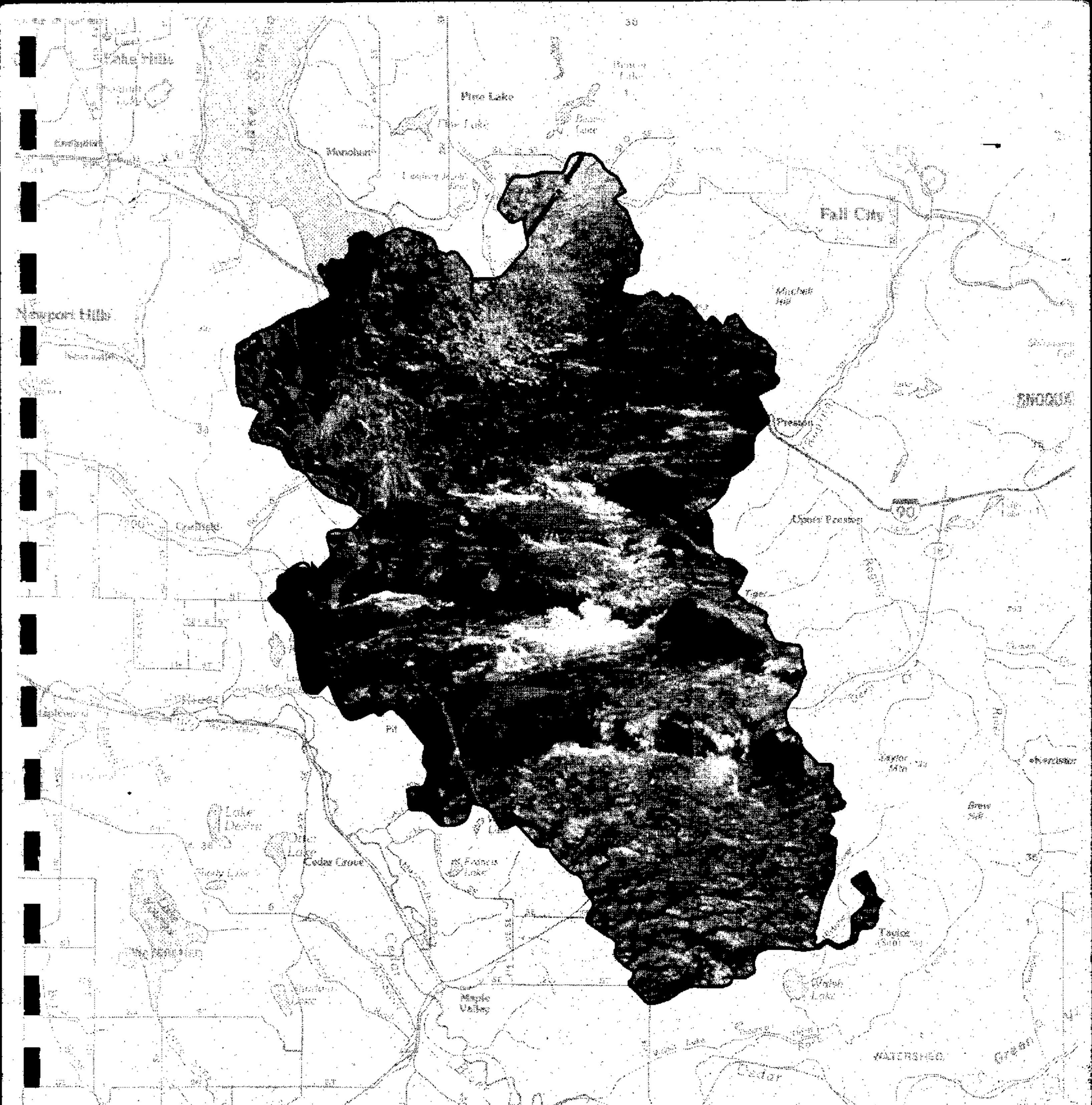

Current/Future Conditions & Source Identification Report

Issaquah Creek Basin

King County Surface Water Management

Everyone lives downstream

CURRENT/FUTURE CONDITIONS
AND SOURCE IDENTIFICATION REPORT

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Chapter 1

Executive Summary

CHAPTER 1: EXECUTIVE SUMMARY

1.1.0 INTRODUCTION

This report documents the condition of surface waters in the Issaquah Creek basin planning area, comprised of the Tibbetts Creek basin and the eight sub-basins of the Issaquah Creek basin. The report assesses current and future problems in the planning area's streams, wetlands, and, to a lesser extent, lakes. The report also predicts how surface water conditions may change in the planning area as changes in land use occur, particularly if those changes are allowed to take place in the absence of corrective actions.

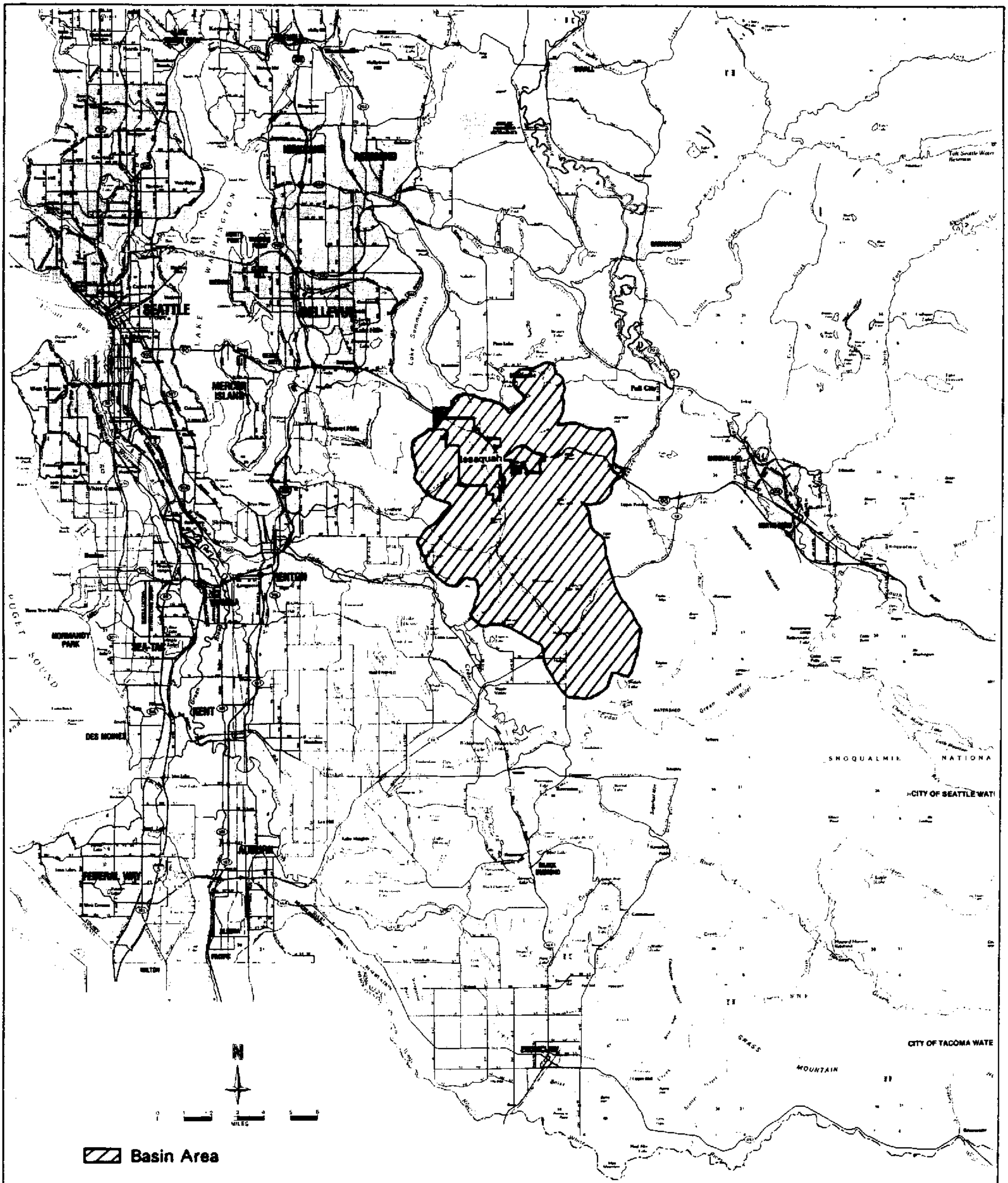
This report, detailing surface water conditions, represents the second of three major steps toward managing surface water in the Issaquah basin planning area. The first step, reconnaissance, occurred in 1986 and 1987, when Surface Water Management Division field biologists, geologists, engineers, and land use planners performed an initial assessment of conditions in the planning area's sub-basins. These field teams' findings are contained in the three-volume set of the Basin Reconnaissance Program Reports, published by King County Surface Water Management Division in 1987.

The present report contains the study findings from an in-depth field investigation and simulation modeling, conducted by interdisciplinary teams in the sub-basins of the Issaquah Creek planning area, during fall 1990 and spring 1991. These study findings from engineers, biologists, soils scientists, and land use planners are intended to provide the essential information needed to begin development of a comprehensive Issaquah Creek Basin Plan and a Nonpoint Action Plan. The preparation of these documents will represent the final step in the development of a surface water management plan in the planning area. The final management plan will be published in late 1992.

A draft of the conditions report was reviewed by all cooperating entities and advisory boards in spring 1991. Reviewers comments were used in preparing this final report during July and August 1991.

1.2.0 BASIN OVERVIEW

The Issaquah Creek Basin planning area encompasses 61 square miles in central King County (Figure 1-1) and incorporates the Tibbetts Creek basin, as well as eight sub-basins of the Issaquah Creek basin system: North Fork Issaquah, East Fork Issaquah, Fifteenmile, McDonald, Holder, Carey, Middle Issaquah, and Lower Issaquah Creeks (Figure 1-2). The Tibbetts Creek drainage is not tributary to Issaquah Creek but rather is located one mile west of Lower Issaquah Creek. The Tibbetts Creek basin rises from near sea level at the south end of Lake Sammamish



ISSAQUAH BASIN VICINITY MAP

Issaquah Creek Basin Planning Area

Figure 1-1

to an elevation of over 3000 feet on Tiger Mountain. It is bounded to the east and south by the largely rural communities of Preston and Hobart, respectively. To the north, the lower reaches of the mainstem creek flow through a rapidly growing urban center, the City of Issaquah. Cougar Mountain forms much of the western boundary. Because of its small size and its proximity to the larger Issaquah Creek basin, Tibbetts Creek basin is occasionally referred to as a sub-basin in this report.

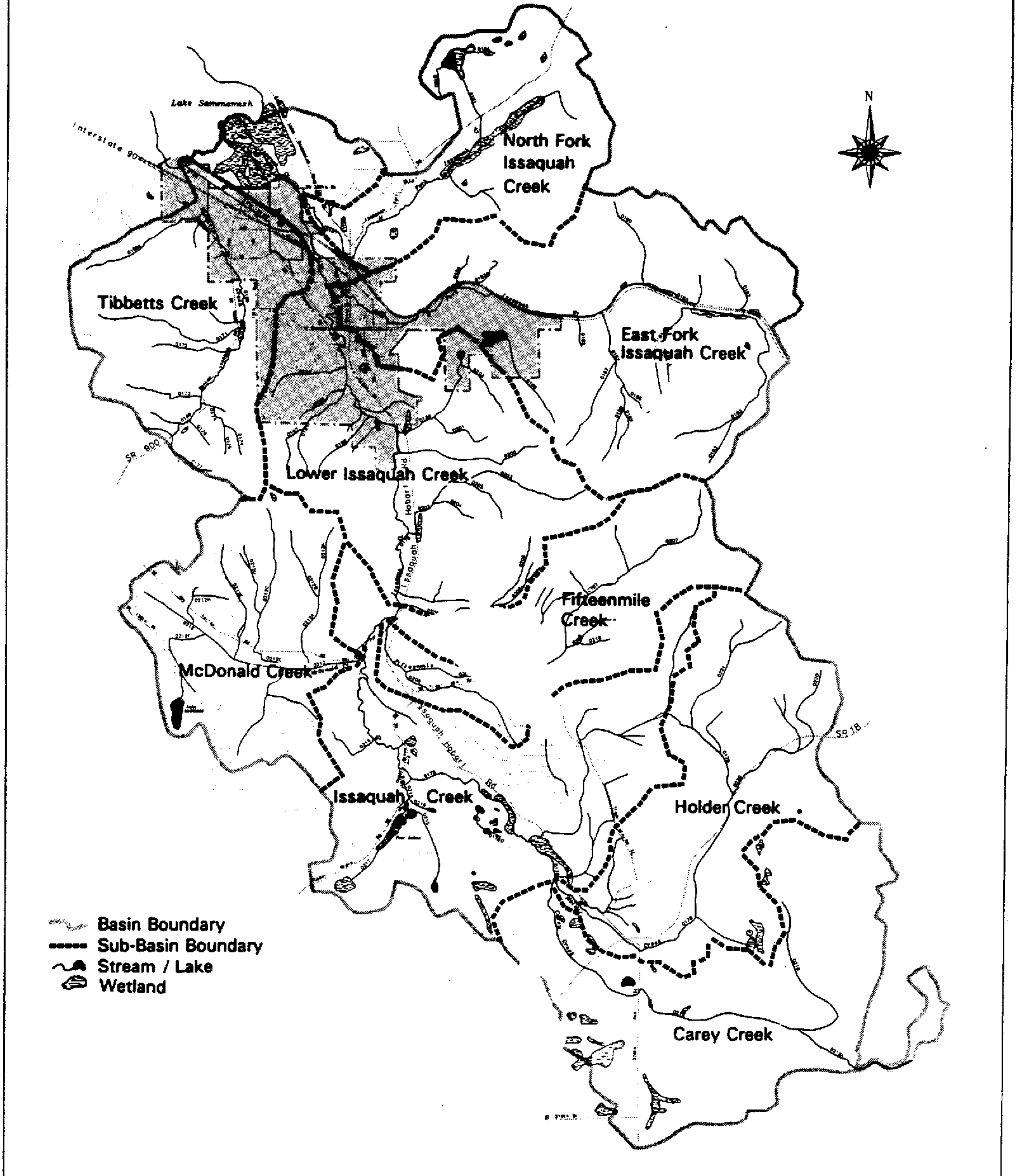
The Issaquah Creek planning area is very diverse in both its natural features and land uses. For example, the stream systems in the planning area basin are a regional resource for salmonid fish production. In addition to the natural spawning of at least seven different salmonid species, the Issaquah State Hatchery harvests millions of salmon eggs each year. The planning area also has a mix of land uses including parks, forestry, mining, livestock farming, and residential, commercial, and light industrial development. The City of Issaquah, located in the planning area's northwestern end, overlaps both the Tibbetts and Issaquah Creek basins.

The surface water systems in the Issaquah Creek basin planning area include a wide variety of streams, wetlands, and lakes that range in condition from almost pristine to very degraded. Some exhibit an advanced degree of degradation as a result of historical and current land use activities. At present, land use in the basin is predominantly rural, with approximately 80 percent of the basin planning area covered by second growth forests.

Tibbetts Creek basin and the Issaquah Creek sub-basins (Figure 1-2) are all distinctive from one another. The two Issaquah basin headwater tributaries, Carey and Holder Creeks, are characterized by largely undeveloped forested watersheds with steep, upper reaches and scattered livestock farming in their lower gradient, downstream reaches. In addition, both systems show residual impacts from historical land use activities, including mining and logging. Both also are capable of supporting major salmonid fisheries, in part due to the presence of relatively stable and diverse habitat conditions.

Tibbetts Creek is a steep gradient system that has also been impacted by historical and current mining activities, livestock keeping, and, more recently, by suburban development. As a result it has significant turbidity, sedimentation, and flooding problems particularly in its lower reaches prior to entering Lake Sammamish. Much of the fish habitat in the stream has been destroyed by sedimentation.

McDonald Creek is a relatively low gradient system; the drainage is characterized by abundant wetland areas that have experienced filling and draining for residential development in recent years. The McDonald Creek valley has historically been the recipient of sediment from the steep mountain tributaries that drain to it. This process has been escalated by upstream development, forestry, and construction in the floodplain, all of which have accelerated flooding in the valley below.



SUB-BASIN & STREAMS MAP

Issaquah Creek Basin Planning Area

Figure

1-2

Middle Issaquah Creek is a moderate-gradient system that supports a regionally significant salmonid fishery in spite of low-level land-use impacts from livestock farming, road building activities, and floodplain encroachment. The Middle Issaquah Creek sub-basin contains a major zone of channel migration, a natural process whose impacts are problematic if development encroaches into the area of migration. In this sub-basin, this encroachment is most damaging in the Four Creeks Ranch area. Localized flooding has been another problem in several locations.

Fifteenmile Creek, the smallest and steepest of the sub-basins, contains several nearly pristine reaches and several reaches that have been destabilized by recent residential development and forestry activities.

Lower Issaquah Creek is a large and varied stream system with a mean annual flow of approximately 130 cfs. The stream channel has been significantly constrained in its floodplain by the rapid growth of the City of Issaquah. As a result of building activity in the immediate floodway, and the natural tendency of the channel to migrate in its lower reaches, major flooding of downtown Issaquah occurs at relatively regular intervals. In spite of this fact, the lower stream system provides important open space and scenic amenities to City residents. It also provides an important salmonid spawning area and migratory pathway for both hatchery and wild fish stocks.

The headwaters of North Fork Issaquah Creek are located in the dense residential area of Klahanie and the forested slopes of Grand Ridge. The largest and most diverse wetland systems in the Issaquah Creek basin planning area occur in the North Fork drainage. Residential, commercial, and mining development have partially degraded these wetlands and associated streams. Flooding has been a problem in the flat lower reaches.

East Fork Issaquah Creek is a steep mountainous watershed that has been heavily impacted by construction of a major interstate highway (I-90) through the stream corridor. Salmon still utilize the stream system all the way to Preston. The lower mile of the East Fork is significantly constrained by residential, commercial, and industrial structures in the floodway and floodplain. Flooding is causing damage to these structures.

The Issaquah Creek basin planning area is still largely rural in character, with many pristine portions seemingly untouched by human activity. To some extent, this character is protected for the future, with the majority of the Issaquah Creek planning area designated for rural, open space, or forest production uses in the 1985 King County Comprehensive Plan. Nevertheless, the significant amount of development that already exists could expand under current zoning in several critical stream reaches. If future development were maximized under existing zoning, floodway encroachment (and subsequent flooding damage), and degradation of water quality and habitat in stream reaches that are still relatively intact could threaten the health of the entire system.

The ability of the system to provide the beneficial uses it currently provides to area residents would become increasingly questionable. For example, under modeled future unmitigated land-use conditions, runoff is predicted to increase by 14 to 78 percent in different sub-basins, with the largest flow increases occurring in the North Fork and McDonald Creek sub-basins. Most of the undeveloped urban zoning outside of the City of Issaquah is concentrated in these two sub-basins.

Future conditions in the resource-rich system of the Issaquah basin planning area are difficult to predict. If existing trends in land use, habitat destruction and floodplain encroachment continue, the future options for surface waters in the basin may be fairly bleak. This is particularly true given the localized severity of current problems and the value of existing natural resources that stand to be destroyed. Appropriate management and mitigation programs, however, could preserve and help restore the rich and complex surface waters in both Tibbetts and Issaquah basins. Such programs must be developed with a thorough understanding of the land surface processes that have been, and will continue to be, active in the basins, and with a recognition of the need to protect the system from additional impacts that localized areas of intense development have already had on parts of the stream system.

1.3.0 CURRENT AND FUTURE CONDITIONS

The impacts of human development are second only to the effects of glaciation on the surface water systems in the Issaquah basin planning area. The most notable of these anthropogenic disturbances are the filling activity across the Issaquah valley that resulted from construction of I-90; development of the Cedar Hills solid waste disposal site; commercial and residential development; increased erosion and sedimentation from all development activities; and potential impacts from groundwater extraction on the baseflows in North Fork and mainstem Issaquah creeks. In addition, drinking water from the shallow ground water aquifer is very susceptible to contamination from adjacent development and the pollutants associated with that development.

Past patterns of logging, clearing, and residential development activities have reduced the stability of many of the stream channels through the removal of large woody material and by increases in stormwater runoff. Historically these woody materials helped to stabilize the channels. These changes have resulted in upland erosion, valley floor deposition, problems due to channel migration, and infilling of stream channels. Extreme examples of destabilized streams are found in tributary 0212E in the McDonald Creek sub-basin and in tributaries 0174 and 0169A in the Tibbetts Creek basin. A good example of valley deposition of eroded materials from upland areas is found in the Sunset Valley Farm development from tributary 0212E and No Name and Nudist Camp Creeks in the Middle Issaquah sub-basin. Channel migration problems are most pronounced in the Four Creeks Ranch area of the Middle Issaquah sub-basin and in the Sycamore area in the Lower Issaquah sub-basin. Erosional processes in upstream areas are causing channel infilling. Problems resulting from such processes are

documented in the City of Issaquah on both the lower mainstem of Issaquah Creek and on Tibbetts Creek. The destabilization of the channels has also reduced the diversity of fish habitat available for salmonids and other aquatic organisms.

Water quality problems in lower Tibbetts and Issaquah Creeks are exhibited by repeated violations of state standards for fecal coliform and enterococcus during baseflows. Nutrient and dissolved oxygen concentrations have also violated state standards in Tibbetts Creek. Water quality samples taken during stormflow events in the Tibbetts, McDonald, and mainstem Issaquah Creek sub-basins in 1990 had elevated concentrations of suspended solids, fecals, nitrogen compounds, and total phosphorus. Almost annual fish kills on the North Fork Issaquah Creek appear to be linked to nonpoint contaminants present in the City of Issaquah storm drain system. Phosphorus loading to Lake Sammamish could increase up to 57 percent under future build-out conditions. In the future, phosphorus from this basin could form up to 70 percent of the total lake phosphorus loading. Underground storage tanks (123 in number) located in various locations in the basin pose a potential (and recently realized) threat to contamination of surface and ground water.

Due to the steep topography, the Tibbetts and Issaquah basins have fewer wetlands than other, similarly sized basins in King County. Except for some streamside wetlands, most area wetlands do not provide significant water quality benefits to stream channels, since they are far off-channel. Notable exceptions to this are the large riparian wetlands in the North Fork drainage. Under future land use conditions, many wetlands will receive a several-fold increase in pollutant loadings and may take on the characteristics of degraded urban wetlands.

The future regional stature of the planning area as a major producer of salmon could be threatened due to continued habitat loss and water quality problems. Already, the kokanee species is threatened in the Lake Sammamish system. Loss of in-stream habitat diversity is already widespread, primarily as a result of a lack of large woody debris that provides cover, channel stability, and pools. The destabilization of channels in upstream, non-salmonid areas is having a negative impact on downstream salmonid areas. For example, the infilling of downstream areas in Tibbetts Creek and in tributary 0212E to McDonald Creek is due to instability in upstream channels in these sub-basins.

