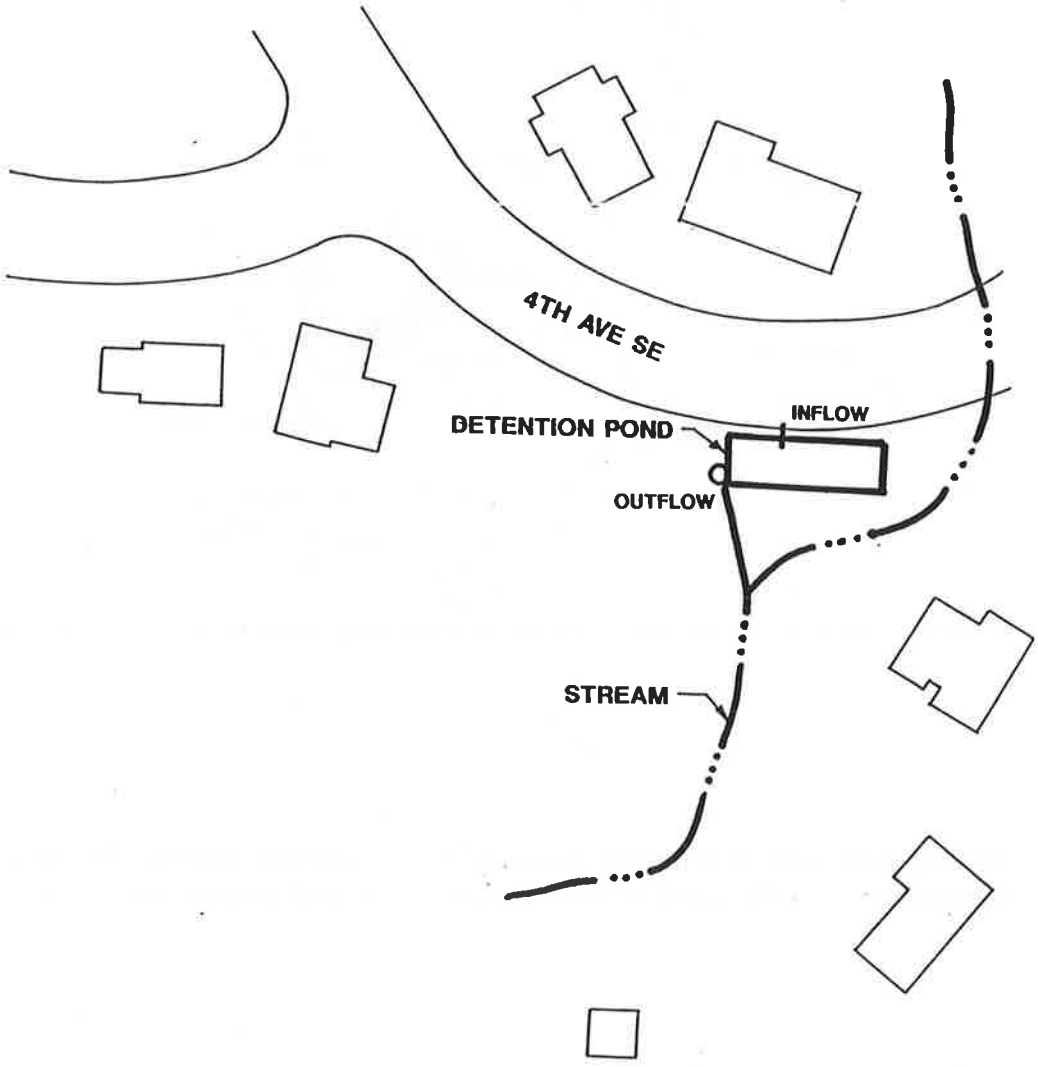
Action: Redesign and construct facility to include a low flow channel and discharge structure to provide staged releases for the 2-year and 25-year storm event.

Cost: **$4,900**

Project D-3

Location: Crystal Ridge Detention Pond near 4th Avenue S.E. and 5th Drive S.E.

Action: Redesign facility to include a discharge structure to provide staged releases for the 2-year and 25-year storm event. Excavate sediments to provide for storage of the 25-year storm event.

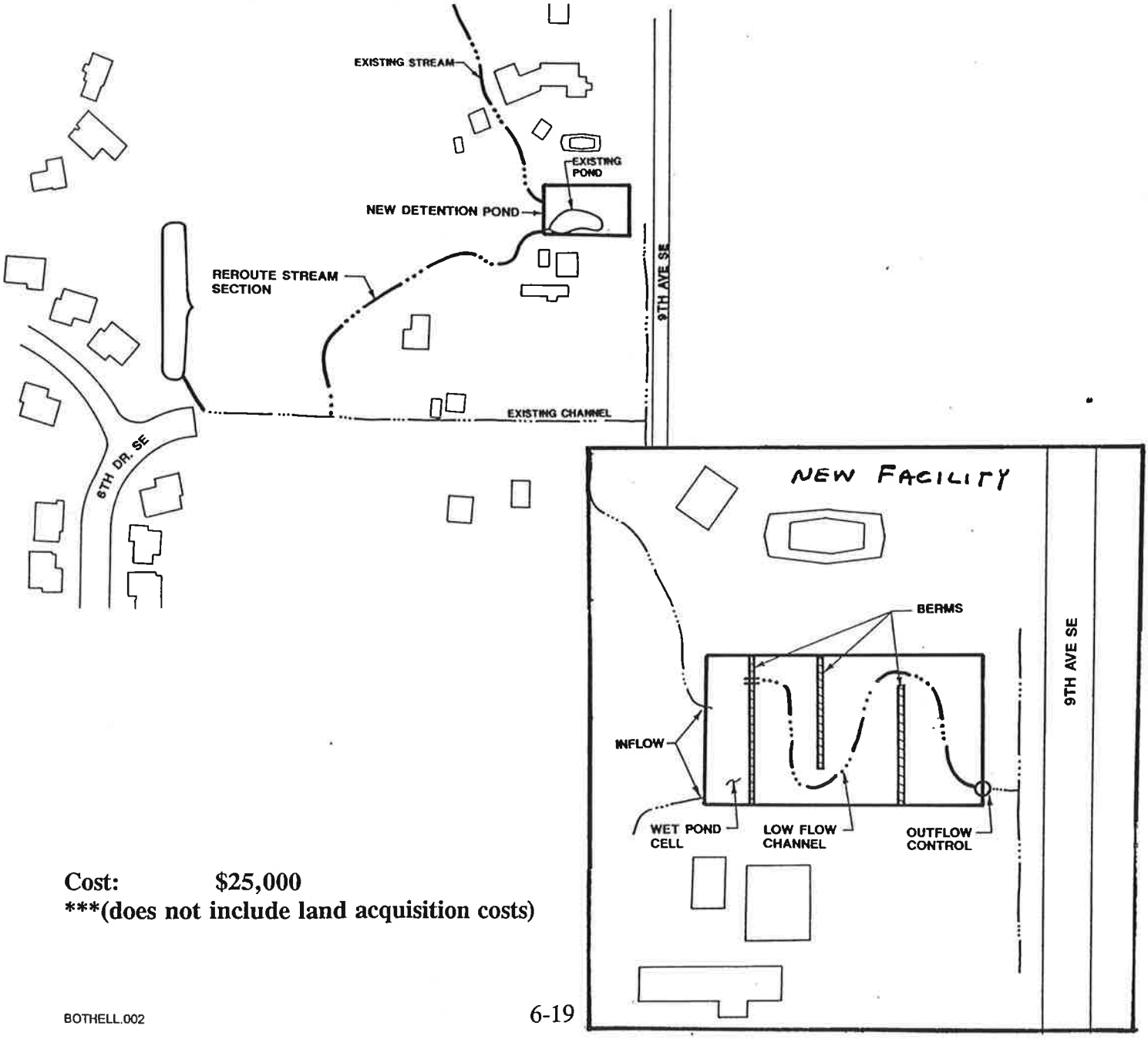


Cost: **$7,000**

Project D-4

Location: Crystal Ridge Regional Detention Pond west of 9th Avenue S.E.

Action: Acquire land necessary to construct regional facility. Reroute one section of stream to new facility. Design facility to store 100-year storm event and provide for staged releases. Include water quality features such as wet pond, low flow channels and vegetation plan into the design.



Cost: $25,000
***(does not include land acquisition costs)**

Project D-5

Location: Regional Detention Pond on Northwest corner of 228th Street S.W. and SR 527