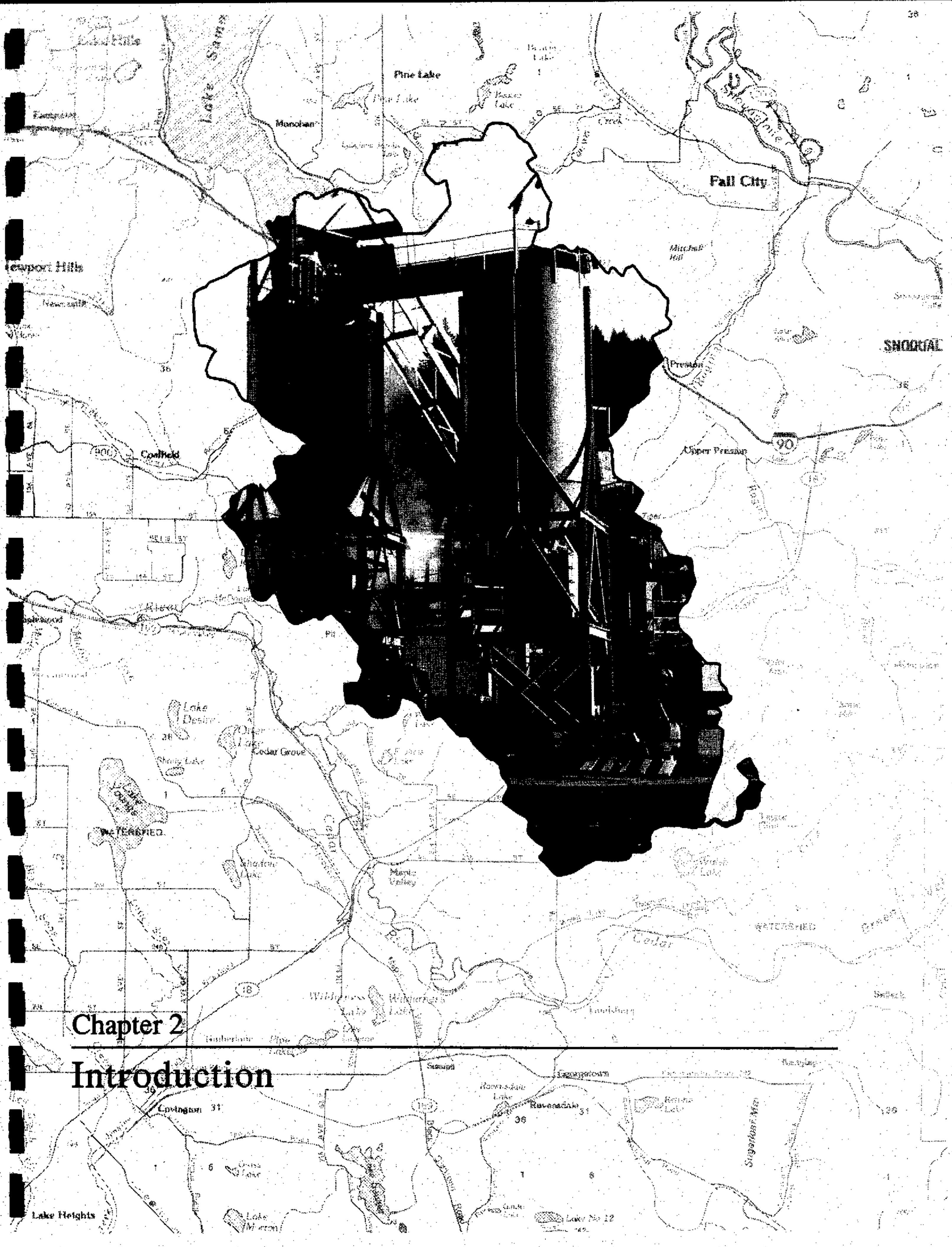
Probably the most visible and best documented problem in the Tibbetts and Issaquah Creek basins is the systemwide flooding, which has caused major damage to public and private property, particularly in the City of Issaquah. The flatter areas in the basins, where the most intense development has occurred, are frequently also part of the active floodplain, wetland, or sediment-deposition zones of Tibbetts and Issaquah Creeks. Development in these areas has increased in recent years, and so when a large storm occurs, it impacts more structures.

Current and future estimates of existing structures that flooded along the mainstem of Issaquah Creek suggest that in a worst-case scenario, residential flooding could increase as much as 60 percent in the next few years, from 87 to 139 homes. Flooding of commercial and multifamily

structures could increase 88 percent, from 24 to 45 structures. Flooding of public facilities could also increase from 1 to 3 structures. The floodplain could also experience an increase in width of up to 500 feet in the North Fork Issaquah, Lower Issaquah, Middle Issaquah, and McDonald Creek sub-basins. In addition, at least 16 public road bridges are predicted to be overtopped by floodwater during a future 100-year storm, compared to the 10 public road bridges currently affected.

1.4.0 CONCLUSION

The Tibbetts and Issaquah Creek basins, together composing the Issaquah Creek basin planning area, include unique and regionally significant surface water resources. Past land use activities, such as logging, mining, the removal of stream buffers, the clearing of steep erosion-prone areas, the removal of woody debris from streams, and development in areas prone to erosion, sedimentation, and flooding have all contributed to problems in the basin. These problems (flooding, erosion, sedimentation, declining water quality, and habitat degradation) will all continue to increase in number of sites and in severity if land management practices do not change. Appropriate basin management practices can help protect these regionally significant existing resources and reduce future degradation. During the next year a comprehensive basin management program will be developed through preparation of the Issaquah Creek Basin Plan and Nonpoint Action Plan. These will propose methods to reduce and mitigate existing problems and prevent future ones. Their shared goal is to allow the beneficial uses of surface waters in these important basins to be enjoyed for many generations to come.



Chapter 2

Introduction

CHAPTER 2: INTRODUCTION

2.1.0 PURPOSE

The Current/Future Conditions and Source Identification Report for the Issaquah Creek basin planning area is comprised of the Tibbetts Creek basin and the eight sub-basins of the Issaquah Creek basin. The report assesses current and future problems in the planning area's streams, wetlands, and, to a lesser extent, lakes. The report recognizes those areas still in excellent condition but also predicts how surface water conditions may change in the planning area as changes in land use occur, particularly if those changes take place in the absence of corrective actions.

The anticipated audiences of this conditions report include the professional planning team who compiled it and who will use it extensively during the solutions phase; King County and City of Issaquah staff who will use it for development review and other planning activities; and other agencies, private consultants, and the general public for whom the report will be a varied reference and resource. This document will also be used for State Environmental Policy Act (SEPA) determinations for projects in the Issaquah Creek basin planning area.

2.2.0 REPORT DEVELOPMENT PROCESS

The development of this report began in 1988 with a precipitation, streamflow, and water quality data collection effort that continues to the present date. Public and agency scoping meetings were conducted in 1990 to aid in compiling as many of the surface water related problems as possible for the basin planning area. These problems then were analyzed by specialists in major disciplines (geology, biology, hydrology, water quality, and land-use planning) for each basin and sub-basin comprising the Issaquah basin planning area. Their findings and assessments were presented initially in a draft conditions report, published by the Surface Water Management Division in May 1991. The draft document was reviewed by all cooperating entities and advisory boards during May and June. Comments and suggestions emanating from this review process were used to prepare this final conditions report during July and August 1991.

This final conditions report also contains several features that were not part of the original draft. One of these features is a more extensive analysis of flooding problems in the basin, the scope and magnitude of which required additional time and personnel to investigate and document than were permitted during the original study. The second feature is a sub-basin section that assembles major problem and resource data by sub-basin from each of the disciplinary chapters. This dual approach--presentation of findings both by disciplines and by sub-basin--is intended to facilitate the development of solutions during the basin plan stage. A third feature is the

addition of appendices containing detailed tables of flooding, flow, and habitat data for the Issaquah Creek basin planning area.

2.3.0 DESCRIPTION OF BASIN PLANNING AREA

This report, the Issaquah Creek Basin Current/Future Conditions and Source Identification Report, is concerned with the Issaquah Creek basin planning area. This geographic area encompasses 61 square miles in central King County, primarily south of Lake Sammamish, north of the community of Hobart, east of Cougar Mountain, and west of the community of Preston. The planning area is traversed in the north by Interstate 90 (I-90) and in the south by State Highway 18 (SR 18). The Issaquah basin is topographically quite varied. It rises from 30 feet of elevation at its mouth at Lake Sammamish, near the City of Issaquah, to 3000 feet on Tiger Mountain, the highest point in the Issaquah Alps.

The Issaquah basin planning area is composed of (from the headwaters down to Lake Sammamish) Holder, Carey, Middle Issaquah, Fifteenmile, McDonald (sometimes called Mason Creek), East Fork Issaquah, North Fork Issaquah, Lower Issaquah Creek sub-basins, and Tibbetts Creek Basin (Figure 1-2). All of these streams drain an area known as the Issaquah Alps with numerous trails and wildlife. The area provides a home to a regional salmon resource, and to a community of people who value the basin's natural resources, wildlife, and quality of life.

Each of the sub-basins and streams are described in more detail within the report. With the exception of Tibbetts Creek and locally severe flooding elsewhere they still exhibit large areas of good habitat and relatively few problems. Many of the side streams and main tributaries are fast moving mountain streams draining steep terrain. When these streams reach the valley floor they slow and create alluvial fans, sediment accumulation, and floodplain areas that become inundated during high flows.

In Chapter 5 (Hydrology), eight sub-basins instead of nine are described. For the hydrologic analysis, Holder and Carey Creek sub-basins were combined and evaluated as the Upper Issaquah Creek sub-basin.

2.3.1 Current and Future Land Cover

The Issaquah Creek basin has a diverse mix of land-use types, ranging from wilderness to intense commercial areas. The Issaquah basin includes one incorporated area, the City of Issaquah, and parts of four community planning areas, East Sammamish, Newcastle, Snoqualmie, and Tahoma-Raven Heights (Figure 2-1). The King County 1985 Comprehensive Plan designates land use in the majority of the basin as rural. Urban designated areas occur near Yellow lake in the North Fork Issaquah sub-basin, near Lake McDonald in the McDonald Creek

Conservation Service maps, and field investigations.

The future land use map was derived by maximizing existing zoning both in the City of Issaquah and King County. The only deviation from this was the Grand Ridge area. Various development proposals are being discussed so that although this area is currently zoned rural, it was modeled at higher land use densities for the future in order to evaluate potential future impacts if the area were to develop. Sources of information for this future scenario came from the current (1989) land use map, City of Issaquah zoning map (1989), King County Comprehensive Plan (1985), the East Sammamish Community Plan before the 1990 adoption of interim zoning, the 1984 Tahoma/Raven Heights Plan and zoning designations, the Snoqualmie Community Plan and zoning (1989), and the Newcastle Community Plan and zoning designations (1983).

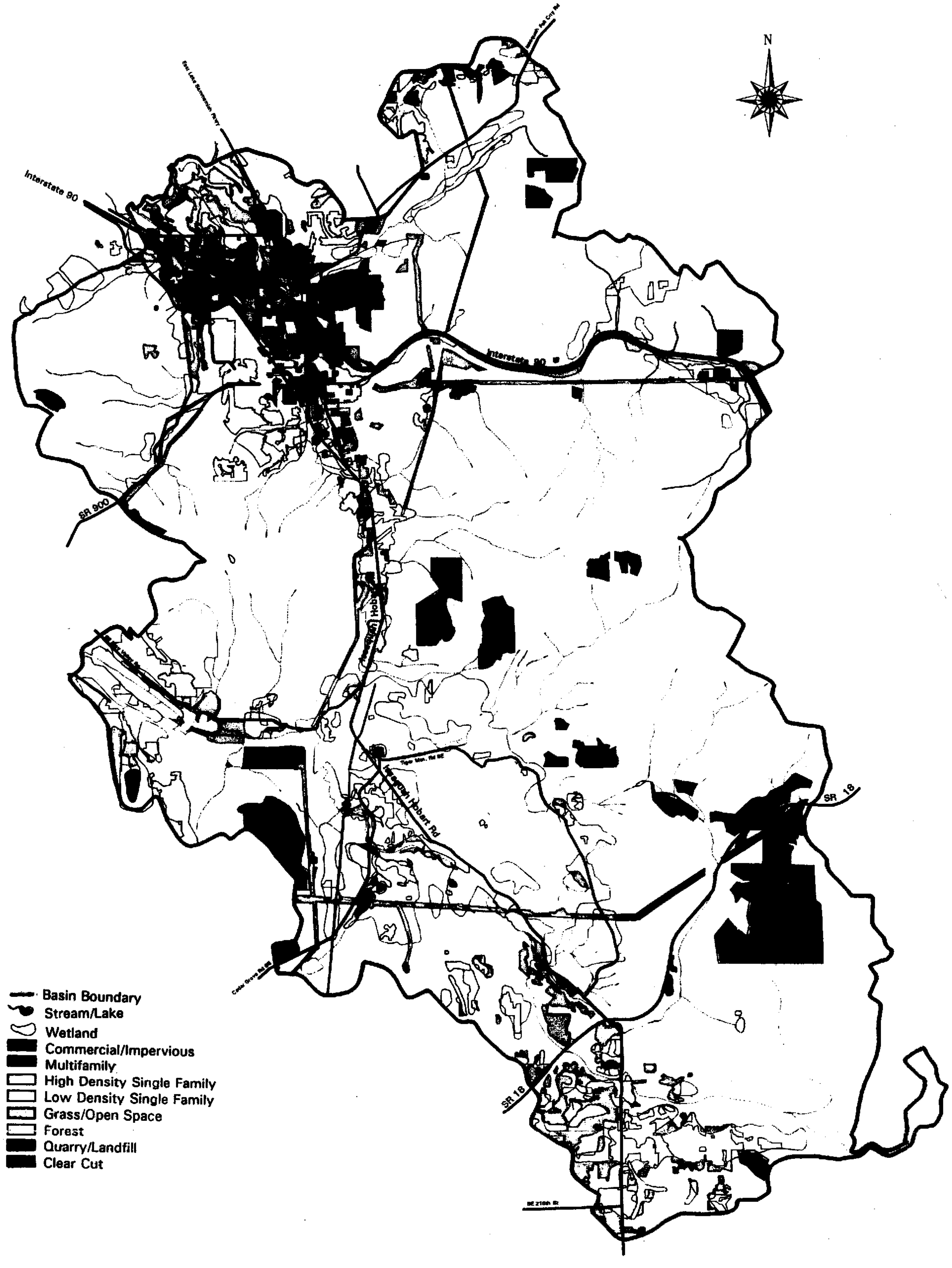
For comparison with future land cover changes, the 1989 land cover was considered the baseline current land cover (Figure 2-2). The map of future land cover presumes a worst-case land-use scenario, namely the highest foreseeable level of development, resulting in the highest potential runoff (Figure 2-3). To better illustrate the natural hydrology of the basin, this scenario assumes no onsite or regional detention is added by future development. Additional future land-use options with various levels of mitigation will be modeled as part of the solutions analysis phase. To account for development limits imposed by the County or City sensitive areas regulations, development is assumed to occur at 20 percent of the underlying density allowed by zoning in landslide areas and where slopes exceed 40 percent. Due to the limits of mapping resolution, stream and wetland buffers adopted in the August 1990 King County Sensitive Areas Ordinance amendments were not considered in the density calculations.

2.4.0 KEY FINDINGS

Each chapter in the conditions report contains a section that lists the key findings of the chapter. These sections summarize the outstanding problems or conditions in the system within each discipline. Some of these findings are quite revealing about the nature of the problems and resources in the basin and suggest early action to address them. For example, the sheer number of structures affected by flooding, identified in flood analysis (Chapter 6) have already generated a preliminary analysis of flooding problem solutions by Surface Water Management staff.

Another significant finding is the drinking water supply wells' vulnerability to contamination near Issaquah. Other key findings are that the Issaquah stream system is underutilized for salmonids above the hatchery, that 80 percent of the basin is still forested, and that Tibbetts Creek's sediment problems are the worst in the planning area.

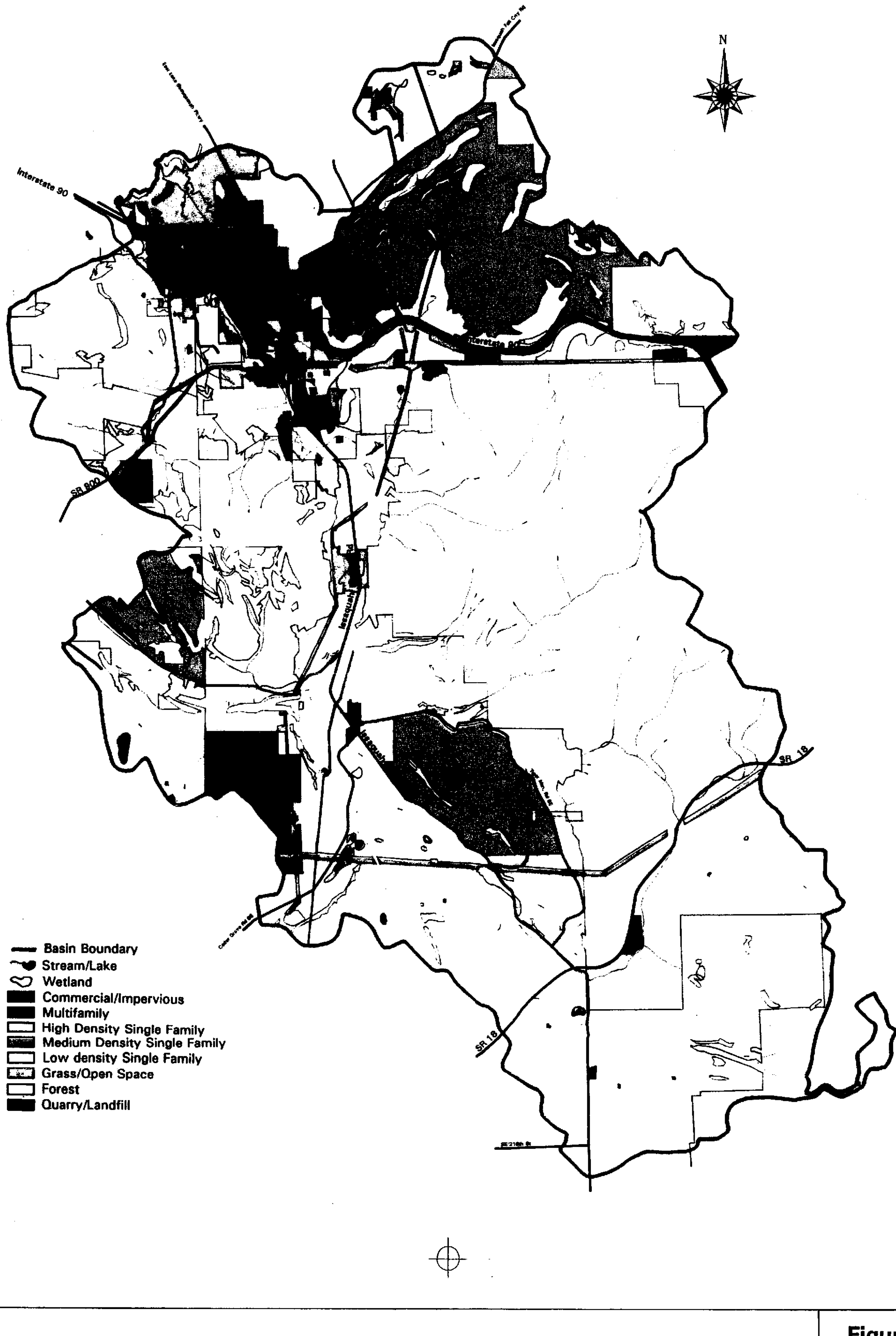
Key findings, and the causes and solutions associated with them, will be treated during the solutions phase of the ensuing basin planning process.



1989 LAND USE/LAND COVER

Issaquah Creek Basin Planning Area

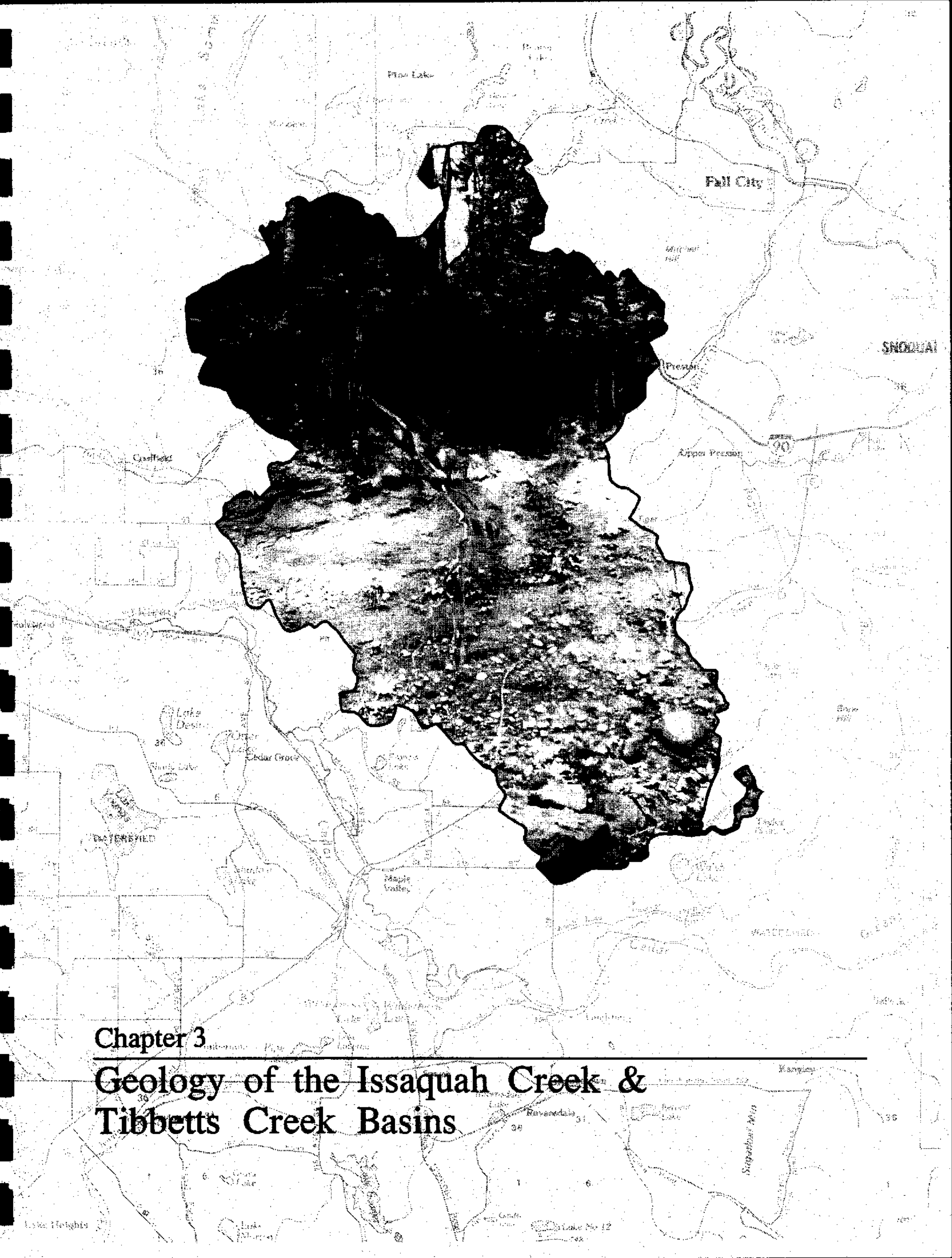
Figure 2-2



FUTURE LAND USE

Issaquah Creek Basin Planning Area

Figure 2-3



Chapter 3

Geology of the Issaquah Creek & Tibbetts Creek Basins

CHAPTER 3: GEOLOGY OF THE ISSAQUAH CREEK AND TIBBETTS CREEK BASINS

3.1.0 INTRODUCTION

The Issaquah Creek and Tibbetts Creek basins occupy a bedrock-bounded valley in central King County. Crustal warping over the past several million years has created a series of northwest-trending folds in the volcanic and sedimentary rocks here. Subsequent to that folding, glacial erosion and deposition have left a complex sequence of materials, particularly in the troughs of the major folds. Sediments underlying these basins, and the south end of Lake Sammamish, now occupy the center of one such trough (Figure 3-1).