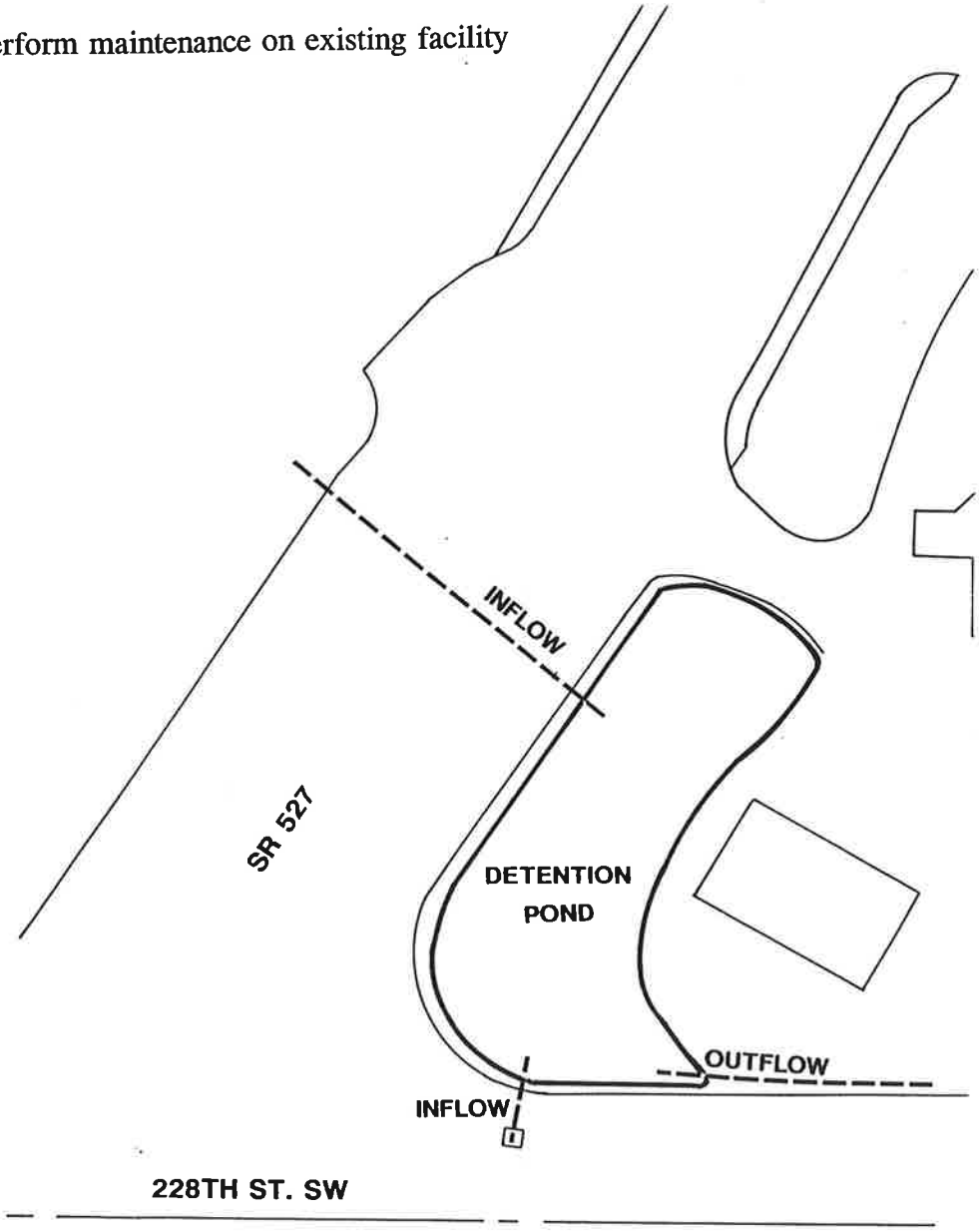
Action: Develop regional facility to include low flow channel and wet pond for water quality enhancement. Provide for storage of the 100-year storm event.

Cost: **$65,000**
*****(does not include land acquisition)**

Project D-6

Location: Canyon Park Center Detention Pond on Northeast corner of 228th Street S.W. and SR 527 and SR20