The basins also lie adjacent to the eastern end of one of the largest recent geologic structures of the central Puget Lowland. An abrupt descent of the upper surface of bedrock, at or near the surface to the south but many hundreds of feet deeper only a short distance to the north, may reflect Quaternary or even Holocene fault displacement (Gower et al., 1985; Yount and others, 1985; Bucknam and Barnhard, 1989). The basins express that southern uplift and so stand in marked contrast to the neighboring region immediately north, whose relief is more subdued and whose hillslope sediments are more intrinsically erodible.

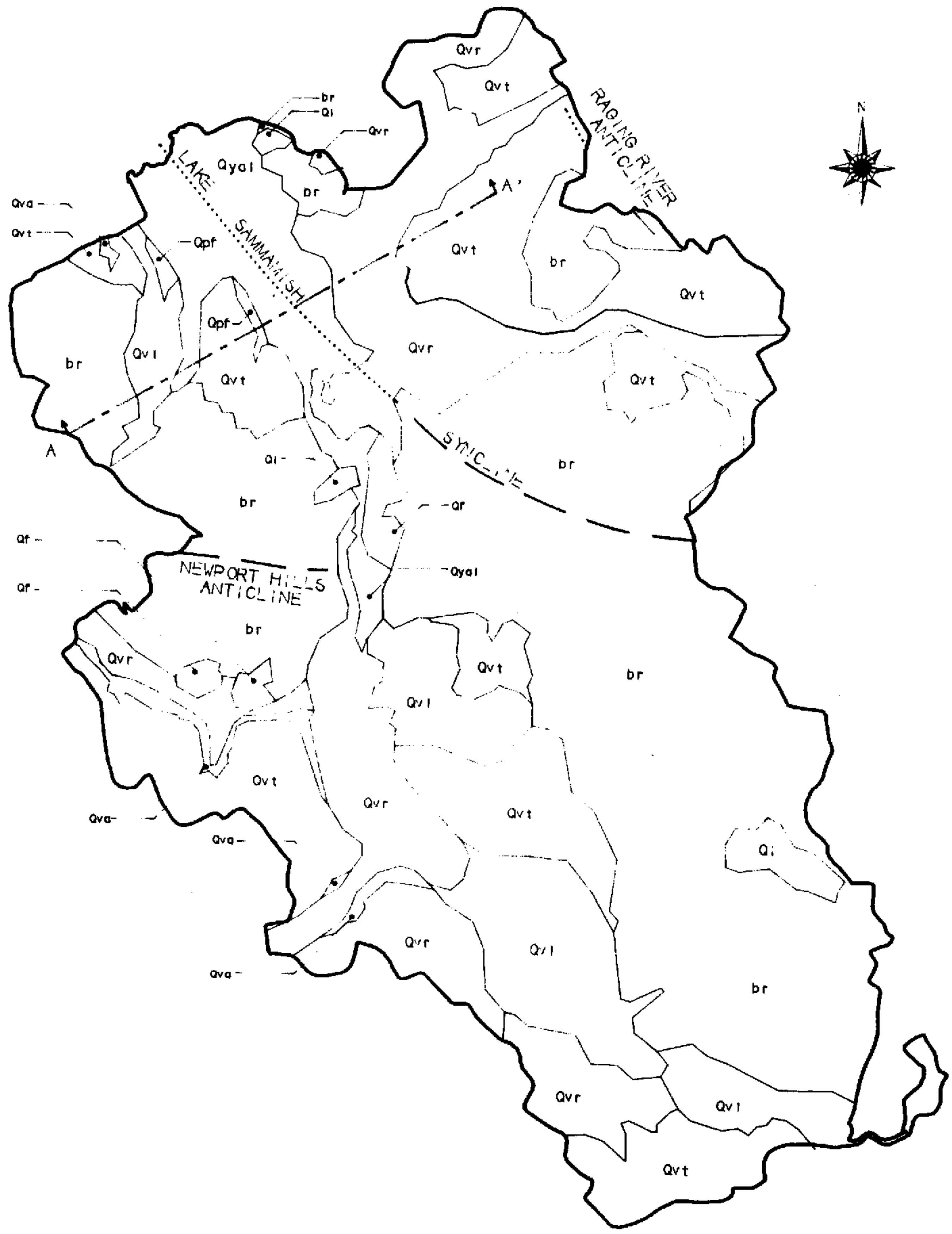
The Issaquah and Tibbetts basins were mapped for this basin plan in 1989 and 1990, using road cuts, stream exposures, construction excavations, and selected well logs. Previous work, particularly Liesch et al. (1963), Rosengreen (1965), and Curran (1965), provided a useful introduction to the area. Most of the information on the bedrock lithology and structure has been compiled from Walsh (1984) with additional structural data on bedrock units collected wherever exposed. Additional sources include Booth (1990) in the extreme northeast corner of the study area and Frizzell et al. (1984) for parts of the eastern Issaquah Creek basin.

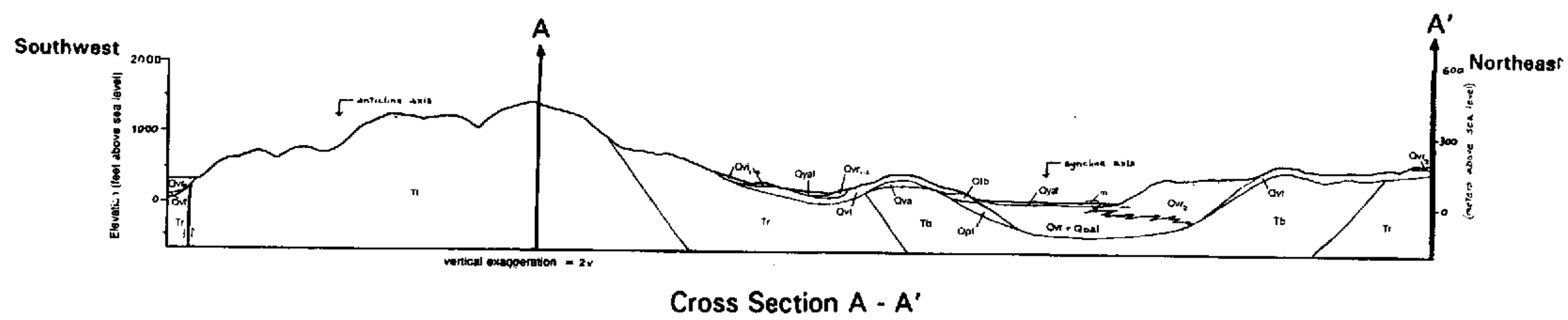
3.2.0 REGIONAL HISTORY AND STRATIGRAPHY

3.2.1 Bedrock Structure

The entire east-central Puget Lowland is underlain by Eocene-age (about 40 million years old) volcanic and sedimentary rocks. In the Issaquah area, these rocks are exposed at the surface in the surrounding highlands of Cougar Mountain, Squak Mountain, Tiger Mountain, and Grand Ridge. Locally, they are overlain by younger sedimentary rocks, exposed mainly in the northern upland areas of the basins.

This sequence of rocks, many thousands of feet thick, has been folded along northwest-trending horizontal axes (Figure 3-1). The dominant fold here is the Lake Sammamish syncline, a





Cross Section A - A'

Qyal	Younger Alluvium	Qvi	Ice-Contact Deposit
Ql	Landslides	Qpf	Pre-Fraser Drift
Qvr	Recessional Outwash	br	Bedrock
Qvt	Till	Tb	Blakely Formation
Qva	Advance Outwash	Tr	Renton Formation
Qtb	Transitional Beds	Tt	Tukwila Formation

GENERALIZED GEOLOGY OF ISSAQUAH BASIN

Issaquah Creek Basin Planning Area

Figure 3-1

DESCRIPTION OF GEOLOGIC MAP UNITS (Shown on Figure 3-1)

HOLOCENE DEPOSITS

Qf FAN DEPOSITS (HOLOCENE) - Boulders, cobbles, and sand, deposited in a lobate form where streams emerge from confining valleys and reduce their gradient, thus depositing some of their sediment load.

Qyal YOUNGER ALLUVIUM (HOLOCENE) - Moderately sorted cobble gravel, pebbly sand, and sandy silt.

Q1 LANDSLIDE DEPOSITS (HOLOCENE)

DEPOSITS OF THE VASHON STADE OF THE FRASER GLACIATION OF ARMSTRONG AND OTHERS (PLEISTOCENE) (divided into):

Qvr RECESSIONAL OUTWASH DEPOSITS - Mainly stratified sand and gravel, moderately to well sorted, with less common silty sand and silt. Subdivided into discrete stages from 1 (oldest) to 5 (youngest).

Qvi ICE-CONTACT DEPOSITS - Similar in texture to unit Qvr but with a higher percentage of silt and showing depressions or other morphology suggesting deposition against stagnant melting ice. Subdivided using the same age convention described for unit Qvr.

Qvt TILL - Compact diamict with subrounded to well rounded lasts, glacially transported and deposited.

Qva ADVANCE OUTWASH DEPOSITS - Well-bedded sand and gravel, deposited by streams and rivers issuing from the front of the advancing ice sheet.

EARLY FRASER TO PRE-FRASER DEPOSITS

Qpf PRE-FRASER DRIFT, UNDIVIDED (PLEISTOCENE) - Mainly moderately to strongly oxidized diamict, with silty matrix and rounded gravel clasts; also includes early Fraser lake sediments.

BEDROCK

br BEDROCK (TERTIARY) - Undifferentiated at map scale.

pronounced downwarp that extends from Lake Sammamish through the city of Issaquah, and which is truncated by faulting east of West Tiger Mountain. The syncline is flanked on the southwest by the Newcastle Hills anticline, whose axis and corresponding bedrock uplift now separate the lower Issaquah valley from May Valley and the May Creek basin to the southwest. On the northeast side of the Issaquah Creek basin, rocks climb up the southwest limb of the Raging River anticline, a less pronounced fold near the eastern basin boundary.

The surface and subsurface expression of the Lake Sammamish syncline dominates the structure in the basins (Figure 3-1). Particularly in the northern third of the basins, not only the bedrock structure but also the glacial sedimentation and the surface topography follow the trend of this trough. Glacial ice has scoured out a valley in the rock, filling it with unconsolidated sediment; these sediments were again scoured to form the yet narrower valley now occupied by the south end of Lake Sammamish and the Issaquah Creek floodplain.

In the remainder of the basins, the structure of folds in the bedrock is still discernible in the rocks themselves. Yet the contact between the rocks and the later glacial and nonglacial sediments that overlie them does not follow the folds in the strata. Instead, erosion of the rock surface follows a much larger subsurface valley extending southeast out of the Issaquah Creek basin, crudely along the modern Cedar River valley, at a maximum depth of over 500 feet below ground level (Hall and Othberg, 1974). The southwest part of the Issaquah Creek basin lies on the northeast flank of that valley, presumably an infilled arm of an ancestral Puget Sound.

3.2.2 Ice Occupation of the Basin

<u>Early Glacial Advances</u>

Multiple invasions of glacial ice into the Puget Lowland have left a discontinuous record of Pleistocene glacial and interglacial periods. Originating in the mountains of British Columbia, this ice was part of the Cordilleran ice sheet of northwestern North America. During each successive glaciation, it advanced into the Lowland as a broad tongue called the "Puget lobe" (Bretz, 1913).

In the basins here, glacial deposits can be unequivocally assigned only to the most recent of these glacial advances, the Vashon stade of the Fraser glaciation (Armstrong and others, 1965). Climaxing about 15,000 years ago, the Vashon stade probably spanned less than 2,000 years (Booth, 1987).

Deposits of one or more earlier glaciations lie in two areas in the basins. The best exposures flank the lower Tibbetts Creek valley; a second locality is poorly exposed in the south-central Issaquah basin, just south of Fifteenmile Creek. Owing to quite limited exposures, no specific age assignment or regional correlation can be made.

Pre- to Early-Vashon Time

Nonglacial conditions prevailed across the basins, and across the North American continent, for at least several tens of thousands of years before the most recent glacial advance. Named the Olympia in this region by Armstrong and others (1965), this nonglacial interval produced deposits of lightly to moderately oxidized fluvial sand and gravel just north of the Issaquah Creek basin (Booth and Minard, 1991; Minard and Booth, 1988).

Laminated silt and clay commonly overlie deposits of inferred Olympia age. In this area, correlative deposits form the lower slopes just west of the town of Issaquah. Reflecting a period of widespread lowland ponding, these sediments probably mark the initial blockage of northern drainage out of Puget Sound by the advancing Puget lobe, about 16,000 years ago. Because the deposits commonly lack dropstones, contorted bedding, or other definitive evidence of glacial activity, their time of deposition is probably transitional between nonglacial Olympia time and the subsequent Vashon stade, whose unequivocal start is marked by coarser outwash and then till derived from the advancing ice sheet.

The Vashon Ice Advance

The most recent ice-sheet occupation of the Puget Lowland climaxed about 15,000 years age (see Booth, 1987, for a summary of current age data). At maximum stage, ice covered the region to a depth of about 3000 feet, but its advance first filled drainages and low-lying upland areas to the north.

Blockage of northward lowland drainage was followed by deposition of river-lain sediments as southerly drainage was established in front of the advancing ice sheet. At any given locality, deposition of sand commonly gave way to gravel, reflecting the increasing gradients adjacent to the approaching ice sheet. These "advance outwash" deposits therefore coarsen upwards and provide good groundwater sources if saturated.

In the two basins, these deposits are exposed only sporadically at the surface and only in the north. More extensive exposures in the general vicinity are found near Landsburg to the south, along the Cedar River near Cedar Grove to the west, and along both the eastern shores of Lake Sammamish and the western valley sidewalls of the Snoqualmie River valley, just north and east of the basin (Frizzell et al., 1984; Booth and Minard, 1991; Booth, 1990).

As ice covered the region, lodgment till was deposited by the melt-out of debris at the base of the glacier. This heterogeneous, compact sediment discontinuously blankets the area to depths of at most several tens of feet. Where present at the surface, it provides a low-permeability cover to underlying aquifers, reducing recharge but also offering protection from surface contaminants.

The Vashon Ice Retreat

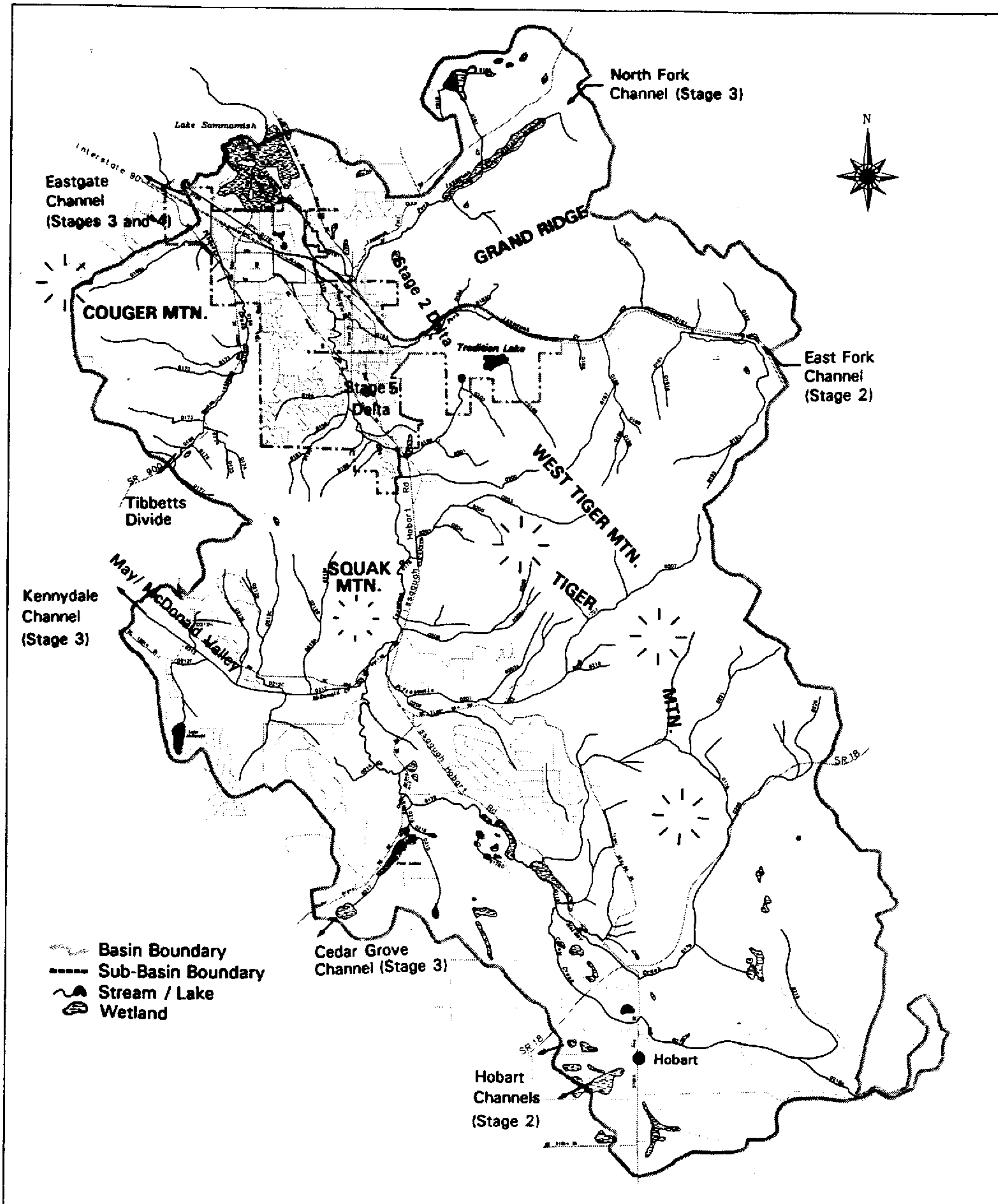
Recession of the ice sheet was accompanied by both outwash deposits and ice-dammed lakes, analogous to those formed during the ice advance. Water from the melting ice sheet and the Cascade Range drained southward and westward, spilling over divides that were later abandoned as the ice pullback exposed lower routes farther north.

In the eastern and west-central parts of the map area, recessional outwash is subdivided into five stages of deposition on the basis of location and altitude (Figure 3-2):

Stage 1 (oldest) includes all time prior to drainage from the Snoqualmie valley into the Sammamish trough. This condition required sufficiently thick ice tongues in these two depressions to force water from the eastern ice margin south over Rattlesnake Lake, about 8 miles east of the basin, and water from ice-sheet drainage in the Issaquah area south past the community of Hobart. These two flows merged near Walsh Lake, just south of the basin, and continued their path to ice-dammed lakes in the central Puget Lowland via the Cedar River valley to just south of Maple Valley and then southwest towards the community of Covington. In the Issaquah Creek basin, this time is represented by valley-wall outwash and ice-contact sediment along the southern edge of Lake Sammamish and near Hobart in the extreme southeastern basin.

Stage 2 encompasses first drainage from glacial Lake Snoqualmie, occupying the present valley of the Snoqualmie River to a depth of several hundred feet, down the present East Fork Issaquah Creek valley into the Lake Sammamish trough (equivalent to interval 5-6 of Booth, 1990). Interstate 90 now follows this same route between the towns of Issaquah and Preston. A large delta, built into glacial Lake Sammamish at altitudes between 400 and 500 feet above modern sea level, forms the broad plateau underlying Tradition Lake. The altitude of the delta marks the altitude of Lake Sammamish during this time, which was controlled by two spillways along the southwest edge of the basins: one along the "Hobart Channel" (present-day spillway altitude 490 feet) at the head of the Issaquah Creek valley (Frizzell et al., 1984); and the other, with a near-equivalent spillway altitude but carrying much more limited drainage, at the upstream (southwest) divide of the Tibbetts Creek valley, about 2 miles southwest of the town of Issaquah.

Stage 3 includes deposits from the drainage of glacial Lake Snoqualmie through the valley of the North Fork Issaquah Creek (interval 8-9 of Booth, 1990). Drainage out of glacial Lake Sammamish at this time shifted successively northward through the "Cedar Grove," "Kennydale," and "Eastgate" channels, with present-day spillway altitudes of 350 feet, 309 feet, and 323 feet (Thorson, 1980). The Cedar Grove and Kennydale channels are expressed in the modern landscape as two flat-bottomed valleys, about 1000 feet wide and 2 or more miles long. The former connects the Issaquah valley with the Cedar River valley southwest along the route of Cedar Grove Road; the latter extends



MAJOR TOPOGRAPHIC AND GLACIAL-AGE DRAINAGE FEATURES

Issaquah Creek Basin Planning Area

Figure 3-2

west from the Issaquah valley, now occupied by McDonald Creek, and continues to Lake Washington as May valley.

The last occupied of these channels, the Eastgate Channel, lies just west of the basin and now provides the route of Interstate 90 between Eastgate and Issaquah. Its occupation by meltwater requires that the basins had become essentially ice-free by the end of this stage.

During Stage 4, glacial Lake Snoqualmie drained west into glacial Lake Sammamish via the "Inglewood Channel," about 4 miles north of the Issaquah Creek basin (Thorson, 1980; equivalent to interval 10-11 of Booth, 1990). Its present-day spillway altitude is 360 feet. The level of glacial Lake Sammamish was unchanged from the end of Stage 3 during this time.

Stage 5 (youngest) is defined by a low delta just south of the Issaquah town center at a present altitude between 100 and 150 feet. It probably reflects the last stage of the lowland recessional lake history (interval 14 of Booth, 1990). During this time, the entire set of interconnected Puget Lowland troughs (Lake Bretz of Waitt and Thorson, 1983) drained through a spillway at about altitude 200 feet on the northeastern Olympic Peninsula, 30 miles northwest of the basins.

Isostatic rebound, the uplift of the earth's crust following an interval of depression, occurred as the weight of the ice sheet melted away. Since deglaciation, it has elevated the northern lowland more than southerly areas, because the Vashon-age ice sheet was thicker to the north. The relative uplift gradient is now observed to be 0.009 (about 1 m per km, or 5 feet per mile; Thorson, 1980; Booth, 1990). Although this phenomenon affected all lake and spillway relationships, it is particularly significant during this stage because the spillway for Lake Bretz lay quite distant from the site of deposition in the Issaquah Creek basin. The Stage 5 delta south of Issaquah lies about 20 miles down-gradient (approximately due south) of its controlling spillway, and thus its present altitude is about 100 feet lower than that of the spillway.

3.3.0 POSTGLACIAL PROCESSES AND DEPOSITS

3.3.1 Deglaciation and Landscape Changes

As the Vashon ice sheet retreated entirely from the region, Lake Bretz drained down to sea level. As a result, the regional base level for the Lowland's rivers and streams first dropped abruptly and then continued a more gradual decline for the next several thousand years, as the land surface continued to emerge by isostatic rebound. Recessional outwash plains and lake-bottom sediments, aggraded to recessional lake levels one to several hundred feet higher than what now prevails, probably incised rapidly. As the rivers and streams first incised through and

then meandered across new valleys cut into these older, higher sediments, new floodplains were established, graded to the lower modern base level.

In these basins, the valley of Issaquah Creek best displays this progression. Where the creek is most competent, in the northern part of the basin, the process is now complete. Nearly all of the glacial-age valley sediments have been removed or reworked, leaving a broad, level floodplain graded to the postglacial base level defined by Lake Sammamish. Farther upvalley, the creek is less competent and thus has only excavated a narrow channel; otherwise, it is still flowing over the surface of the glacial deposits without significant regrading.