Action: Perform maintenance on existing facility

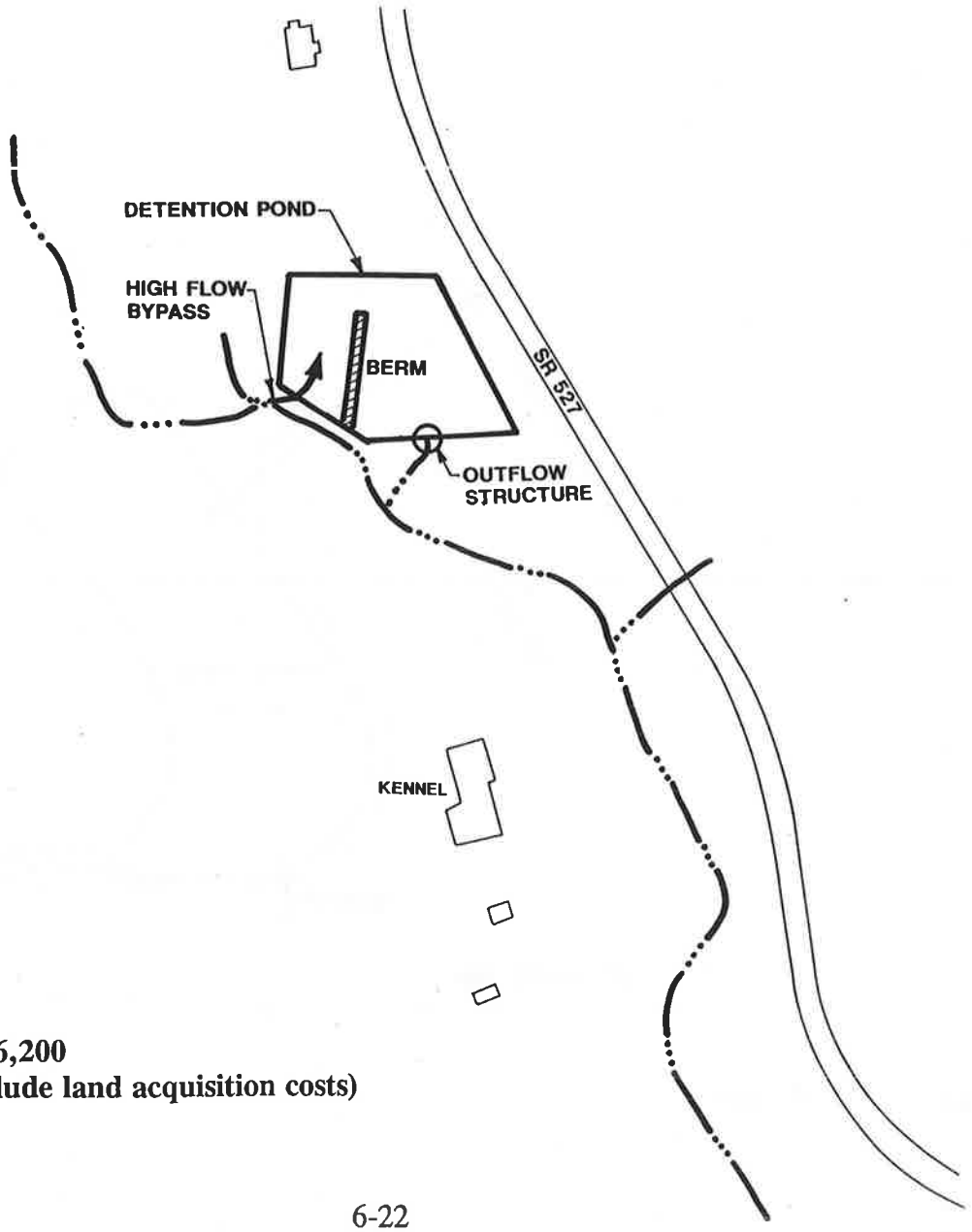


Cost: **$4,200**

Project D-7

Location: Horse Creek Regional Detention Pond adjacent to SR 527 and north of dog kennel

Action: Acquire land and design facility to provide for a 100-year level of protection. Include a high flow bypass and staged outflow structure in the design.

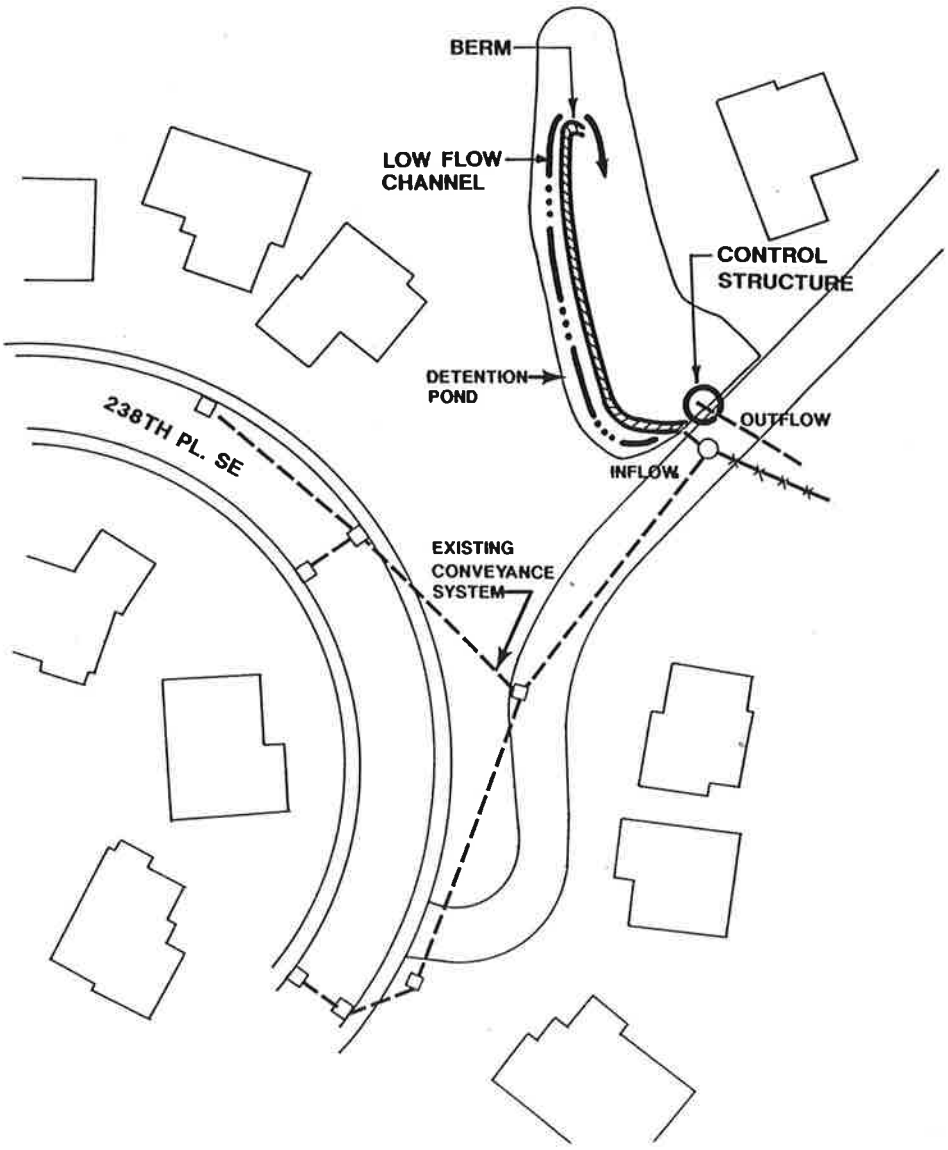


Cost: **$66,200**
*****(does not include land acquisition costs)**

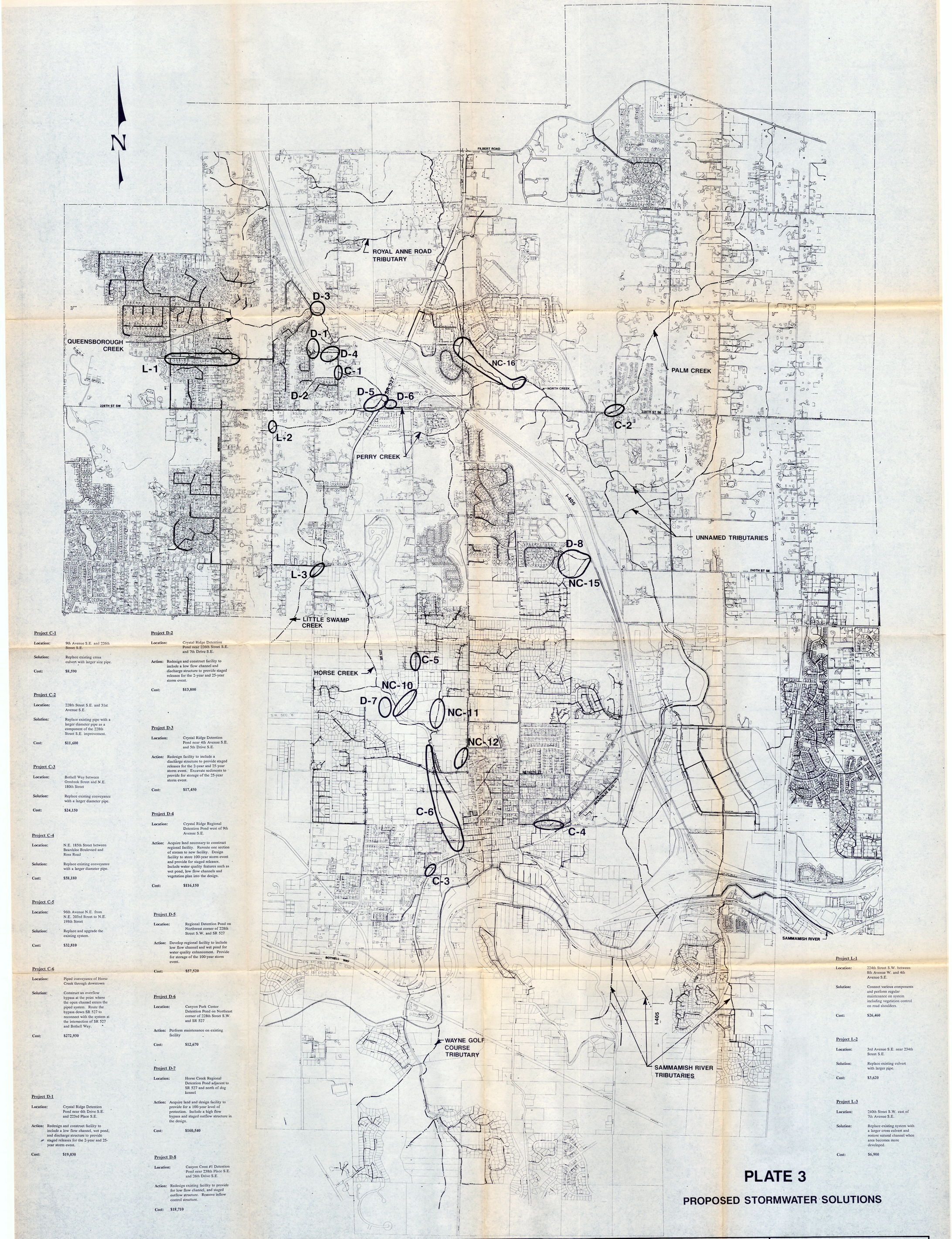
Project D-8

Location: Canyon Crest #1 Detention Pond near 238th Place S.E. and 26th Drive S.E.