Hillslope erosion was also profoundly affected by the passage of the ice sheet. Once deglaciation of an area was complete, bare slopes of rock, soil, and glacial sediment were exposed to rain for perhaps centuries or more without benefit of a thick vegetative cover. Erosion rates would have been very high; similarly, deposition rates at the base of those slopes would have been substantial. The basins display many examples of these processes, because the large expanse of steep slopes off of Squak and Tiger Mountains directly abut the flat valley floors of McDonald and Issaquah Creeks. Alluvial fans at the edges of these valleys cover 10 to several hundred acres. Many are now inactive, because the conditions of their formation have not been repeated since shortly after deglaciation. However, several still suffer inundation by water and sediment over a significant fraction of their total area.

Landsliding was also a likely consequence of postglacial conditions in the basins. The combination of slopes locally oversteepened by glacial erosion, relatively weak bedrock, and minimal vegetation allowed several very large slides to occur, the largest covering over one-half square mile. Their movement may also be related to large earthquakes that have likely shaken the region every several hundred to thousand years since deglaciation (Atwater, 1987). None of these large slides appear to be active presently, but their permanent inactivity cannot be assured with existing information.

3.3.2 Urbanization and Landscape Changes

Over the last 15,000 years, the alteration to geologic process caused by urban development has been second only to glaciation and deglaciation in significance. The most noteworthy of these alterations have been topographic, resulting from massive quarrying of clay and bedrock in the Tibbetts Creek basin and the excavation of recessional outwash deposits in the Stage 2 and 3 deltas at the mouth of the North Fork Issaquah Creek. Mine tailings, transportation corridors, and the Cedar Hills landfill have also created significant topographic changes. Other types of human alteration involve (1) increases in stormwater runoff, resulting in substantially more rapid stream-channel erosion and downstream deposition, and (2) groundwater extraction for water supplies in the lower Issaquah Creek valley, which has the potential for affecting stream flow in the lower reaches of both Issaquah Creek and its North Fork tributary.

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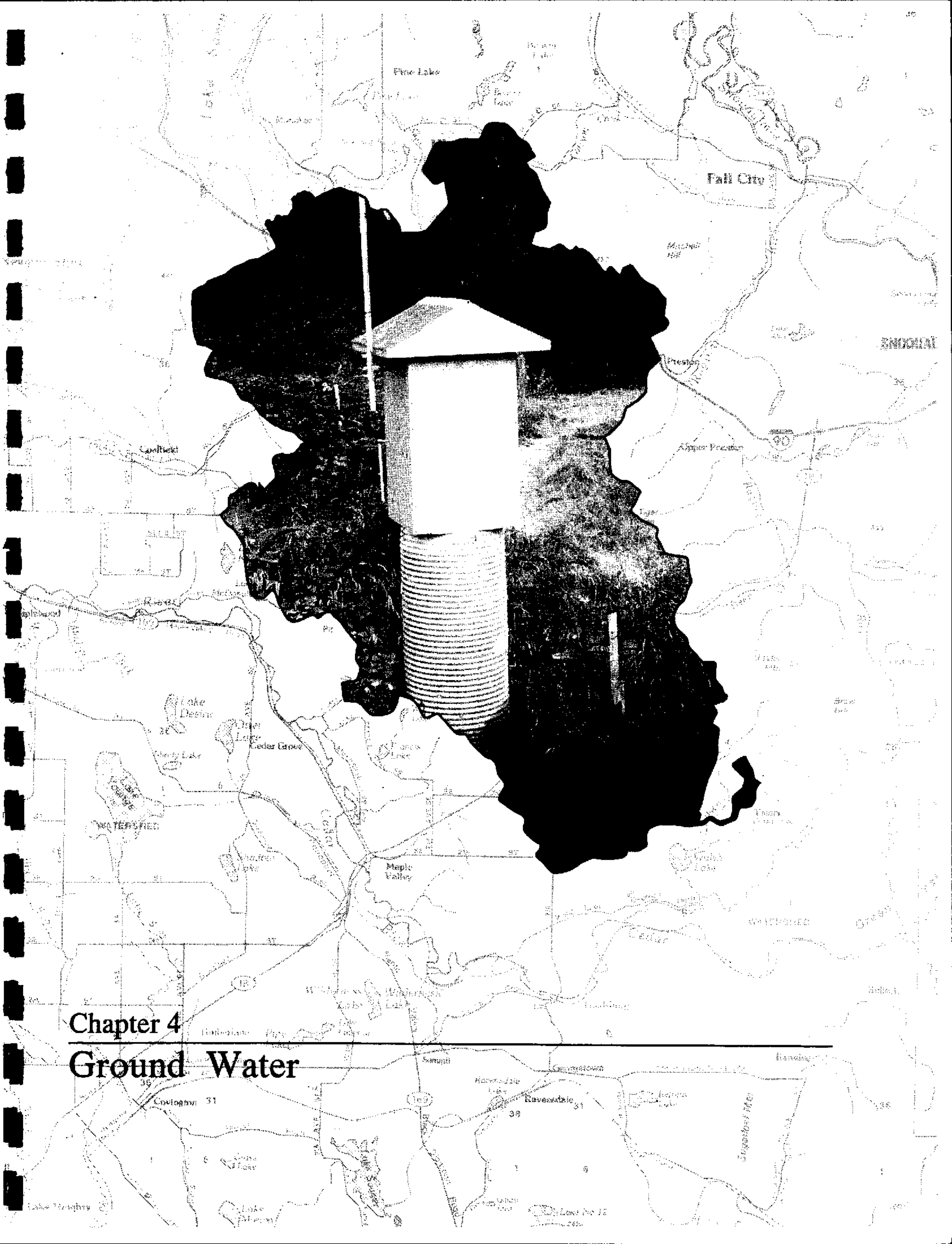

Chapter 4
Ground Water

CHAPTER 4: GROUNDWATER

4.1.0 INTRODUCTION

4.1.1 Background Information

Groundwater performs many functions in the Issaquah and Tibbetts Creek basins. Discharge of groundwater supports year-round flow in many of the basins' streams, particularly in their lower reaches. Infiltration of stormwater to the groundwater provides significant attenuation of flood peaks in certain areas. Finally, groundwater provides virtually all of the drinking water for residents in the basins.

All of these functions of groundwater are interrelated. The ultimate source of most of the groundwater here is direct precipitation onto the ground surface; what is neither evaporated, transpired by plants, nor lost rapidly by surface flow enters the groundwater system. That water is eventually discharged from the basin as well, though at much slower rates than surface-water runoff. Withdrawal for drinking water uses the same supply that supports the perennial base flow to streams and lakes, and so an increase in the former must eventually result in a reduction or local elimination of the latter.

Although groundwater exists by definition in all saturated geological materials, it is accessible for water use or discharge to surface-water bodies only where it can move freely through subsurface deposits. These freely transmitting deposits are characterized by relatively large pores and are known as aquifers. In this basin, the various outwash deposits of the last glaciation form the most common aquifers. In contrast, deposits that restrict the movement of groundwater are called aquitards (if they are moderately restrictive) or aquicludes (if they are strongly restrictive).

The infiltration, movement, and storage of groundwater is controlled by the characteristics of the surface and subsurface deposits. Infiltration at the surface depends on the permeability of the surface sediments and the accessibility of those sediments to precipitation. Thus outwash deposits, consisting of silt-poor sand and gravel, provide the best opportunities for infiltration where exposed at the ground surface. They also form the primary aquifers of the area. Till, in contrast, has a much higher percentage of silt and clay and so offers significantly more resistance to flow. It acts as the uppermost aquiclude or aquitard, with rates of infiltration through the unweathered deposit of approximately 1 inch per month (Olmstead, 1969). The soil layer developed on top of the till, however, has much greater infiltration, but the movement of water is largely restricted to that thin upper zone ("interflow").

The sequence of layered aquifers and aquicludes also affects groundwater. Aquifers exposed at the surface provide not only areas of easy infiltration but also shallow zones of groundwater storage and movement. If shallowly underlain by an aquiclude, typically till, then the

groundwater is "perched" above deeper zones and may locally appear at the surface as springs or wetlands. Aquifers at greater depth may have less direct access to surface waters, with recharge occurring only by slow percolation through overlying aquitards. Discharge from these deeper aquifers is most commonly at hillside springs and along hillside drainage courses, where the groundwater reemerges along the exposed edge of the deposit. During the course of a year, that discharge may fluctuate, as the water level in the aquifer rises and falls with seasonal precipitation patterns. Conversely, aquifers that are well-isolated from surface recharge areas may show very little seasonal variation in either water-table level or baseflow discharge, because the rate at which water reaches the aquifer is so slow.

4.1.2 Other Studies

The Issaquah Creek basin is coincident with the Issaquah Creek Groundwater Management Study area, which involves a multi-year cooperative effort by the local municipalities, water purveyors, and the Seattle-King County Department of Public Health. The first draft of that study, which will address both groundwater quantity and groundwater quality in this area, should be completed in 1991. As the most systematic review of groundwater in this area to date, that upcoming report renders all preceding data-collection efforts and studies, including this one, as preliminary only. A parallel study of wellhead protection needs for this area is in progress. Other sources of presently available information include a regional review of groundwater resources (Liesch and others, 1963) and a comprehensive discussion of the groundwater system in the lower Issaquah Creek valley based on a recent pumping test (Carr/Associates, 1990).

4.2.0 CONDITIONS

4.2.1 Groundwater Systems in the Study Area

Because of the diverse topography and geology of the Issaquah Creek and Tibbetts Creek basins, no universal description of groundwater in this area applies. Instead, the area can be subdivided into several regions, or "systems". They are in part interrelated, because there is no absolute barrier to groundwater flow between them, but their characteristics are sufficiently distinct that separate discussions are valid. These systems also vary dramatically in their productivity and importance to both groundwater supply and surface-water interactions.

The "mountain system" comprises the bedrock uplands of Grand Ridge, Cougar, Squak, and Tiger Mountains. Only thin glacial deposits overlie bedrock, and so it is the structure of that bedrock that controls the movement and storage of groundwater. The sedimentary rocks, mainly sandstone, of the Renton Formation provide the only significant water sources, but their limited recharge areas and only moderate permeability has made them suitable only for small domestic supplies. Coal mines in this deposit further complicate the movement of groundwater, by

creating a labyrinth of subterranean passageways. At greater depths, the volcanic rocks of the Tukwila Formation preclude significant yields.

The non-mountainous, glacial uplands form a second groundwater system. They lie mainly southwest of the Issaquah Creek valley; in contrast, uplands to the northeast of the valley are underlain at relatively shallow depth by bedrock. The uplands also are not significant groundwater producers, owing to their capping by low-permeability till which limits recharge. This system is analogous to the area tapped by many of the existing water-supply wells of the East Lake Sammamish plateau (King County, 1990). The limitations for groundwater on that plateau as well has motivated a search for more abundant and reliable sources (SPWSD, 1990).

The third groundwater system includes the glacially-carved outwash troughs of McDonald Creek, Cedar Grove, and the East and North Forks of Issaquah Creek. Their deposits are relatively limited, both laterally and probably vertically as well, but they lie in a favorable location for groundwater recharge and storage. Runoff from the surrounding uplands drains into these valleys, providing a ready source. Subsurface information on the deposits is limited, but the mode of formation of these valleys suggests that relatively porous sediment probably fills much of their subsurface extent. The setting of this system thus is favorable for groundwater resources; only the small size of these glacial troughs precludes their significance.

That limitation of size is absent from the fourth groundwater system, that of the main Issaquah Creek valley. As with its smaller neighbors to the south and east, this valley was carved by glacial action and filled with mainly porous glacial outwash. But whereas the valleys of the third system are hundreds or a few thousand feet in lateral extent and probably a few tens or a hundred feet in depth, the Issaquah valley covers over a square mile and is filled to a depth of several hundred feet. It also lies in close hydraulic connection with Lake Sammamish, a regional lake with nearly limitless recharge potential (relative to typical groundwater withdrawal rates). All significant groundwater usage in the area, and potential impacts with that usage, are associated with this system.

4.2.2 The Lower Issaquah Creek Valley System

<u>Geologic Setting</u>

The lower Issaquah Creek valley has been shaped by a variety of geologic processes. It lies in the trough of a large fold in the regional bedrock, with the uparched ridges of Cougar Mountain and Tiger Mountain forming its lateral boundaries. This uparching has focussed glacial activity into this area, first the scouring by south-flowing ice, next the impoundment of recessional meltwater, and finally the drainage of that meltwater to the south and then northwest (see GEOLOGY, Chapter 3). In addition, drainage of meltwater and sediment from the Snoqualmie valley entered the lower Issaquah valley via the valleys of what are now the East and North Forks of Issaquah Creek, building extensive deltas into the lake and onto the lake bottom of that

time. In total, this erosional and depositional history has left a complexly interlayered and interfingered sequence of gravel, sand, and silt, whose groundwater is supported by the inflow of Issaquah Creek, its tributaries, Tibbetts Creek, and (at modest depth) Lake Sammamish itself.

Well logs and pumping behavior in this area clearly support this interpretation (Carr/Associates, 1990). Multiple aquifer zones are identified within the upper 200 feet of the valley deposits, with varying elevations recorded at different water-supply wells. Interactions between these different aquifer levels are observed but are also variable--connections between "upper" and "lower" zones are seen at some, but by no means all, wells.

Water-Supply Pumping

A number of large water users currently tap water from the multiple, interrelated aquifers of the main valley system. Noteworthy among them are the Sammamish Plateau Water and Sewer District (SPWSD) and the city of Issaquah. In total, water rights of over 10,000 gallons per minute (instantaneous) and over 8,000 acre-feet per year have been granted, with applications in progress to increase these values by about 20 percent. By comparison, these values are about 20 cfs (instantaneous) and 10 cfs (annual), the same order of magnitude as the mean annual flow of the East Fork Issaquah Creek (18 cfs) and the annual summer low flow on the main stem of Issaquah Creek (between 5 and 20 cfs; see HYDROLOGY, Chapter 5).

The greatest potential impact of pumping is on the North Fork Issaquah Creek, which passes less than 100 feet from two of the main water-supply wells of the valley, SPWSD wells 7 and 8. The annual summer low flow of the North Fork Issaquah Creek is only a few cfs; the rate of current and proposed pumping is several times this value. Thus even a weak connection between groundwater and surface water, as suggested in some (but not all) of the monitoring wells during a September 1990 pump test (Carr/Associates, 1990) could have a significant effect on the stream itself. For example, monitoring well "E", lying 1000 feet southeast of SPWSD wells 7 and 8, showed almost 4 feet of drawdown in its shallow zone (28-38 feet) during the September 1990 pump test. Yet the King County Surface Water Management gage on the North Fork, also 1000 feet from wells 7 and 8 to the northeast, showed no flow reduction whatever during the period of the pump test. Measurements and observations of the North Fork itself during the pump test were insufficient to determine any impacts downstream of the wells, because the pumped water was discharged directly into the creek.

Concerns over surface-water impacts from existing and projected groundwater withdrawals in this area are therefore generic at this time, without adequate data either to confirm or to dispute. As the population continues to increase in this area, however, continued expansion of water-supply needs is likely. Greater care should be made in future tests to evaluate the impact of such expansion on surface-water bodies, and efforts should be made to pump from deep sources (to better isolate surface and subsurface systems) and from new locations (to better distribute any impacts that may be occurring).

Groundwater Contamination

The nature of the Issaquah valley groundwater system, that of a large basin of interconnected and unconfined aquifer zones, makes the area particularly susceptible to contamination. No surface layer provides intrinsic protection from contaminants, and so protection is provided only by the absence of pollutants entering the ground from sewer systems, accidental spills, or intentional dumping. The land use in the area, however, is almost the exact antithesis of what would provide such protection--not only does a major population center lie directly above its own aquifer, but the state's major east-west transportation corridor traverses the valley for 2 miles and passes only a few hundred feet from the major production wells for the region. The recent (spring 1991) discovery of petroleum products leaking into this aquifer, from near the intersection of Front Street and Gilman Avenue, underscores this danger. Thus an aggressive program of aquifer protection, as is in progress, is probably overdue in this area.

4.3.3 KEY FINDINGS

- Surface-water impacts from water-supply pumping in the lower Issaquah Creek valley are potentially significant but presently unknown. The North Fork of Issaquah Creek is most susceptible to these impacts, which should be investigated more fully.

- Water-quality threats to the aquifer are high, because of the lack of intrinsic geologic isolation from the surface and a large population overlying its (unprotected) water supply.

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Chapter 5
Hydrology

CHAPTER 5: HYDROLOGY

5.1.0 INTRODUCTION

This chapter describes hydrologic conditions in the Issaquah Creek and Tibbetts Creek basins. These two basins are located south of Lake Sammamish and encompass an area of approximately 61 square miles (Figure 5-1). Elevation ranges from near sea level to almost 3,000 feet. Based on the nearby Landsburg gage, yearly precipitation ranges between 33 and 76 inches, with a mean of 57 inches. On average, July is the driest month with 1.42 inches of precipitation and December is the wettest month with 8.15 inches. About 70 percent of the yearly precipitation falls from October through March. There is a general trend of increasing precipitation with elevation. Precipitation totals near the summit of Tiger Mountain are about 40 percent greater than those for gages located in the valley. Most of the precipitation is in the form of rain although snow does fall at high elevations during the coldest months of the year.

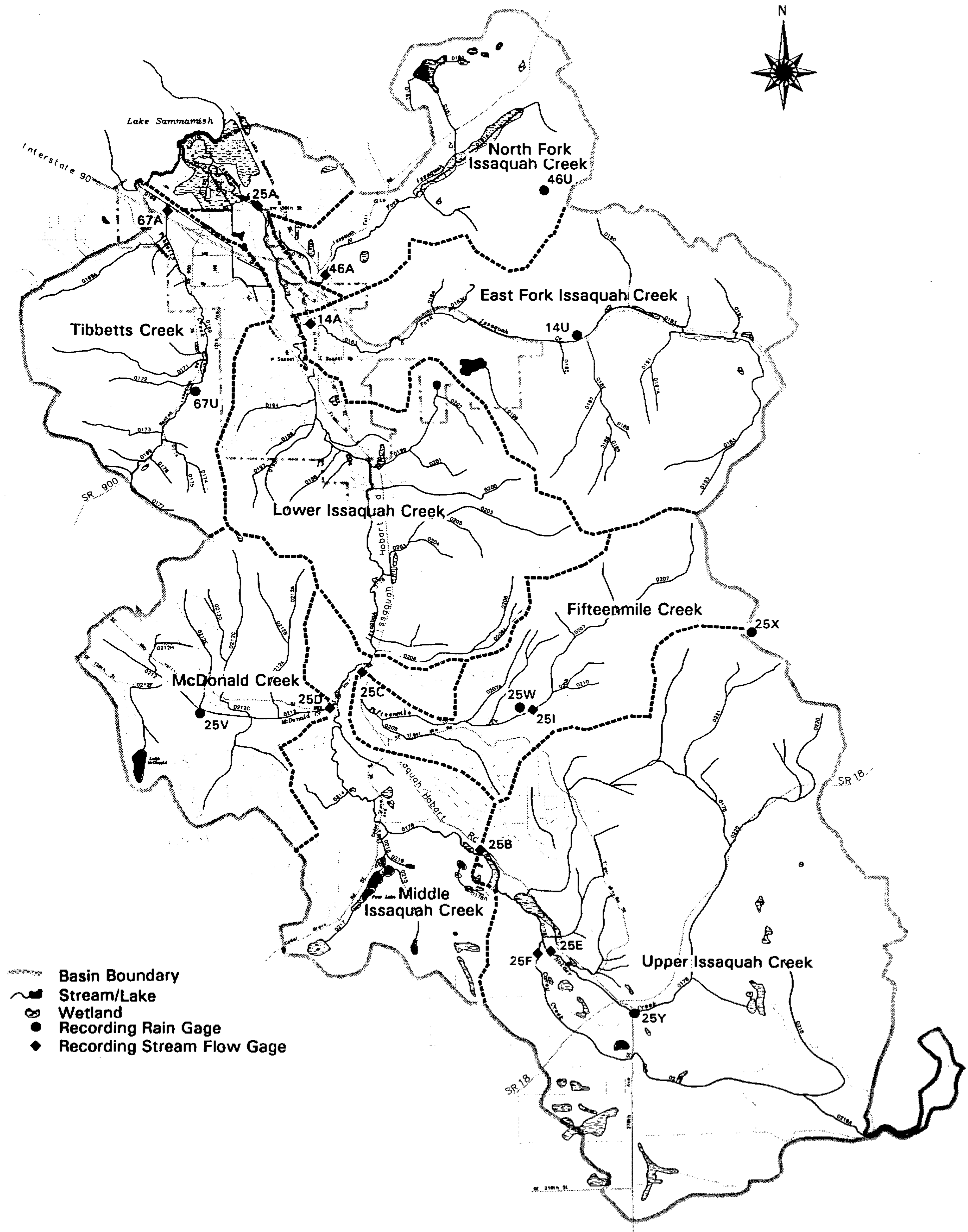
Both Tibbetts and Issaquah Creek basins were modeled using the Hydrologic Simulation Program-Fortran (HSPF) (U.S. E.P.A., 1984). Northwest Hydraulic Consultants Inc. (NHC) was contracted by the King County Surface Water Management (SWM) Division to calibrate the HSPF model. The SWM Division developed land use and soils maps, identified sub-basin boundaries, and developed storage-discharge relations for stream reaches and lakes within the two basins. This information was provided to NHC along with all hydrometeorologic data and initial HSPF input files. NHC was responsible for adjusting the model parameters and refining the model configuration to achieve proper calibration (King County, 1990a). The SWM Division then used the calibrated model in long-term simulations to analyze hydrologic conditions under current conditions. To evaluate the effects of land-use change on basin hydrology, long-term simulations were also run under future and forested land-use scenarios.

The remainder of this section begins with a discussion of the HSPF model, explains how this model was applied to the Issaquah and Tibbetts Creek basins, and concludes with detailed discussions of hydrologic conditions under the three land-use scenarios listed above.

5.2.0 THE HSPF HYDROLOGIC SIMULATION MODEL

5.2.1 Runoff Processes

Runoff can be divided into several related, yet distinct, components. Hillslope runoff that causes high rates of channel flow (i.e., discharge) within a day or so of rainfall is usually classified as storm runoff. Precipitation that percolates to the water table and reaches the stream slowly is called groundwater or base flow. Storm runoff, in turn, can be generated by one or a combination of several mechanisms: Horton overland flow, shallow subsurface flow, or saturation overland flow.



HSPF MODELED SUB-BASIN CONFIGURATION

Issaquah Creek Basin Planning Area

Figure 5-1

Horton overland flow is generated when the rainfall intensity is in excess of the current infiltration capacity of the soil, which is a function of soil type and its moisture content. Over the Puget Lowland, the 100-year one-hour rainfall is about one inch per hour. Most undisturbed, vegetated soils in this area have a limiting infiltration rate of two to six inches per hour. As a result, under natural conditions little Horton overland flow is generated, because even the maximum rainfall intensity is easily exceeded by the minimum infiltration rates.

Shallow subsurface flow is generated from the rapid infiltration of rainwater and subsequent movement of this water through near-surface soil layers. This runoff mechanism is commonly associated with hillslopes underlain by nearly impermeable substratum (typically glacial till or bedrock) covered by shallow, much more permeable soils. The flow rate is proportional to the slope of the restricting layer. At breaks in slope or topographic convergences, water can reemerge on to the surface (return flow), resulting in a ten- to one hundred-fold increase in downslope flow velocity.

Saturation overland flow is produced by rain falling directly on saturated soils. This mechanism commonly occurs under moderate to wet antecedent conditions in topographic hollows and wetlands, and adjacent to stream channels, where the land surface becomes saturated by a rising water table. Irrespective of soil infiltration rates, the ground cannot absorb any additional precipitation and all additional rainfall will flow over the surface.

Groundwater flow is generated from the infiltration and transmission of precipitation via flow paths that are modeled as much longer than those followed by shallow subsurface flow. Groundwater is a dominant runoff mechanism in areas where permeable soils are underlain by glacial outwash. The flow rate is proportional to the slope of the water table, which is generally low in outwash deposits. The longer flow paths, lower driving gradients, and generally larger storage capacities result in dramatically attenuated flow responses when compared to those of shallow subsurface flow or overland flow.

5.2.2 General Model Structure

HSPF is a general, continuous, hydrologic model. Surface, shallow subsurface (interflow), and groundwater flows can be simulated, lagged, and combined as discharge into a drainage network. In application, the basin to be modeled is divided into a number of subcatchments connected by channel reaches. This subdivision is based on topography, hydrological characteristics, the channel network, and locations of desired model output.

Individual subcatchments are further divided into pervious and impervious land segments. Each pervious segment is assumed to be homogeneous with respect to soils, vegetation, topography, and precipitation. Impervious land segments represent the effective impervious area (EIA) within the subcatchment. The EIA is the total impervious surface area that is connected directly

to the drainage system. Individual segments are simulated separately, with the results combined with other segments to yield the total subcatchment discharge.

Flows from subcatchments are combined and routed through the drainage network using a storage routing routine. Any conveyance system with a fixed relationship between depth, surface area, volume, and discharge can be modeled. This includes stream channels, lakes, retention/detention ponds, and reservoirs.

5.3.0 HSPF MODEL CONFIGURATION AND APPLICATION TO THE ISSAQUAH AND TIBBETTS CREEK BASINS

5.3.1 Drainage Network

For the purposes of computer modeling, the Issaquah Creek basin was broken into seven major sub-basin drainages (Figure 5-1). From upstream to downstream, these sub-basins are Upper Issaquah, Middle Issaquah, McDonald (Mason) Creek, Fifteenmile Creek, East Fork Issaquah, North Fork Issaquah, and Lower Issaquah. The Holder and Carey Creek drainages were grouped into the Upper Issaquah sub-basin. Tibbetts Creek was modeled as a single basin. Sub-basins (and the Tibbetts Creek basin) were further divided into a number of subcatchments and stream reaches, ranging from two subcatchments and two stream reaches in Fifteenmile Creek sub-basin up to 13 subcatchments and 14 reaches in the Upper Issaquah sub-basin.

5.3.2 Land Use

Simulating the hydrology of the Issaquah and Tibbetts Creek basins required grouping soils, land cover, and surface topography into hydrologically similar categories. This sub-section describes the characteristics of each of these categories.

Soils were grouped into four broad categories: outwash, till, bedrock, and wetland. Outwash soils consist of sand and gravel deposits that have high infiltration rates. Rainfall in these areas is quickly absorbed and percolates to the groundwater table. Creeks draining outwash deposits often intersect the groundwater table and receive most of their flow from groundwater discharge, unless the channel bed is located above the water table. Even for the largest storms stream flow response is slow, with peak flow often lagged up to several days.

Till deposits contain large percentages of silt or clay and have low percolation rates compared to outwash soils. Only a small fraction of infiltrated precipitation reaches the groundwater table. The rest moves laterally through the thin surface soil above the till deposit (as shallow subsurface flow), often reemerging at the base of hillslopes. Soils may become saturated in large storms and produce significant amounts of surface runoff. The peak runoff rate from till areas is therefore generally much higher than from outwash soils.

Areas with shallow soils overlying bedrock respond to precipitation in a manner similar to areas of glacial till. However, bedrock areas were considered less pervious than till and were modeled to produce a greater interflow response.

Wetland soils remain saturated throughout much of the year. The hydrologic response from wetlands is variable depending on the underlying geology, the proximity of the wetland to the regional groundwater table, and the bathymetry of the wetland. Generally, wetlands provide some base flow to streams in the summer months and attenuate storm flows via temporary storage and slow release in the winter.

Four types of land cover were considered in analyzing the hydrology of the Issaquah and Tibbetts Creek basins: forest, grass/pasture, clear-cut, and impervious. Forested areas generate the least amount of surface runoff. Forest cover is most significant in regions of glacial till where the vegetative root system breaks up the soil structure, allowing for increased infiltration. Forest litter provides additional soil-water storage and protects against compaction of near-surface soils. Interception of rainfall by leaves and removal of soil-water by evapotranspiration is also greater in forested areas than in the other cover categories.

Grassed areas produce more surface runoff than forested areas. Surface soils are generally compacted during clearing, reducing infiltration capacities. Furthermore, because grass is shallow-rooted, it does not contribute to infiltration as forest cover does. Grassed areas therefore saturate more quickly and produce more overland flow in large storms than forested areas.

Till soils covered by clear-cut were modeled as forested till except that the surface interception capacity, the surface roughness, and lower zone evapotranspiration parameters were reduced to values corresponding to till grassed soils.

Impervious areas produce the most surface flow of all cover categories. The infiltration rate in impervious areas is zero and water storage in surface depressions is minimal. As a result, virtually all rainfall runs directly off to produce high peak flows.

The combination of forest cover on outwash produces the lowest peak flows, followed by clear-cut-covered outwash, grass-covered outwash, forested-till, clear-cut-till, grassed-till, and finally impervious cover. Peak flows from wetland soils are variable, depending on the characteristics of the wetland and the time of year.

Slopes influence the rate at which runoff discharges to the creek in till and bedrock soils. Slopes in these areas were grouped into three broad categories: flat (0 to 6 percent), moderate (6 to 15 percent), and steep (> 15 percent). Steeper slopes have faster subsurface responses than flatter slopes. This allows the thin surface soil in steeper sloping areas to drain faster than flat sloped regions. Because the flat sloped areas do not drain as well, the soil remains wet longer and

saturates more quickly in large storms, producing more surface runoff than neighboring steeper slopes.

In outwash deposits, groundwater flow rates are proportional to the slope of the water table, but the water table is usually only mildly sloping in these deposits. As a result, no slope classification is used for outwash soils.

Receiving creeks, lakes, and wetlands also affect runoff characteristics. When water enters a receiving body it does not flow out immediately. Rather, some of the input is stored, raising the water level progressively and causing outflow to increase. Because some of the input is stored, the outflow rate can not be as high as the input rate. When the rate of input decreases, the stored water is slowly released, and outflow exceeds input. The degree of flow attenuation depends upon the roughness, slope, size, and shape of the water body. The most sensitive of these parameters is channel size. Thus wetlands and lakes, by virtue of their larger storage volumes, are typically more effective than channels at reducing stream flow peaks.

5.3.3 Hydrometeorologic Data

The HSPF model was calibrated by NHC to the Issaquah and Tibbetts Creek basins using ten stream flow gages and seven precipitation stations (Figure 5-1). All sub-basins except Middle Issaquah contained a stream flow gage. Data for these stations were provided by SWM for the period from October 1987 to January 1990. Missing rainfall data were filled by SWM with values recorded during the same time period at nearby stations without adjustment (King County, 1990a).

Gage data show a general increase in rainfall with elevation. This fact, plus the possible need to conduct snowmelt modeling, led SWM to divide the basin into these elevation bands of below 900 feet, from 900 to 1800 feet, and above 1800 feet. This allows recorded rainfall to be scaled according to elevation during model runs. The appropriate scale factors were determined during model calibration by NHC.

NHC used two methods to determine the role of snowmelt in the generation of flood flows in the Issaquah Creek basin: 1) a simple snow-accumulation and melt model for the calibration period and 2) a comparison of snow on the ground data with flood flows at the Lower Issaquah stream gage (King County, 1990a). Although the analyses were carried out for Issaquah Creek, the results can also be extrapolated to the Tibbetts Creek basin. The following is a brief summary of these analyses.

Snowmelt contributions during the calibration period were analyzed using a simple temperature indexed snow-accumulation and melt model. Precipitation and air temperature recorded at the Tiger Mountain gage (elevation 3,000 feet) were input to the model which produced a time series of snow water equivalent for snow on the ground and liquid water input to the soil.

Recorded precipitation at the Tiger Mountain gage was compared against the simulated liquid water input. From this analysis, NHC concluded that for the calibration period "precipitation in the form of snow, and its accumulation and subsequent melt, do not appear as an important factor in the global water budget and timing of runoff in these basins" (King County, 1990a).

Field staff obtained the annual maximum flood series in order to evaluate the effect of snow cover on historic flood flows for the Lower Issaquah stream flow gage, for the period of record 1964 to 1990. These data also allowed the dates of the seven largest floods to be determined. Recorded values of snow on the ground for these dates were obtained from the Landsburg and Cedar Lakes weather stations. Daily values of precipitation and maximum and minimum temperature were also obtained from Cedar Lake. The Landsburg gage is located about eight miles south of the Tiger Mountain gage at an elevation of 535 feet. The Ceder Lake station is located at an elevation of 1,560 feet, approximately twelve miles southeast of the Tiger Mountain gage. For comparison, the Issaquah basin has a mean elevation of 750 feet. Within the basin, 80 percent of the total area is below 1,560 feet and 88 percent is below 1,800 feet.

For the seven events in question, snow on the ground was reported as zero at the Landsburg gage. For the dates on which peak flow occurred, snow on the ground at Cedar Lake was also zero; however, traces of snow were reported in some cases on the preceding days. A trace is a depth of snow on the ground less than one inch. Assuming a specific gravity of 25 percent, at most, these traces should have represented 0.25 inches of equivalent water depth. Rainfall values recorded the day before or the day the flood occurred were large enough to guarantee that the floods were rainfall induced. As a result, NHC concluded that "no evidence was found to support the hypotheses that major flood flows in the Issaquah and Tibbetts Creek basins are the result of superposition of rain-on-snow events." Therefore, no snow-related processes were incorporated as part of the HSPF modeling for the Issaquah and Tibbetts Creek basins for flows up to the 100-year flood, although additional investigation on the role of snow in even more extreme flood events is described later in this chapter.

For long-term simulations, a 42-year continuous record of rainfall collected at the Seattle-Tacoma Airport weather station was applied by SWM to the calibrated model, producing a 42-year record of flows at the outlet of each sub-basin. Transformation coefficients were used to translate the Seattle-Tacoma record to the Tibbetts and Issaquah Creek sub-basins. These coefficients were determined by NHC during model validation (King County, 1990a).

5.4.0 CURRENT CONDITIONS

5.4.1 Land Cover

Simulated flows for the current land-use scenario are based on 1989 conditions as described in Chapter 2 and presented in Figure 2-2. Current land cover is depicted by sub-basin in Figures 5-2 through 5-4. Forest remains the predominant land cover in the Issaquah and Tibbetts Creek

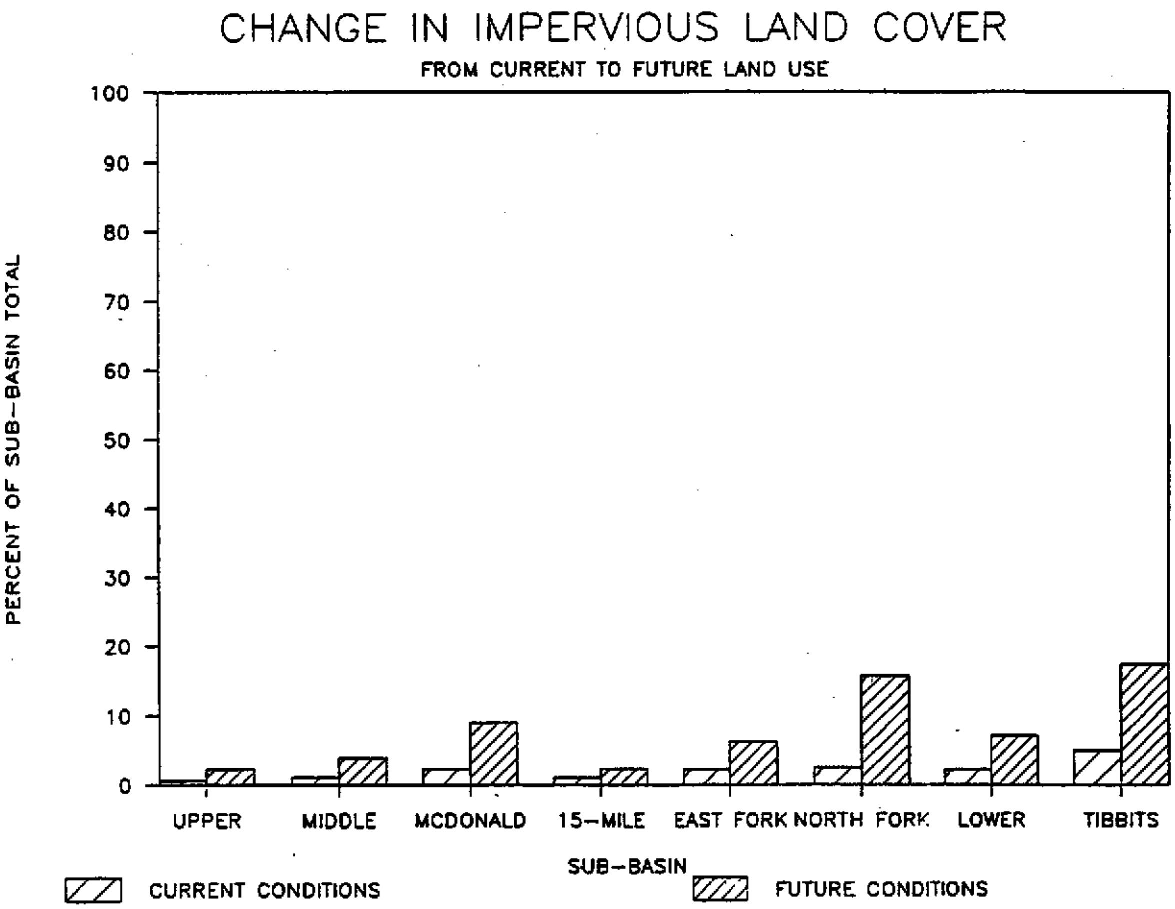

CHANGE IN IMPERVIOUS LAND COVER
FROM CURRENT TO FUTURE LAND USE
PERCENT OF SUB-BASIN TOTAL
100
90
80
70
60
50
40
30
20
10
0
UPPER
MIDDLE
MCDONALD
15-MILE
EAST FORK
NORTH FORK
LOWER
TIBBITS
SUB-BASIN
CURRENT CONDITIONS
FUTURE CONDITIONS

Figure 5-2

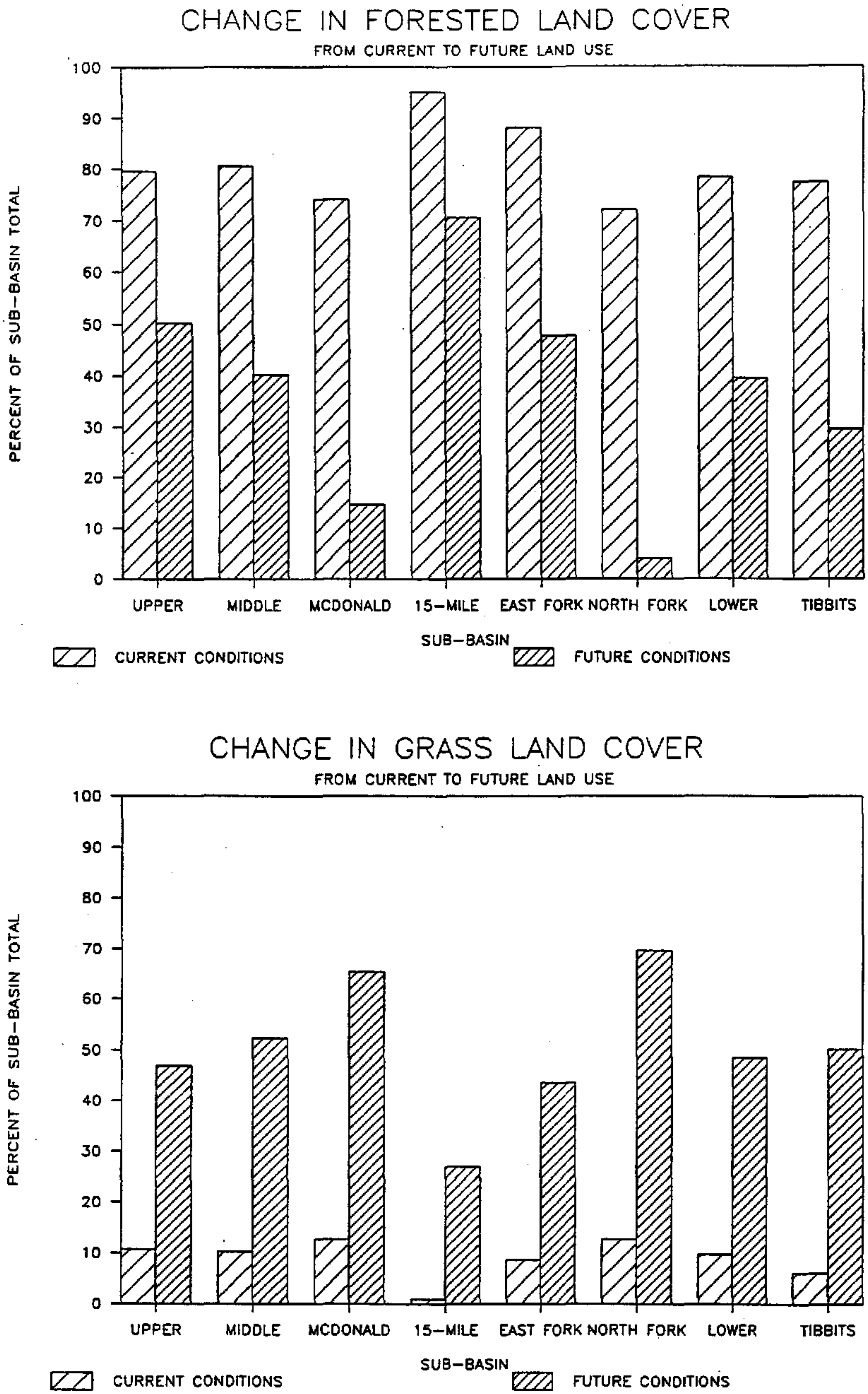
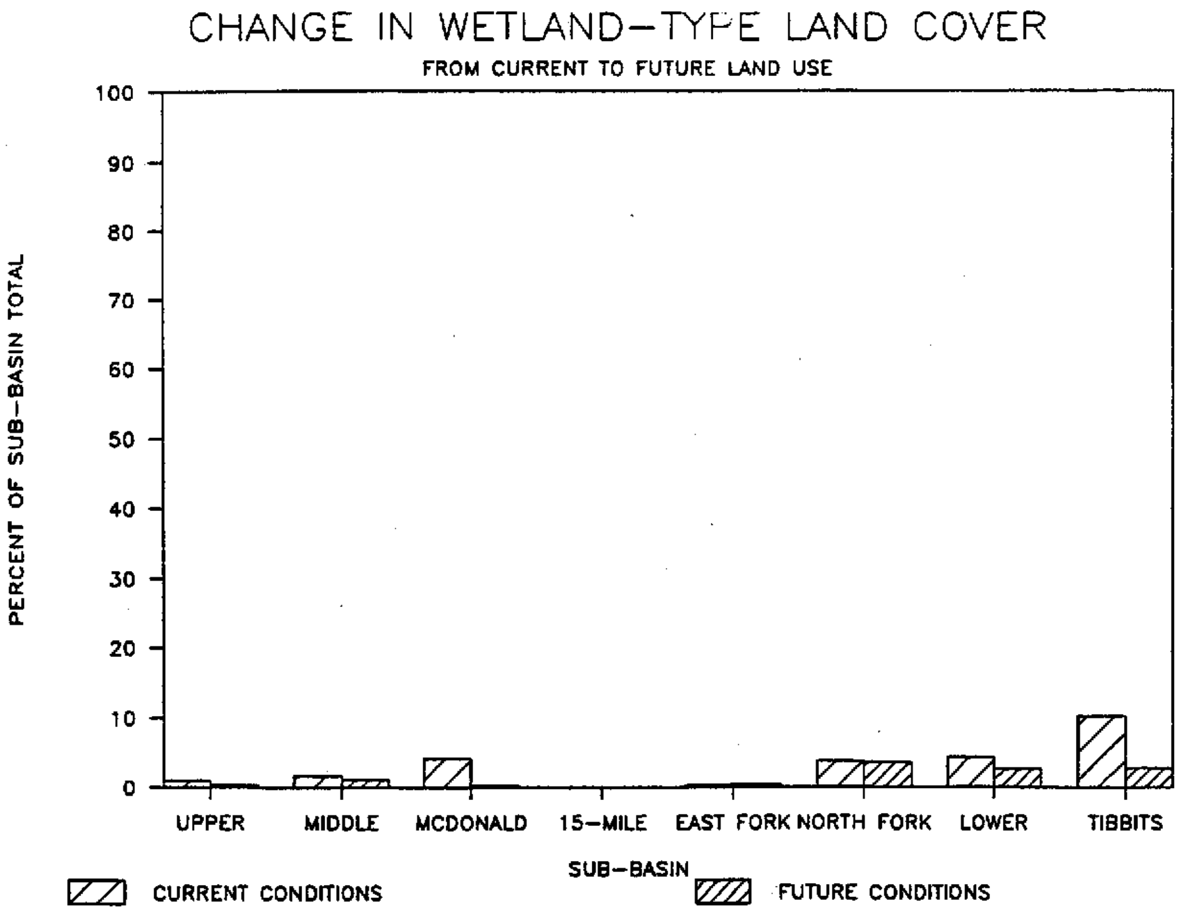
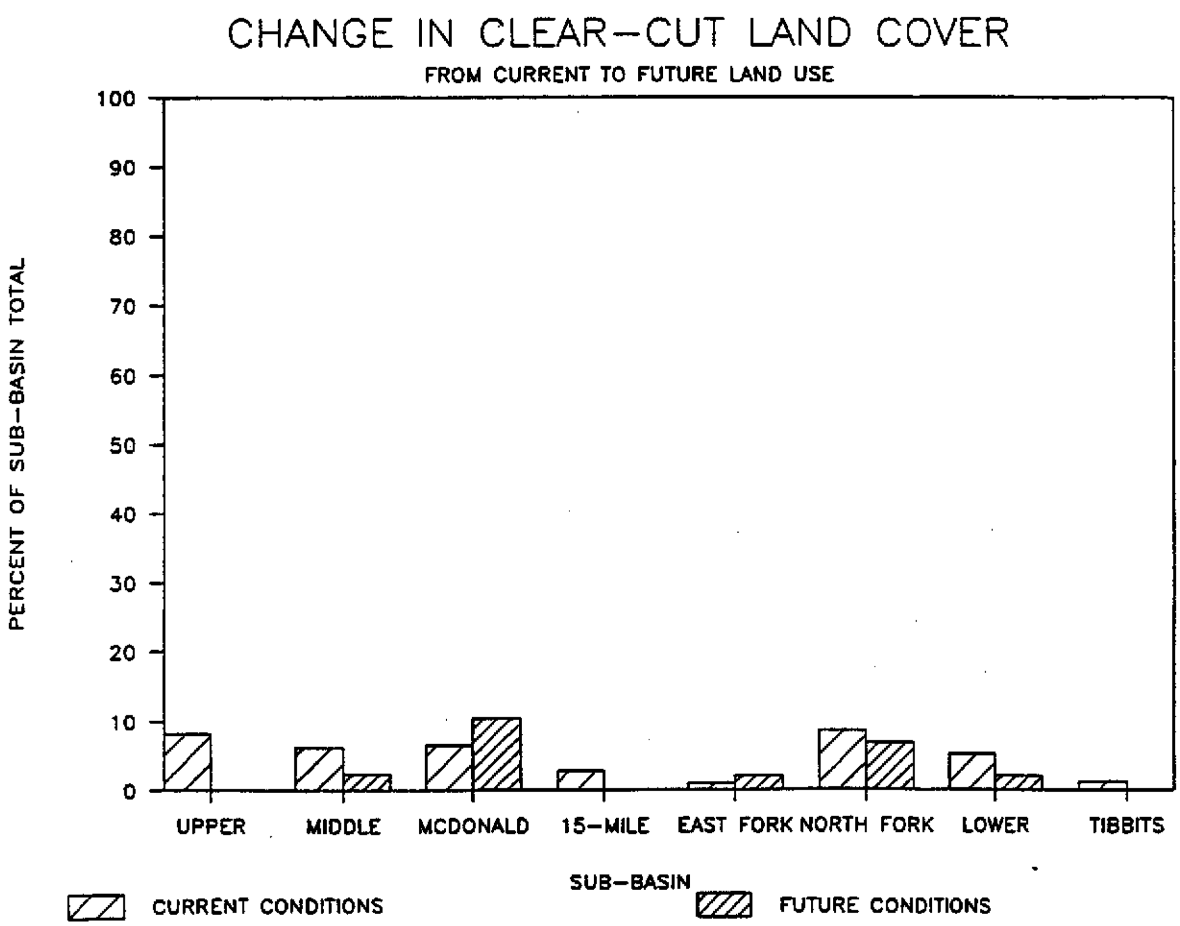

CHANGE IN FORESTED LAND COVER
FROM CURRENT TO FUTURE LAND USE
PERCENT OF SUB-BASIN TOTAL
100
90
80
70
60
50
40
30
20
10
0
UPPER
MIDDLE
MCDONALD
15-MILE
EAST FORK
NORTH FORK
LOWER
TIBBITS
SUB-BASIN
CURRENT CONDITIONS
FUTURE CONDITIONS
CHANGE IN GRASS LAND COVER
FROM CURRENT TO FUTURE LAND USE
PERCENT OF SUB-BASIN TOTAL
100
90
80
70
60
50
40
30
20
10
0
UPPER
MIDDLE
MCDONALD
15-MILE
EAST FORK
NORTH FORK
LOWER
TIBBITS
SUB-BASIN
CURRENT CONDITIONS
FUTURE CONDITIONS

Figure 5-3



CHANGE IN WETLAND-TYPE LAND COVER
FROM CURRENT TO FUTURE LAND USE
PERCENT OF SUB-BASIN TOTAL
100
90
80
70
60
50
40
30
20
10
0
UPPER
MIDDLE
MCDONALD
15-MILE
EAST FORK
NORTH FORK
LOWER
TIBBITS
SUB-BASIN
CURRENT CONDITIONS
FUTURE CONDITIONS



CHANGE IN CLEAR-CUT LAND COVER
FROM CURRENT TO FUTURE LAND USE
PERCENT OF SUB-BASIN TOTAL
100
90
80
70
60
50
40
30
20
10
0
UPPER
MIDDLE
MCDONALD
15-MILE
EAST FORK
NORTH FORK
LOWER
TIBBITS
SUB-BASIN
CURRENT CONDITIONS
FUTURE CONDITIONS

Figure 5-4

basins, ranging from 72 percent in the North Fork sub-basin up to 95 percent in the Fifteenmile Creek sub-basin. Impervious cover accounts for less than 5 percent of total cover in all sub-basins.