Action: Redesign existing facility to provide for low flow channel, and staged outflow structure. Remove inflow control structure.



Cost: $7,600



Project C-1

Location: 9th Avenue S.E. and 226th Street S.E.

Solution: Replace existing cross culvert with larger size pipe.

Cost: $8,590

Project C-2

Location: 228th Street S.E. and 31st Avenue S.E.

Solution: Replace existing pipe with a larger diameter pipe as a component of the 228th Street S.E. improvement.

Cost: $11,600

Project C-3

Location: Bothell Way between Ormbrek Street and N.E. 180th Street

Solution: Replace existing conveyance with a larger diameter pipe.

Cost: $24,150

Project C-4

Location: N.E. 185th Street between Beardslee Boulevard and Ross Road

Solution: Replace existing conveyance with a larger diameter pipe.

Cost: $58,180

Project C-5

Location: 96th Avenue N.E. from N.E. 203rd Street to N.E. 198th Street

Solution: Replace and upgrade the existing system.

Cost: $32,810

Project C-6

Location: Piped conveyance of Horse Creek through downtown

Solution: Construct an overflow bypass at the point where the open channel enters the piped system. Route the bypass down SR 527 to reconnect with the system at the intersection of SR 527 and Bothell Way.

Cost: $272,930

Project D-1

Location: Crystal Ridge Detention Pond near 6th Drive S.E. and 223rd Place S.E.

Action: Redesign and construct facility to include a low flow channel, wet pond, and discharge structure to provide staged releases for the 2-year and 25-year storm event.

Cost: $19,030

Project D-2

Location: Crystal Ridge Detention Pond near 226th Street S.E. and 7th Drive S.E.

Action: Redesign and construct facility to include a low flow channel and discharge structure to provide staged releases for the 2-year and 25-year storm event.

Cost: $13,800

Project D-3

Location: Crystal Ridge Detention Pond near 4th Avenue S.E. and 5th Drive S.E.

Action: Redesign facility to include a discharge structure to provide staged releases for the 2-year and 25-year storm event. Excavate sediments to provide for storage of the 25-year storm event.

Cost: $17,450

Project D-4

Location: Crystal Ridge Regional Detention Pond west of 9th Avenue S.E.

Action: Acquire land necessary to construct regional facility. Reroute one section of stream to new facility. Design facility to store 100-year storm event and provide for staged releases. Include water quality features such as wet pond, low flow channels and vegetation plan into the design.

Cost: $116,150

Project D-5

Location: Regional Detention Pond on Northwest corner of 228th Street S.W. and SR 527

Action: Develop regional facility to include low flow channel and wet pond for water quality enhancement. Provide for storage of the 100-year storm event.

Cost: $57,520

Project D-6

Location: Canyon Park Center Detention Pond on Northeast corner of 228th Street S.W. and SR 527

Action: Perform maintenance on existing facility

Cost: $12,670

Project D-7

Location: Horse Creek Regional Detention Pond adjacent to SR 527 and north of dog kennel

Action: Acquire land and design facility to provide for a 100-year level of protection. Include a high flow bypass and staged outflow structure in the design.

Cost: $160,540

Project D-8

Location: Canyon Crest #1 Detention Pond near 238th Place S.E. and 26th Drive S.E.

Action: Redesign existing facility to provide for low flow channel, and staged outflow structure. Remove inflow control structure.

Cost: $18,710

Project L-1

Location: 224th Street S.W. between 8th Avenue W. and 4th Avenue S.E.

Solution: Connect various components and perform regular maintenance on system including vegetation control on road shoulders.

Cost: $26,460

Project L-2

Location: 3rd Avenue S.E. near 234th Street S.E.

Solution: Replace existing culvert with larger pipe.

Cost: $3,620

Project L-3

Location: 240th Street S.W. east of 7th Avenue S.E.

Solution: Replace existing system with a larger cross culvert and restore natural channel when area becomes more developed.