5.4.2 Peak Flow Rates

Flow Frequencies by Sub-basin

The continuous HSPF simulation record was used to compute return frequencies for peak flows. A Log-Pearson analysis, based on U.S. Water Resources Council Bulletin 17B guidelines (U.S. Water Resources Council, 1982), was performed using the peak annual flow from each of the 42 years. Bulletin 17B describes procedures for the detection and treatment of outliers (those data points which depart from the trend of the rest of the data). The peak annual flow for Water Year 1977 was found to be a low outlier in almost all subcatchments. This peak was removed in accordance with Bulletin 17B procedures. As can be seen in Figure 5-5, this procedure substantially improves the Log-Pearson fit to peak annual flows. Flows were determined at the outlet of each subcatchment for the 1.01-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return periods. A listing of the 2-, 10-, 25-, and 100-year flows at the outlet of each sub-basin is given in Table 5-1.

Table 5-1

Modeled Flow Frequencies Under Current Land Use
Peak Annual Flow Frequency
(in cubic feet per second)

Sub-basin	2-year	10-year	25-year	100-year
Upper Issaquah	775	1287	1564	1999
Middle Issaquah	1086	1816	2220	2866
McDonald	111	200	251	338
Fifteenmile	195	319	388	498
East Fork	350	601	742	968
North Fork	73	142	185	260
Lower Issaquah	1765	2876	3478	4425
Tibbetts	194	329	403	521

AFFECT OF LOW OUTLIER REMOVAL ON LOG PEARSON ANALYSIS OF SIMULATED FLOWS AT THE LOWER ISSAQUAH CREEK GAGE

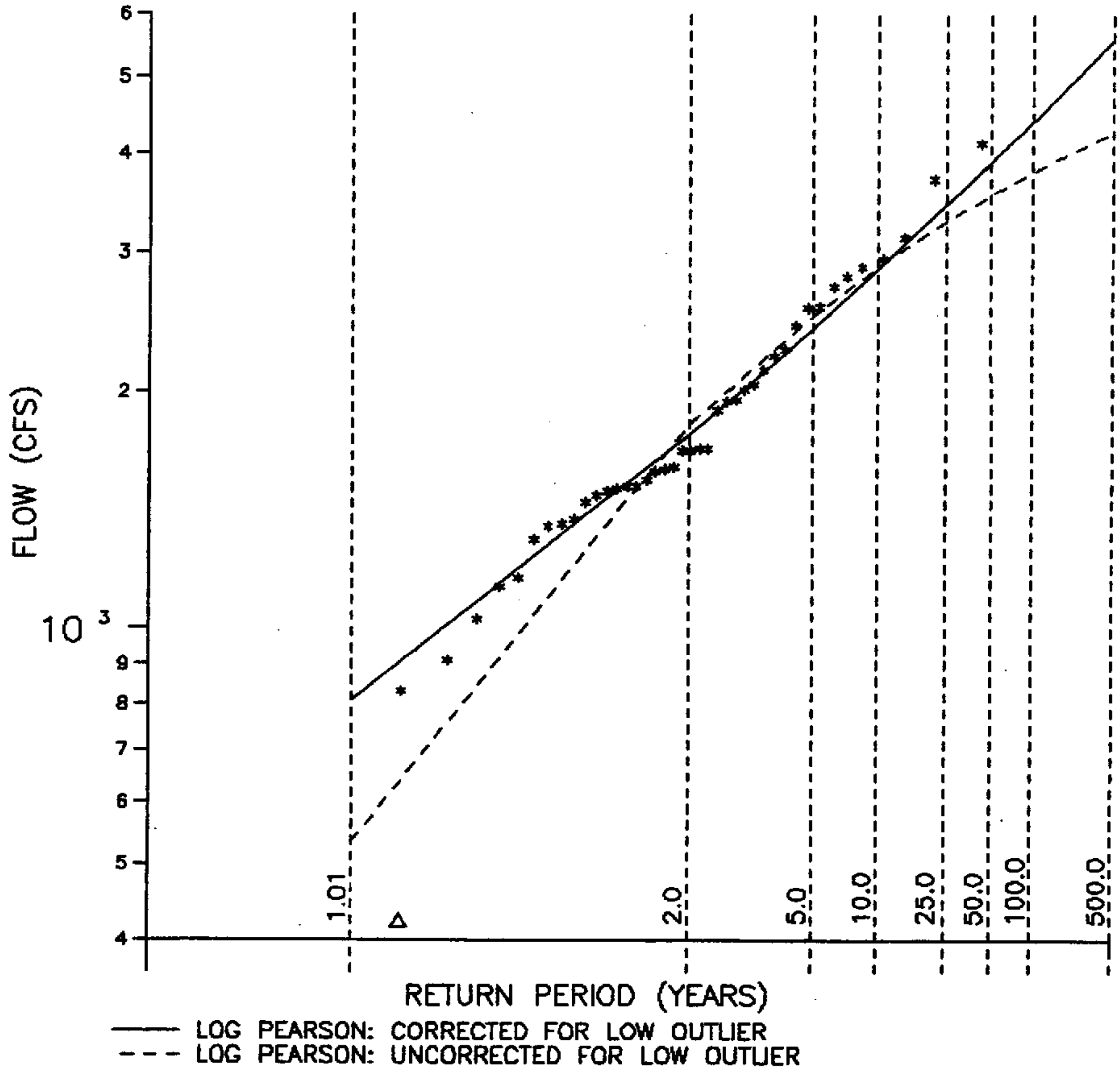


Figure 5-5

Unit Area Discharge Rates

Unit area discharges (peak flow rate divided by upstream catchment area) were calculated to assess the integrated runoff characteristics of the Issaquah Creek and Tibbetts Creek sub-basins. These discharges use the average of the 2-, 5-, 10-, 25-, 50-, and 100-year flow frequencies given in Table 5-2. Unit area discharges under current conditions range between 0.06 and 0.12 cfs/acre (Table 5-2), with a mean of 0.099 cfs/acre.

Table 5-2

Unit Area Discharge Under Current Land Use (cfs/acre)

Sub-basin	Area (acres)	Rainfall Scaling (1)	% Area <900' Elev.	% Area <1800' Elev.	% Forest Cover	Current Unit Area Disch.
Upper Iss.	11,539	1.33/ 1.46	52	88	80	0.12
Middle Iss.	20,911	1.17/ 1.29	58	86	81	0.10
McDonald	3,200	1.17/ 1.29	77	99	74	0.07
Fifteenmile	2,928	1.17/ 1.29	23	51	95	0.12
East Fork	5,606	1.42/ 1.56	52	83	88	0.12
North Fork	2,855	1.29/ 1.42	95	100	72	0.06
Lower Iss.	35,080	1.29/ 1.42	62	88	79	0.09
Tibbetts	3,460	1.29/ 1.42	65	99	78	0.11

(1): Multiplying factors for precipitation from Sea-Tac weather station. First value for areas <900 feet in elevation; second value for areas between 900 and 1800 feet in elevation.

For comparison, average unit area discharge values in the highly urbanized Hylebos and Lower Puget basins are somewhat lower at 0.078 cfs/acre (King County, 1990b). The largely forested, till-capped Bear/Evans Creek system has a current condition average of 0.044 cfs/acre (King County, 1989). Sub-basins east of Lake Sammamish have an average unit area discharge of 0.035 cfs/acre (King County, 1990c). The larger unit area discharges in the Issaquah Creek and Tibbetts Creek basins are the result of greater local precipitation rates, generally steeper topography, and a local geology dominated by significant amounts of bedrock and till.

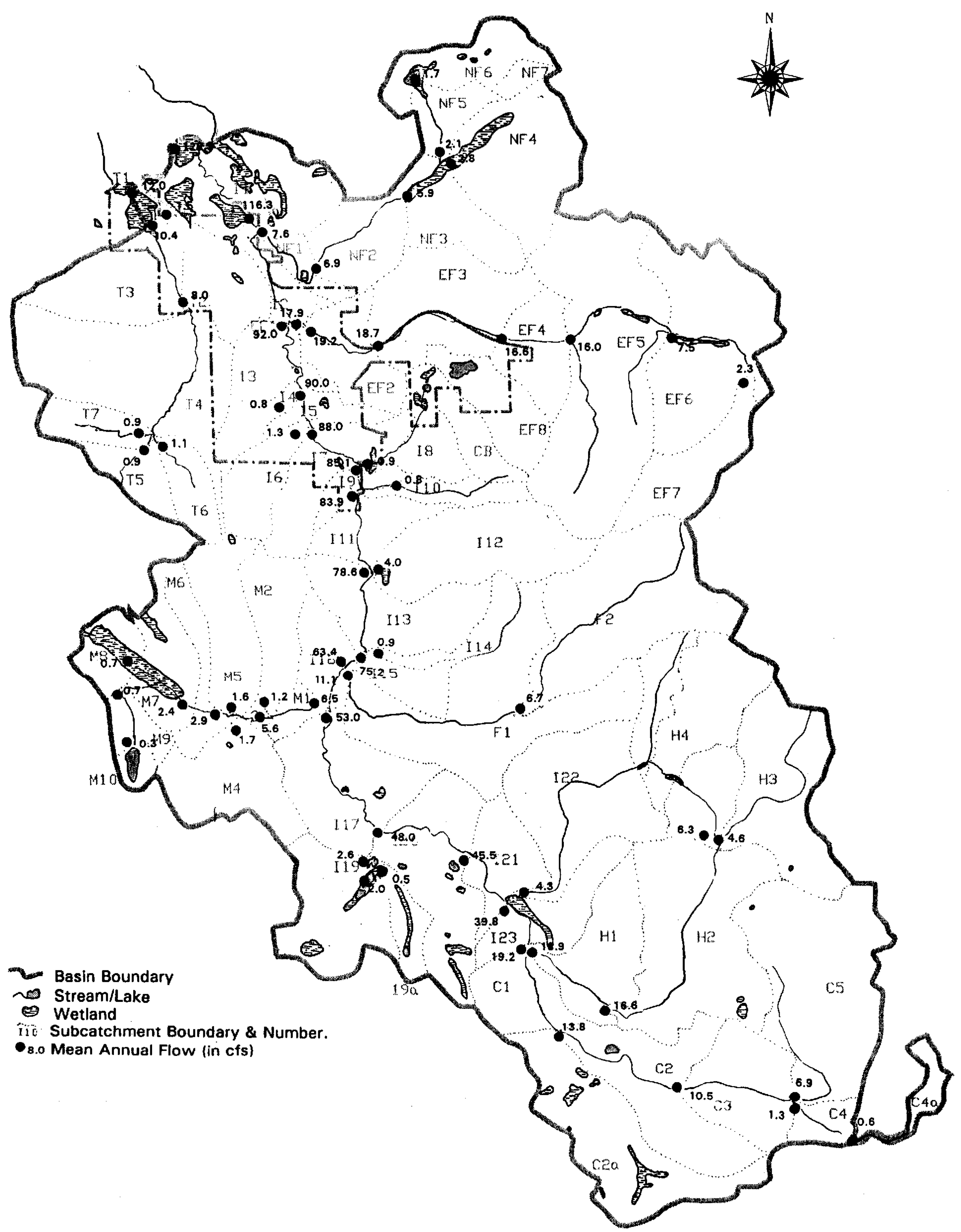
Headwater sub-basins (first six rows of Table 5-2) can be used to illustrate the influence of rainfall distribution on unit area discharge. Column three in Table 5-2 gives scaling factors used in applying rainfall recorded at the Sea-Tac Weather Station to specific sub-basins. The higher the scale factor, the greater the local precipitation. Columns four and five present the percent of sub-basin area below 900 and 1800 ft respectively. The three sub-basins with the highest local rainfall and the greatest percentage of land area above 1800 ft, Fifteenmile, East Fork Issaquah, and Upper Issaquah, also share the highest unit area discharge of 0.12 cfs/acre. In contrast, the McDonald (Mason) Creek and North Fork Issaquah sub-basins, which are the lowest in elevation and receive the least rainfall, generate the lowest unit area discharges.

The Fifteenmile Creek sub-basin is predominantly underlain by steeply sloping bedrock and is exposed to high local precipitation. This is particularly true for the upper subcatchment (F1) which is over 90 percent bedrock. The entire Fifteenmile sub-basin shares the highest unit area discharge despite retaining a 95 percent forest cover. As will be shown, similar combinations of topography, geology, and precipitation patterns make many of the modeled subcatchments extremely sensitive to the affects of future land-use change.

5.4.3 Mean Annual Flow

Mean annual flow is used to determine whether the filling of wetlands adjacent to a channel is subject to U. S. Army Corps of Engineers "Nationwide 26" permits (flow less than 5 cfs) or U.S. Army Corps of Engineers "Individual Section 404" permits (flow equal or greater than 5 cfs). Channels with mean annual flows greater than 20 cfs are considered a "Shoreline of the State" and are designated Class 1 under the King County Sensitive Areas Ordinance, and as Type 1 in the King County Surface Water Design Manual.

Mean annual flows at the outlets of all modeled subcatchments are presented in Figure 5-6. Mean annual flow exceeds 5.0 cfs at the outlets of all major sub-basins, ranging from a low of 6.5 cfs for the McDonald (Mason) Creek sub-basin to a high of 128.9 cfs for the Lower Issaquah sub-basin. Only on Issaquah Creek, from just below the confluence of Carey and Holder Creeks, does mean annual flow exceed 20.0 cfs.



MEAN ANNUAL FLOW AT SUBCATCHMENT OUTLET

Issaquah Creek Basin Planning Area

Figure 5-6

5.4.4 Rain-on-Snow

Rain-on-snow conditions were investigated for extreme events in excess of the 100-year condition. A storm event was constructed assuming that a 7-day, 100-yr rainfall follows and melts a 7-day, 100-yr snowfall. Both the rainfall and snowfall frequencies were determined from the long term gage at Landsburg. The 100-yr rainfall totals 10.8 inches and the 100-yr snowfall depth equals 39 inches. It was assumed that the rate of snow melt is proportional to rainfall intensity. The resulting liquid water contents were scaled for elevation. This allowed higher elevations to accumulate snow depths greater than 39 inches and receive a total amount of rainfall in excess of 10.8 inches.

The simulation results are summarized in Table 5-3 for current land use. Absolute increases in peak discharge resulting from the rain-on-snow event over the current 100-yr flow range from 88 cfs at the outlet of the North Fork sub-basin to 2404 cfs at the outlet of Lower Issaquah Creek. Percent increases in discharge range from 34 percent in the North Fork to 58 percent in the Tibbetts Creek sub-basin. Under future land-use absolute increases in peak discharge resulting from the rain-on-snow event over the 100-yr discharge range from 185 cfs in the North Fork to 2900 cfs at the outlet of Lower Issaquah Creek. Percent increases in discharge range from 40 percent in the North Fork to 55 percent in the Upper Issaquah Creek sub-basin. The role of snow in extreme flood events therefore could be significant. However, this analysis does not contradict the decision to omit snowmelt in the initial calibration and in model runs of flows up to the 100-year condition, because the period of gaged flows included no evidence of significant (i.e. > 1") accumulation of snow. The data in Table 5-3 do demonstrate, however, that for extreme events the inclusion of snowmelt may be necessary in formulating management alternatives.

Table 5-3

Flow Increases from Rain-on-Snow Event:
100-Year 7-Day Snowfall, 100-Year 7-Day Rainfall

Current Land Use

Sub-basin	Rain Only (cfs)	Rain-on-Snow (cfs)	Absolute Increase	Percent Increase
Upper Iss.	1999	3143	1144	57
Middle Iss.	2866	4301	1435	50

Sub-basin	Rain Only (cfs)	Rain-on-Snow (cfs)	Absolute Increase	Percent Increase
McDonald	338	529	191	56
Fifteenmile	498	774	276	55
East Fork	968	1438	470	49
North Fork	260	348	88	34
Lower Iss.	4425	6829	2404	54
Tibbetts	521	822	301	58

5.5.0 FUTURE CONDITIONS

5.5.1 Land Cover

Land use for the modeled future scenario was derived from maximizing existing zoning and comprehensive plans for King County and the City of Issaquah as described in Chapter 2. Future build-out conditions will result in a 50-percent reduction in forest cover, from 30,677 acres to 15,403 acres. The remaining forest cover is unevenly distributed, ranging from 71 percent in the Fifteenmile sub-basin down to 4 percent in the North Fork sub-basin (Figures 5-2 through 5-4). Land-use conversions from forest will result in an additional 321 acres of commercial and 365 acres of multifamily development. High-, medium-, and low-density single-family residential will increase by 3,348, 4,215, and 5,757 acres respectively. Approximately 622 acres of wetland-type soils are assumed lost to development (a 37-percent reduction). Most of this loss is the result of development on poorly drained (Soil Conservation Service type "D") soils. Inventoried wetlands are assumed to remain undeveloped. On the average, individual reaches will be affected by a 50-percent loss of forest cover, while grass and impervious areas will increase by 396 and 227 percent respectively.

5.5.2 Peak Flow Rates Under Future Land Use

The modeled future land cover is a "worst case" scenario used to estimate the upper limit of possible future flows. As such, it assumes no onsite or regional detention in any part of the basin. However, most future development will be subject to detention requirements depending on location and date of project approval. The degree to which actual future flow increases approach the modeled "worst-case" scenario will depend on the integrated affects of development locations, densities, and detention requirements. The effectiveness of various on-site detention

standards for new development will be analyzed in the basin plan, and the solutions developed in that plan will identify and presume a recommended detention criterion.

Peak annual flow data for each reach were analyzed using the procedure outlined under current conditions. A listing of the 2-, 10-, 25-, and 100-year flows is given in Table 5-4.

Table 5-4

Modeled Flow Frequencies Under Future Land Use
Peak Annual Flow Frequency
(in cubic feet per second)

Sub-basin	2-year	10-year	25-year	100-year
Upper Issaquah	930	1595	1977	2604
Middle Issaquah	1320	2267	2855	3765
McDonald	169	309	398	554
Fifteenmile	211	358	443	585
East Fork	429	731	902	1183
North Fork	135	256	332	463
Lower Issaquah	2078	3439	4210	5471
Tibbetts	287	474	576	739

Increases in discharge range from a low of 14 percent at the outlet of the Fifteenmile Creek sub-basin (which experiences the least reduction in forest cover) to a high of 78 percent for the North Fork sub-basin (Figures 5-7 and 5-8). Those sub-basins with the largest reduction in forest cover generally exhibit the greatest percent increases in peak annual flow. Interior subcatchments show flow increases from nearly zero to over 100 percent. The North Fork subcatchments and the upper reaches in the McDonald (Mason) Creek sub-basin show the largest percent increases.

In both the McDonald (Mason) and North Fork sub-basins the upper channel is low-gradient and fed by much steeper lateral tributaries. Much of the sediment derived from the steep tributaries is deposited in the lower-gradient valley. In McDonald Creek, increased runoff from clearing and development has caused a greater load of this sediment to be transported to the downstream

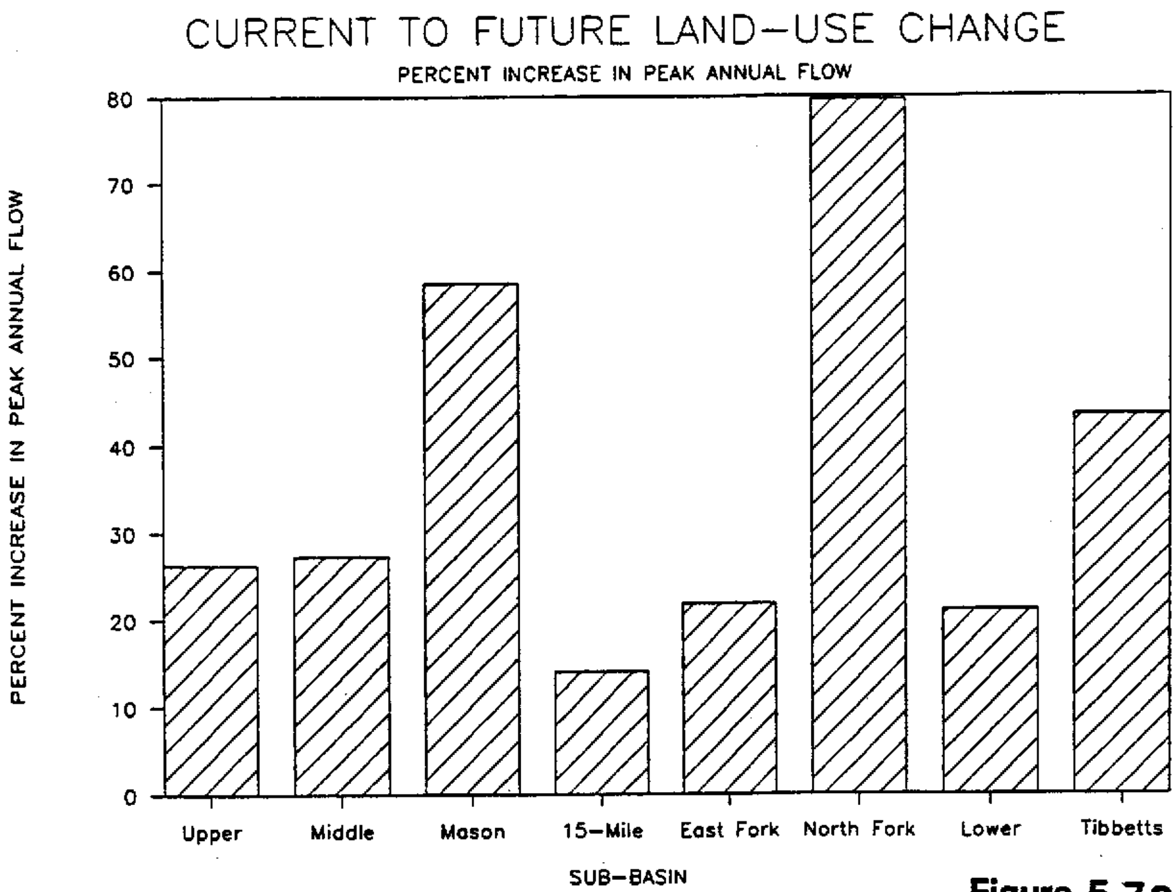


Figure 5-7a

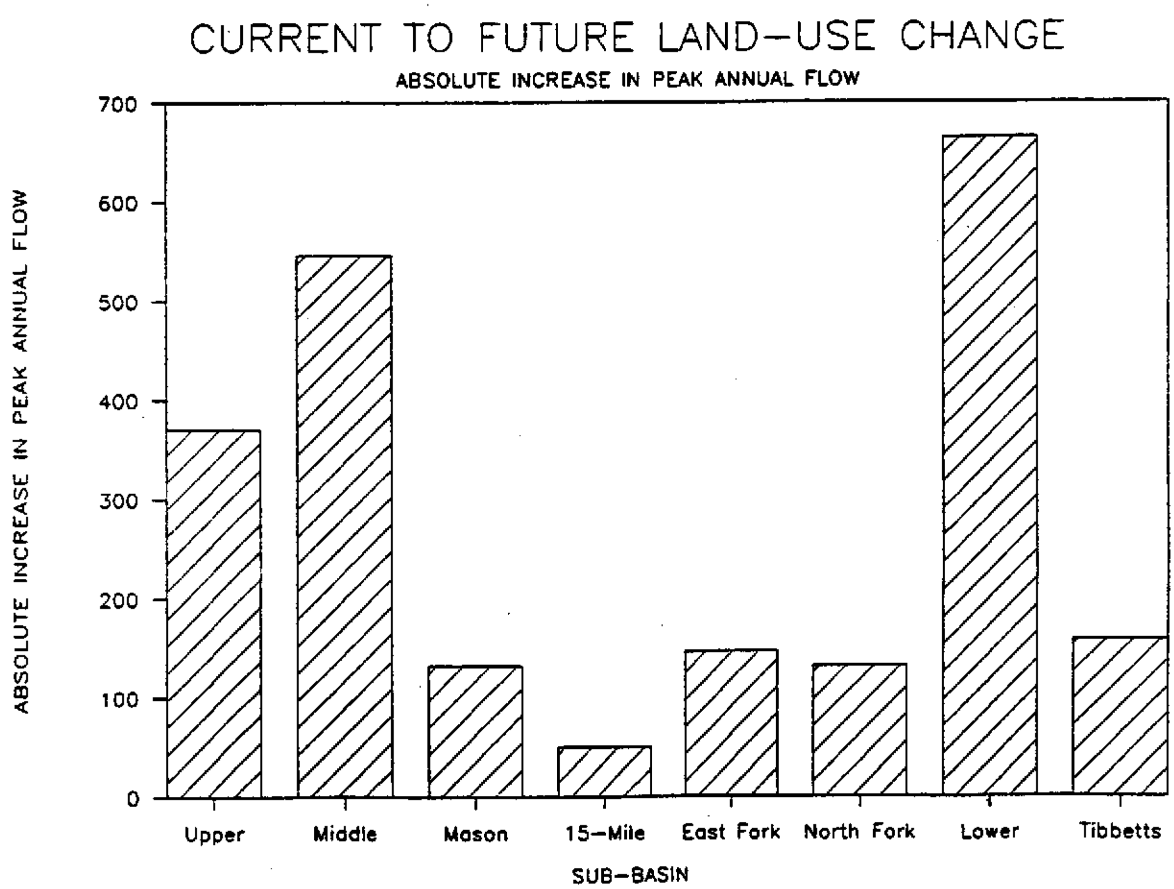
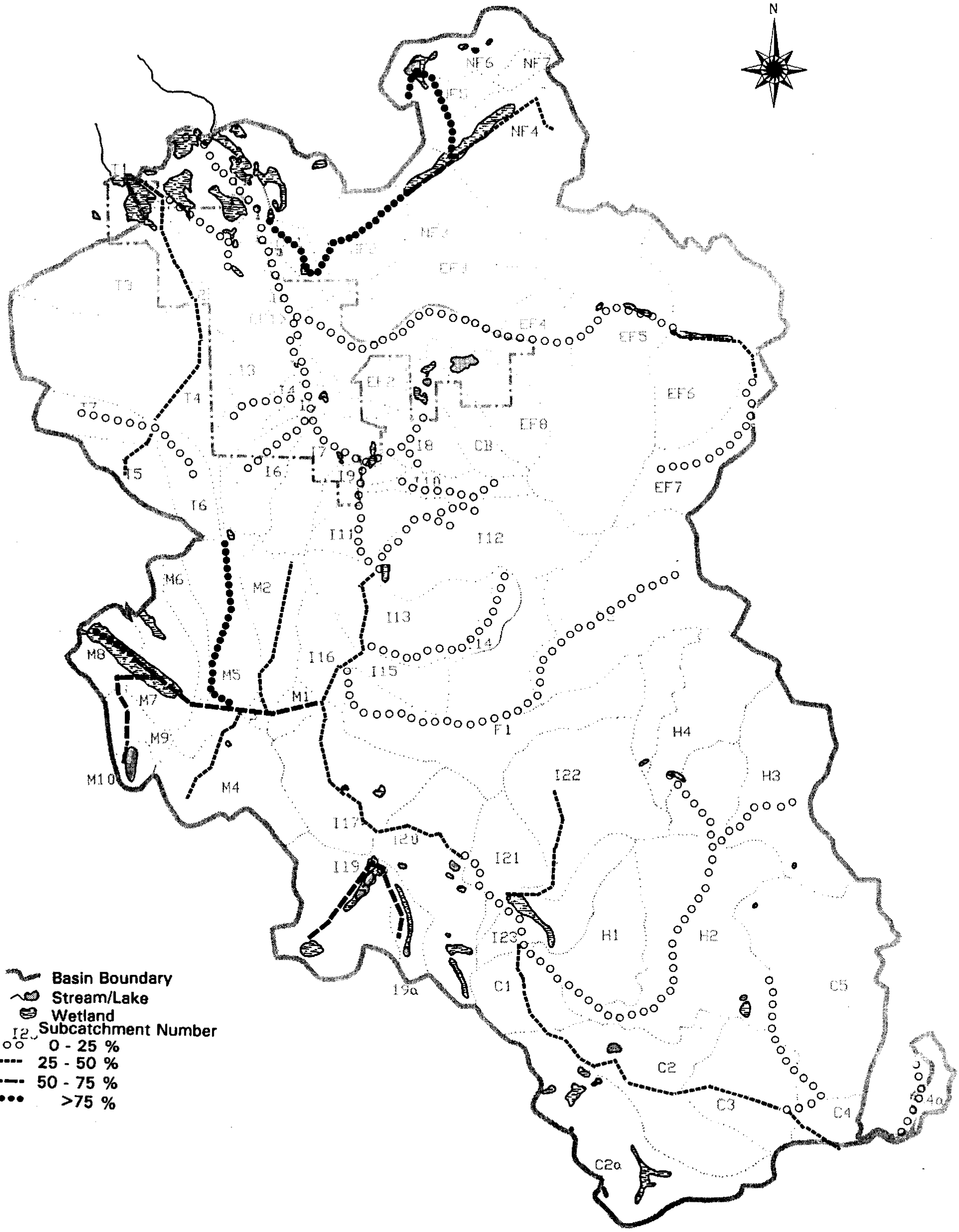


Figure 5-7b



PERCENT FLOW INCREASES FROM CURRENT TO FUTURE LAND USE

Figure

5-8

Issaquah Creek Basin Planning Area

system, causing infilling of the channel in some locations (see EROSION AND DEPOSITION OF STREAM CHANNEL SEDIMENTS, Chapter 7). This increase in runoff and decrease in channel conveyance has been particularly severe in the plat of Sunset Valley Farms. The large projected increases in future flows will substantially increase these flooding problems.

Generally, absolute increases in peak flow are directly tied to upstream contributing area. As a result, whereas the Lower Issaquah sub-basin only shows a 21 percent increase in peak annual flow, it produces the largest absolute increase of 664 cfs (Table 5-5 and Figure 5-9).

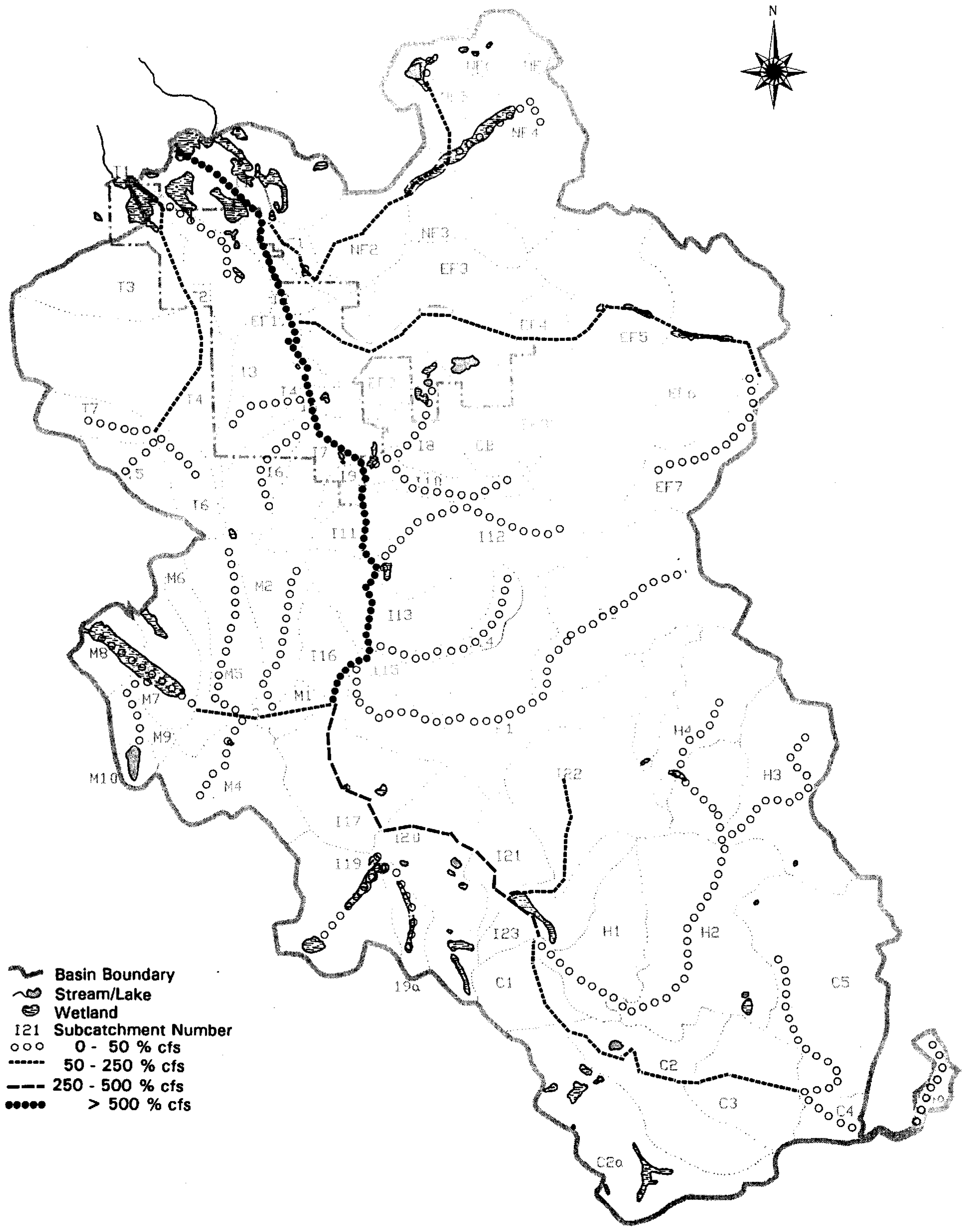
Table 5-5

Changes in Flow Frequency from Current to Future Land Use

Sub-basin	Area (Acres)	2-100 yr Average, Current (cfs)	2-100 yr Average, Future (cfs)	Absolute Increase (Fut-Cur) (cfs)	Percent Increase
Upper Iss.	11,539	1413	1784	371	26
Middle Iss.	20,911	2006	2553	547	26
McDonald	3,200	226	358	132	59
Fifteenmile	2,928	351	401	50	14
East Fork	5,606	668	814	146	22
North Fork	2,855	165	297	132	80
Lower Iss.	35,080	3151	3815	664	21
Tibbetts	3,460	363	521	158	43

Land-use change also affects the frequency at which a given discharge is exceeded. For example, at the outlet of the North Fork sub-basin the current 100-year flow has a return period of about 10 years under future conditions. In Lower Issaquah, the current 100-year flow corresponds to a 25- to 50-year flow under future conditions, and the current 25-year flow has a return period of about 10 years under future conditions.

The projected increases in peak flows will further aggravate existing flooding problems and introduce flooding in previously flood free areas. The accompanying increases in peak flow frequencies will cause a given level of flooding to occur more often in the future. Areas which



ABSOLUTE FLOW INCREASES FROM CURRENT TO FUTURE

Average of the 2-yr through 100-yr Peak Annual Flow

Issaquah Creek Basin Planning Area

Figure 5-9

are particularly affected include, lower North Fork Issaquah Creek, McDonald Creek, and Lower Issaquah Creek (see FLOODING, Chapter 6).

5.6.0 FORESTED CONDITIONS

5.6.1 Assumptions

Mitigating potential problems identified by the future land-use simulations may require reducing flow below current levels. To examine pre-development flow characteristics a model run was performed on all sub-basins in the Issaquah and Tibbetts basins. Under this forested scenario, all development was replaced by forest cover.

Data describing the physical characteristics of the basin in a pre-developed state are limited or nonexistent, necessitating the following assumptions:

1. The channel cross sections used in the model to route flows were not changed from either of the preceding land-use scenarios.

2. Culverts and other engineered structures were assumed to be present.

3. The amount of wetlands was assumed to be the same as in the current land-use scenario, even though significant wetland areas may have been lost during development to the present level.

4. All stream channels are assumed to remain in their present locations.

5.6.2 Peak Annual Flows

Peak annual flow data for each reach were analyzed using the procedure outlined under current conditions. A listing of the 2-, 10-, 25-, and 100-year flows is given by sub-basin in Table 5-6. Table 5-7 and Figure 5-10(a) summarize the affect of forest to current land-use conversion on flow frequencies. Percent increases in discharge at the sub-basin outlets are between 3 and 14 percent. These values are about one-fifth to one-sixth the increases associated with projected current to future land-use change.

Table 5-6

Modeled Flow Frequencies Under Forested Land Use
Peak Annual Flow Frequency
(in cubic feet per second)

Sub-basin	2-year	10-year	25-year	100-year
Upper Issaquah	707	1169	1419	1810
Middle Issaquah	1018	1686	2051	2632
McDonald	97	176	221	293
Fifteenmile	189	310	377	485
East Fork	324	541	658	842
North Fork	67	129	168	236
Lower Issaquah	1651	2684	3239	4106
Tibbetts	171	299	373	493

Table 5-7

Changes in Flow Frequency from Forest to Current Land Use

Sub-basin	Area (Acres)	2-100 yr Average, Forest (cfs)	2-100 yr Average, Current (cfs)	Absolute Increase (Cur-For) (cfs)	Percent Increase
Upper Iss.	11,539	1283	1413	130	10
Middle Iss.	20,911	1856	2006	150	8
McDonald	3,200	198	226	28	14
Fifteenmile	2,928	342	351	9	3
East Fork	5,606	594	668	74	12
North Fork	2,855	151	165	14	9
Lower Iss.	35,080	2935	3151	216	7
Tibbetts	3,460	335	363	28	8

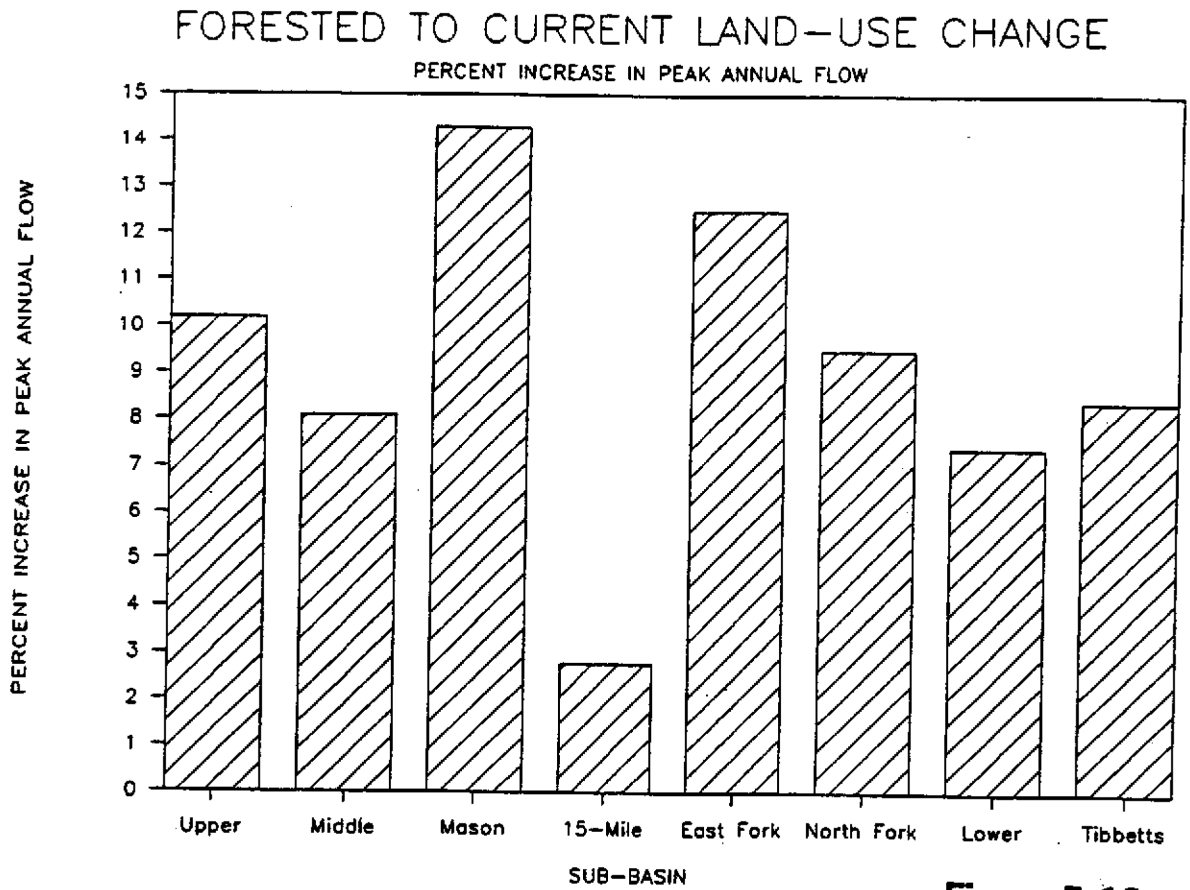


Figure 5-10a

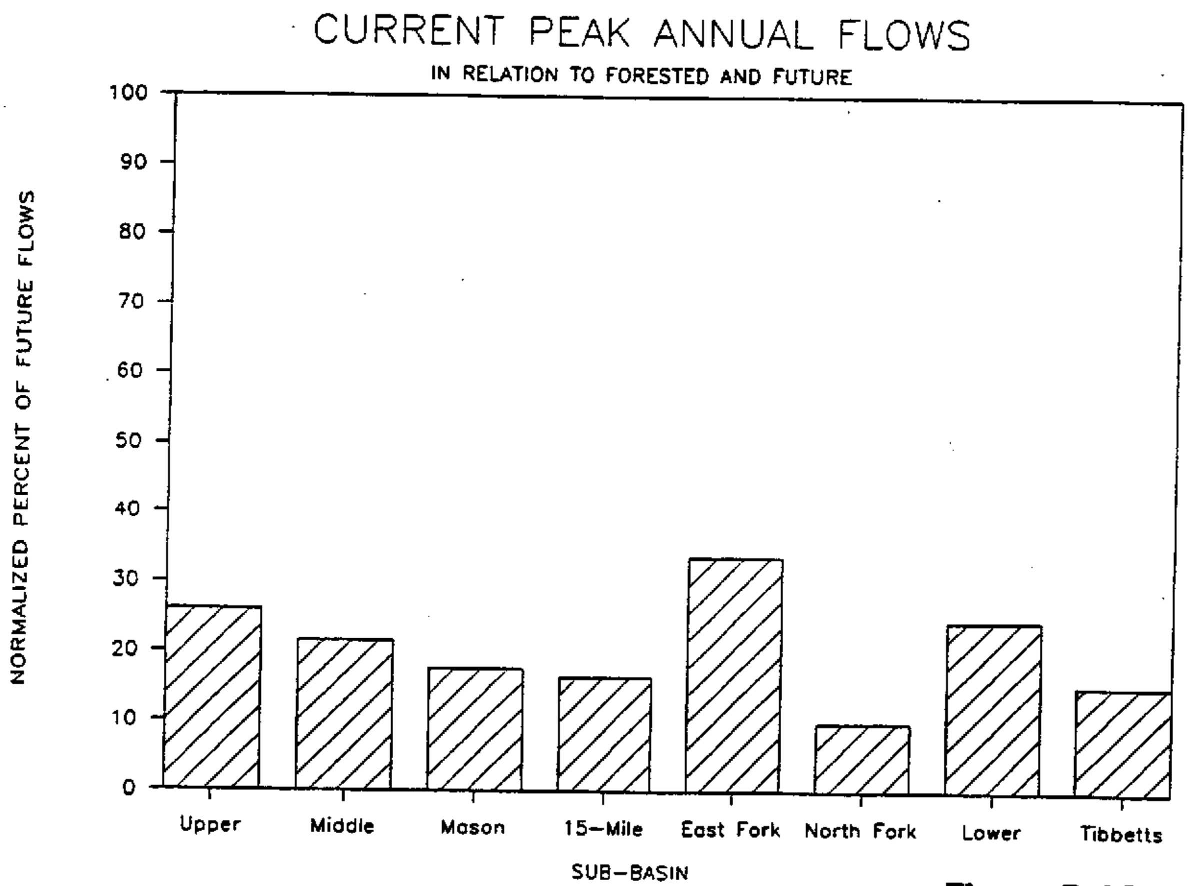


Figure 5-10b

The relationship of current flows to forested and future flows can be seen in Figure 5-10(b). In this figure the vertical axis ranges from zero to 100 percent. A value of zero corresponds to forested conditions while a value of 100 equals future conditions. As can be seen, normalized current flows range between about 10 and 35 percent of the total possible flow increase between forested and future build-out. This suggests that regulatory measures could be effective in controlling future flow related problems in all sub-basins. Obviously, structural solutions may be required in locations currently experiencing problems.