Cost: $6,900

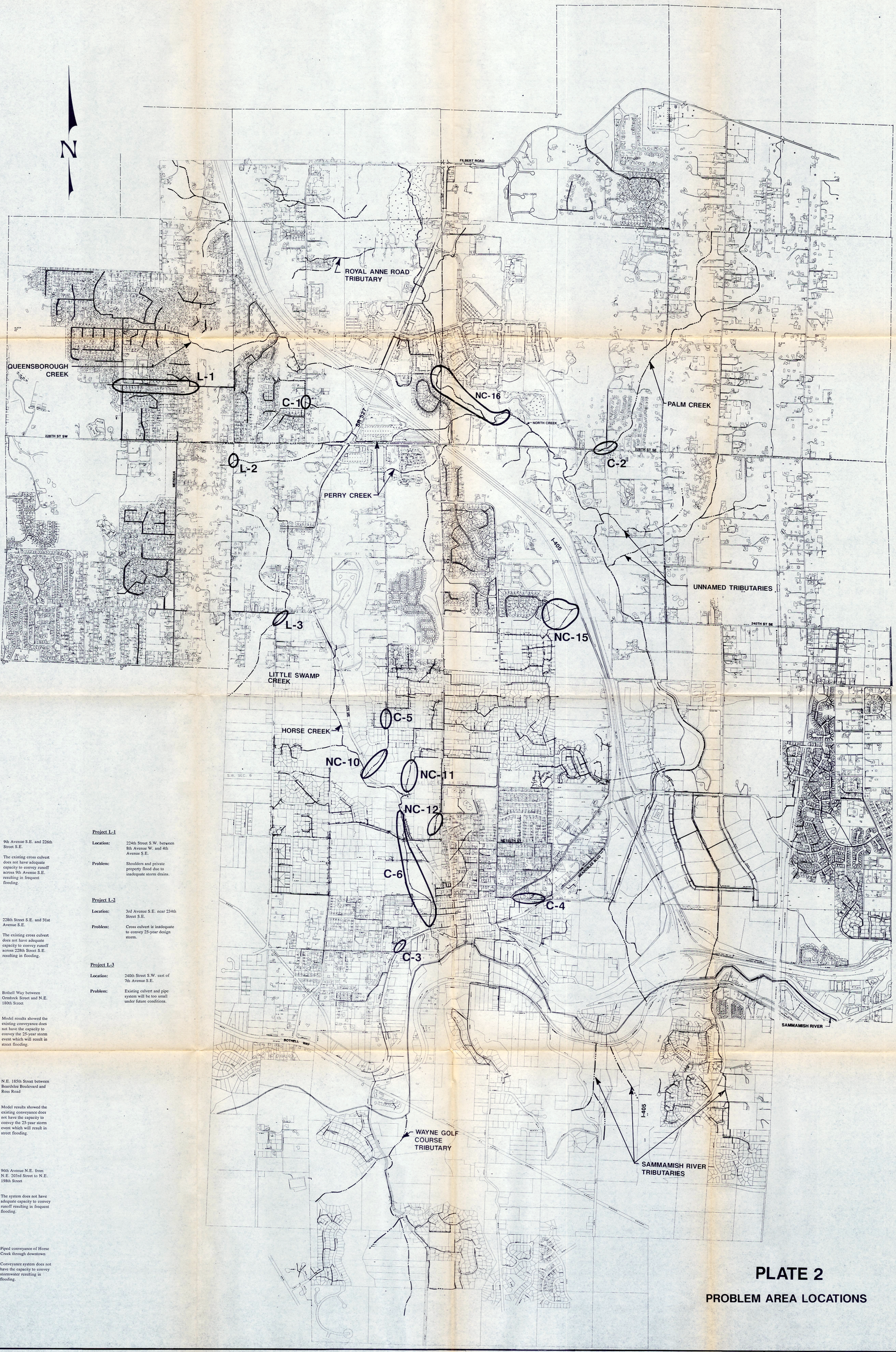
PLATE 3

PROPOSED STORMWATER SOLUTIONS

CITY OF BOTHELL COMPREHENSIVE STORM WATER MASTER PLAN

Barrett Consulting Group
10800 N.E. 8th Street, Seventh Floor
Bellevue, WA. 98004
206-455-9494 • FAX: 206-453-9470

NOVEMBER 1993



Project C-1

Location: 9th Avenue S.E. and 226th Street S.E.

Problem: The existing cross culvert does not have adequate capacity to convey runoff across 9th Avenue S.E. resulting in frequent flooding.

Project C-2

Location: 228th Street S.E. and 31st Avenue S.E.

Problem: The existing cross culvert does not have adequate capacity to convey runoff across 228th Street S.E. resulting in flooding.

Project C-3

Location: Bothell Way between Ormbrek Street and N.E. 180th Street

Problem: Model results showed the existing conveyance does not have the capacity to convey the 25-year storm event which will result in street flooding.

Project C-4

Location: N.E. 185th Street between Beardslee Boulevard and Ross Road

Problem: Model results showed the existing conveyance does not have the capacity to convey the 25-year storm event which will result in street flooding.

Project C-5

Location: 96th Avenue N.E. from N.E. 203rd Street to N.E. 198th Street

Problem: The system does not have adequate capacity to convey runoff resulting in frequent flooding.

Project C-6

Location: Piped conveyance of Horse Creek through downtown

Problem: Conveyance system does not have the capacity to convey stormwater resulting in flooding.

Project L-1

Location: 224th Street S.W. between 8th Avenue W. and 4th Avenue S.E.

Problem: Shoulders and private property flood due to inadequate storm drains.

Project L-2

Location: 3rd Avenue S.E. near 234th Street S.E.

Problem: Cross culvert is inadequate to convey 25-year design storm.

Project L-3

Location: 240th Street S.W. east of 7th Avenue S.E.

Problem: Existing culvert and pipe system will be too small under future conditions.

PLATE 2

PROBLEM AREA LOCATIONS

CITY OF BOTHELL — COMPREHENSIVE STORM WATER MASTER PLAN

Barrett Consulting Group
10800 N.E. 8th Street, Seventh Floor
Bellevue, WA 98004
206-455-9494 • FAX: 206-453-9470

NOVEMBER 1993

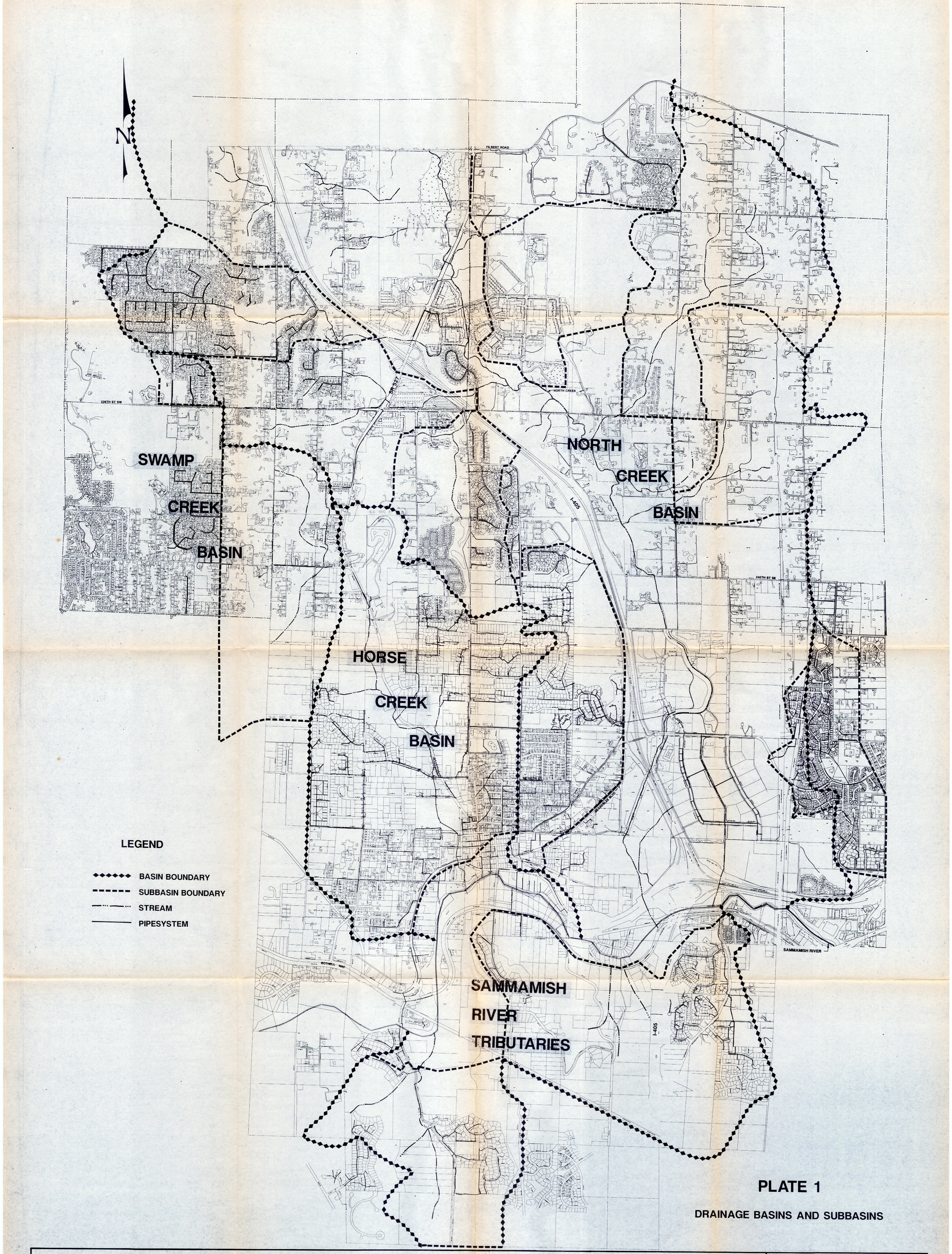


PLATE 1

DRAINAGE BASINS AND SUBBASINS

CITY OF BOTHELL — **COMPREHENSIVE STORM WATER MASTER PLAN**

Barrett Consulting Group
10500 N.E. 8th Street, Seventh Floor
Bellevue, WA 98004
206-455-9494 • FAX: 206-453-9470

NOVEMBER 1993