Changes in specific flow frequencies between forested and future land use can also be estimated. For example, at the outlet of the North Fork sub-basin the forested 100-year flow has a return period of about 5 to 10 years under future conditions. In Lower Issaquah the forested 100-year flow corresponds to about a 25-year flow under future conditions. The forested 25-year flow has a return period of about 5 to 10 years under future conditions.

5.6.3 Flow Durations

As discharge increases the potential rate of channel erosion and sediment transport increases (see EROSION AND DEPOSITION OF STREAM-CHANNEL SEDIMENT Section). The net volume of material eroded and transported by a given discharge is proportional to the duration of flow. Urbanization will increase not only the number and magnitude of peak flows but also their aggregate duration over the simulation period. Flow durations at the outlets of the North Fork and Lower Issaquah sub-basins are presented for the three land-use scenarios in Figures 5-11 and 5-12. The North Fork sub-basin was chosen because it experiences the largest percent increases in future flows. Lower Issaquah was selected because of the numerous downstream flooding problems near and within the City of Issaquah (see FLOODING, Chapter 6).

In the North Fork sub-basin the forested 2-year flow is exceeded an average of 19 hours per year under 1989 land-use conditions, a slight increase over forested conditions. However, the amount of time the forested 2-year flow is exceeded under future conditions is about 3 times as long as under the forest condition. The affect of land use is even more apparent when the forested 25-year flow is examined. The amount of time this flow is exceeded is about 5 times as long under current land use, and almost 60 times as long under future conditions as it was under forested conditions.

The Lower Issaquah sub-basin follows a similar, but less extreme pattern. Durations above the forested 2-year flow are about twice as long under future conditions as they are under forested conditions. This discrepancy increases when the 25-year forested flow is considered. The amount of time this flow is exceeded is about 4 times as long under future conditions as it is under forested conditions. These projected increases in flow durations (and peak discharges) will severely aggravate the existing sedimentation problems within the City of Issaquah.

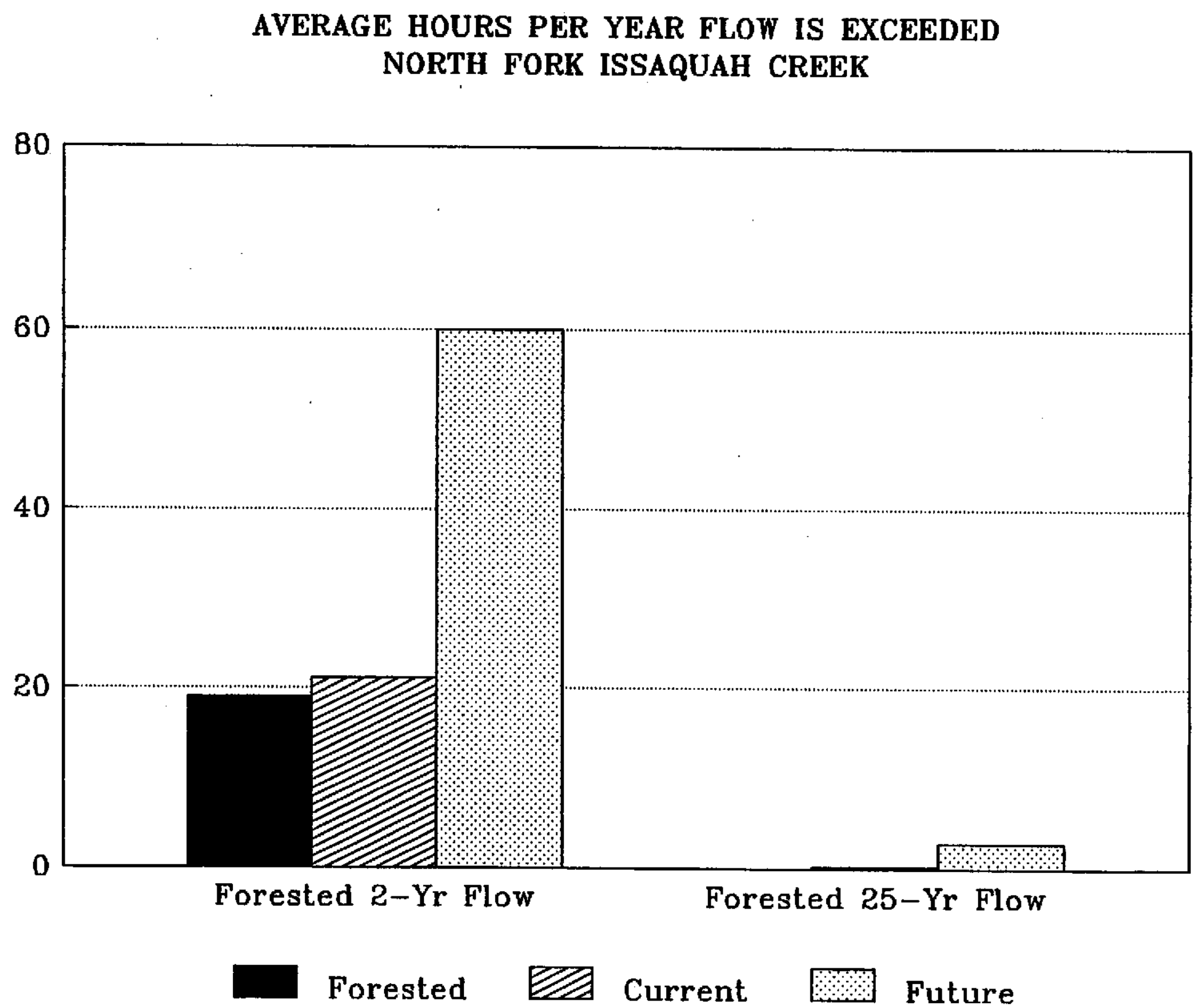

AVERAGE HOURS PER YEAR FLOW IS EXCEEDED
NORTH FORK ISSAQUAH CREEK
80
60
40
20
0
Forested 2-Yr Flow
Forested 25-Yr Flow
Forested
Current
Future

Figure 5-11

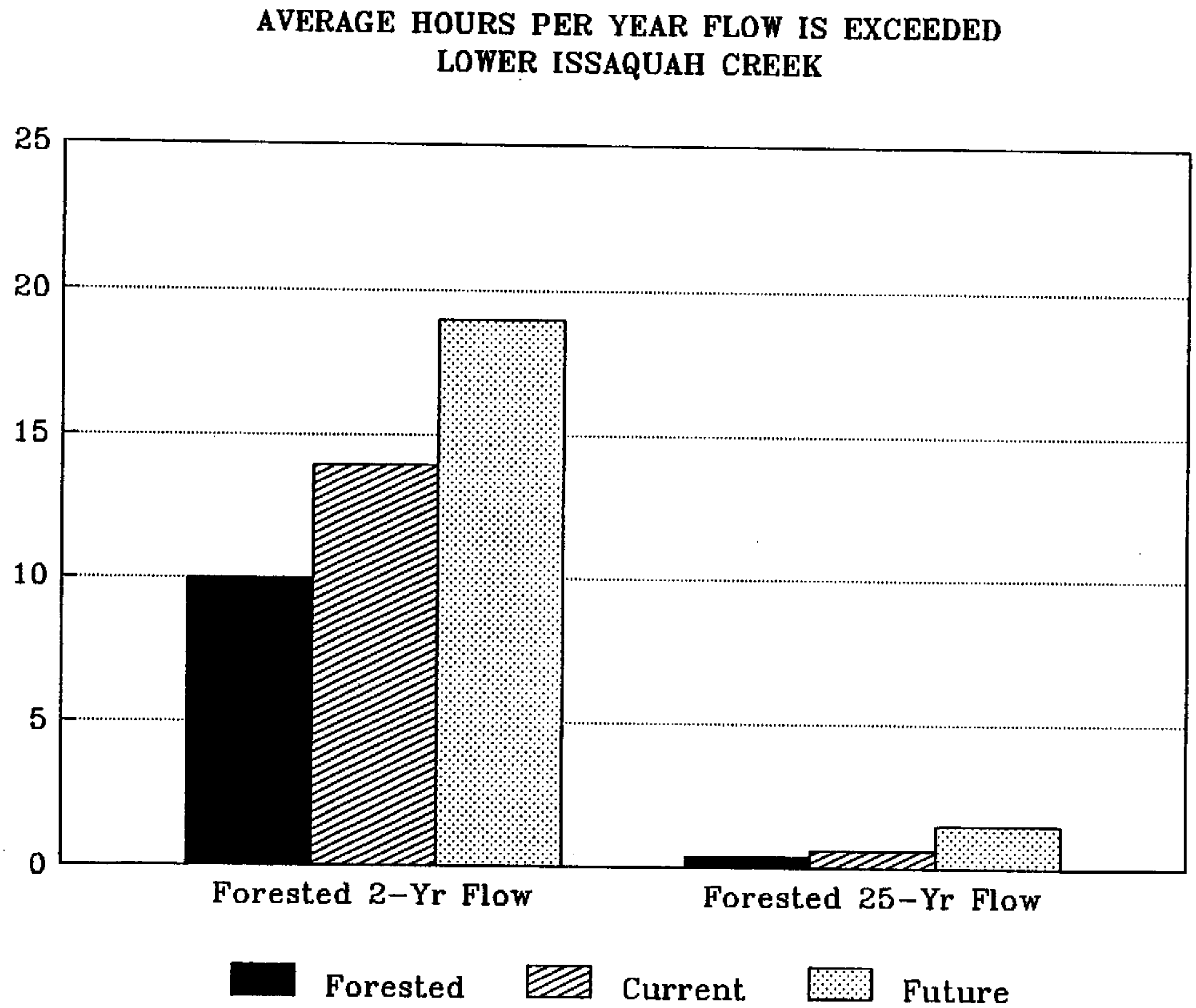

AVERAGE HOURS PER YEAR FLOW IS EXCEEDED
LOWER ISSAQUAH CREEK
25
20
15
10
5
0
Forested 2-Yr Flow
Forested 25-Yr Flow
Forested
Current
Future

Figure 5-12

Through urbanization, a basin becomes more responsive to rainfall patterns and is less able to dampen the effects of individual storms. Figures 5-13 and 5-14 present the number of flow excursions at the outlets of the North Fork and Lower Issaquah sub-basins. A flow excursion is defined as the period when the hydrograph rises above a given flow level, peaks, and then drops below that level. As discharge fluctuates during a storm a given flow level may experience numerous excursions. Therefore, while the number of excursions does not directly correspond to the number of storm peaks that occur during a model simulation run, it does reflect a basin's responsiveness to precipitation patterns. For the North Fork sub-basin, there are roughly 5 times as many forested 2-year excursions under future conditions as under forested conditions. This difference increases to 20 times the number of excursions when the 25-year forested flow is considered. The Lower Issaquah sub-basin again shows a similar pattern, with about twice as many forested 2-year excursions under future conditions as under forested conditions. This difference increases to 4 times as many future condition excursions with the 25-year forested flow.

It has been demonstrated that under future conditions without mitigation, the number, magnitude, and aggregate duration of peak flows will increase significantly. This would further aggravate the extent and occurrence of existing flooding problems and introduce flooding into previously flood-free areas. These unmitigated flows would also increase the severity of channel erosion and sedimentation problems. As a result, the nature and degree of mitigation needed to avoid such flow increases will be evaluated as pat of the development of the basin plan.

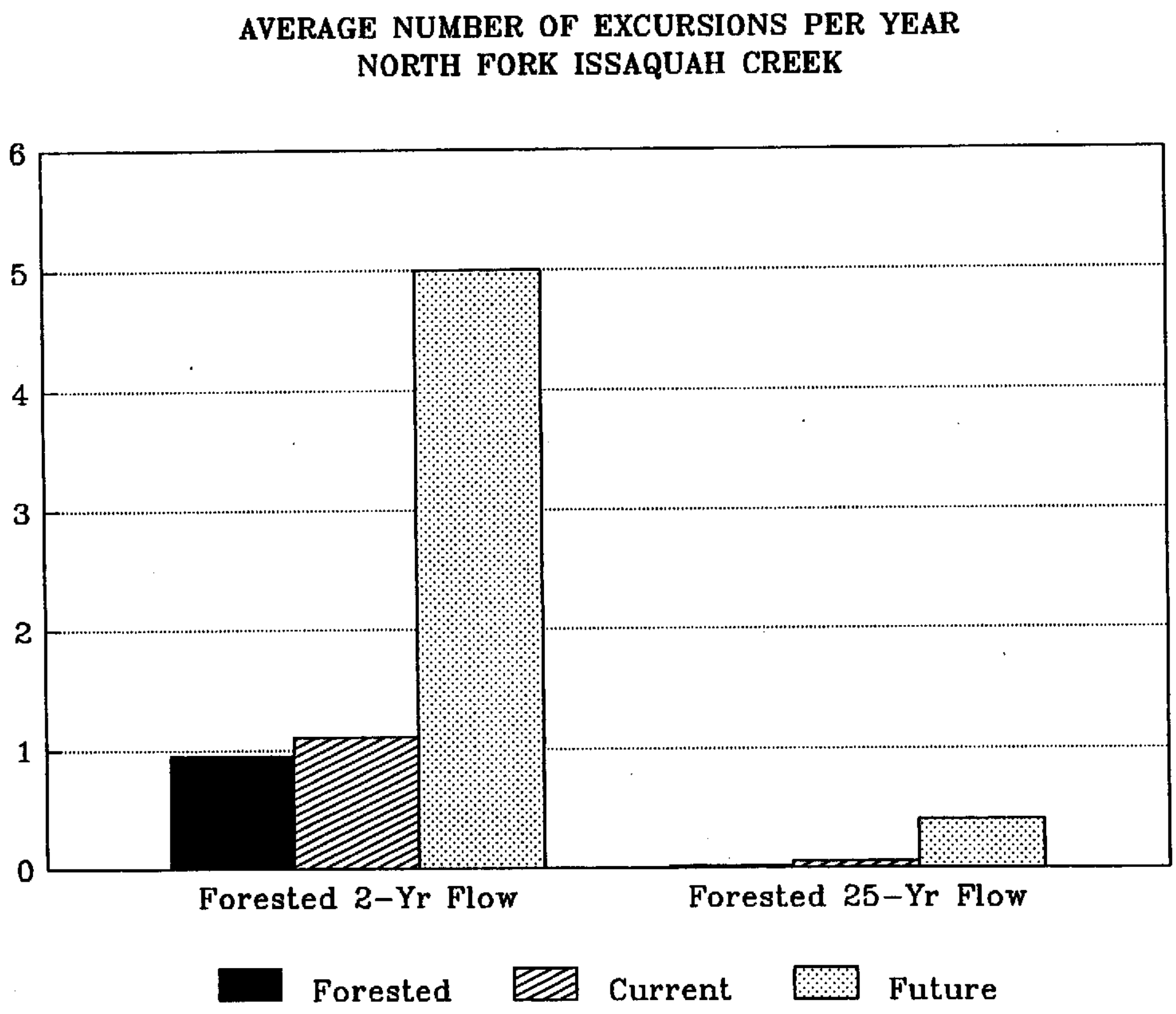

AVERAGE NUMBER OF EXCURSIONS PER YEAR
NORTH FORK ISSAQUAH CREEK
6
5
4
3
2
1
0
Forested 2-Yr Flow
Forested 25-Yr Flow
Forested
Current
Future

Figure 5-13

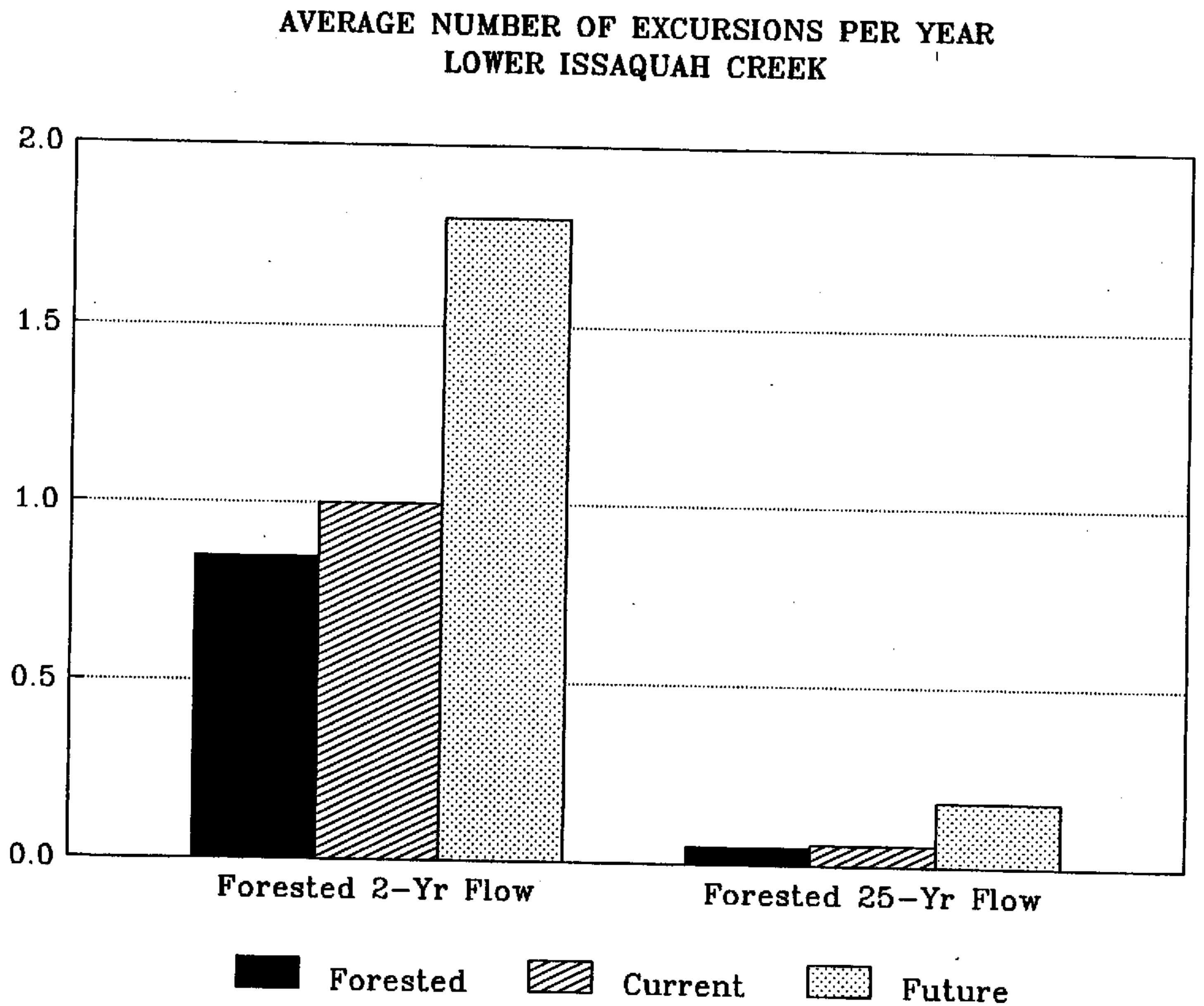

AVERAGE NUMBER OF EXCURSIONS PER YEAR
LOWER ISSAQUAH CREEK
2.0
1.5
1.0
0.5
0.0
Forested 2-Yr Flow
Forested 25-Yr Flow
Forested
Current
Future

Figure 5-14

5.6.0 KEY FINDINGS

- o Unit area discharges under current conditions range from 0.06 to 0.12 cfs/acre. These relatively large unit area discharges are the result of high precipitation rates, generally steep topography, and much bedrock and till in the basin. This combination of topography, geology, and precipitation patterns makes many of the modeled subcatchments extremely sensitive to the affects of future land-use change.

- o Under current conditions, mean annual flow exceeds 5 cfs at the outlets of all major sub-basins, ranging from 6 to 130 cfs. Only in Issaquah Creek, from just below the confluence of Carey and Holder Creeks, does mean annual flow exceed 20 cfs.

- o The increases in peak flows associated with the change from current to future land use range from 14 to 78 percent at major sub-basin outlets. Those sub-basins with the largest reduction in forest cover generally exhibit the greatest increases in peak flow. Interior subcatchments show flow increases from nearly zero to 114 percent. The North Fork sub-basin and the upper reaches of the McDonald (Mason) Creek sub-basin show the largest percent increases.
- o Current sub-basin flows account for between 10 and 35 percent of the total possible flow increase between forested and future build-out (i.e., most of the total increase has not occurred yet), suggesting that regulatory measures could be effective in controlling future flow related problems. Structural solutions may be required in locations currently experiencing problems.

- o Further urbanization of the Issaquah and Tibbetts Creek basins will substantially increase the number, magnitude, and cumulative duration of peak flows. This will further aggravate the extent and occurrence of existing flooding problems and introduce flooding into previously flood free areas. The severity of erosion and sedimentation problems will also be increased.

- o During the period of record, snowmelt did not significantly increase flows in Issaquah and Tibbetts Creek. Such an increase is likely only for combinations of extreme events in excess of anticipated 100-year conditions.

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Chapter 6
Flooding Analysis

CHAPTER 6: FLOODING ANALYSIS

6.1.0 INTRODUCTION

The Issaquah Creek Basin Planning Area has examples of many of the flooding processes that can affect small river systems in the Puget Sound basin. Storm runoff in the upper portions of the basin produces bank and bed erosion. Stream flow transports this sediment through the system. In lowland valleys, flat gradients slow the conveyance of runoff and sediment. The river deposits a part of these sediments in the floodplain. In the times since the last glaciation, stream channels migrated freely between the valley walls, forming meandering channels in the recently deposited alluvial plains and deltas. The forested floodplains in the valley bottoms provided storage for relatively rare high flows.

Since the settlement of the Issaquah basin, artificial constraints on the river system have resulted in problems not seen in the natural system. Undersized culverts in the upper tributaries clog with sediment and debris, flooding and washing out roads. Channelized lowland streams, now constrained in their migration, erode banks and damage buildings and roadways. Filled floodplains no longer store floodwaters, resulting in higher flood stages upstream and downstream.

This study of flood conditions in the Issaquah basin investigates two questions: first, what is the extent of flooding and flood-related problems in the basin, both presently occurring and expected in the future based on current zoning? Second, what is the status of previously adopted plans and proposed projects to address these problems? Alternative solutions to the system-wide flooding problems identified in this report will be evaluated in the basin plan. These alternatives will be drawn both from currently proposed projects and newly formulated solutions.

When reviewing the data from this basin, it became apparent that the flooding problem of most concern in the basin was the frequent flooding of the lower mainstem of Issaquah Creek between Sycamore Drive and Lake Sammamish. Related to this problem were flooding in the lower portions of Tibbetts Creek and the North and East Forks of Issaquah Creek. Since the scope of this problem and the range of solutions possible were well beyond those considered in previous basin plans, it was decided that a separate feasibility study of alternative solutions would be completed for this problem. This study is currently underway and will be used in preparing the final draft of this conditions report as well as the basin plan itself.

6.2.0 BACKGROUND INFORMATION

6.2.1 Current Projects and Studies

Flooding problems in the basin will result in solutions that include capital improvement projects. Basin Planning Program reconnaissance and drainage studies completed by the City of Issaquah, SWM Project Management and Design (PM&D) and Drainage Investigation (DI) units will be used to identify future projects. The King County Roads Division also has several projects in progress which have drainage design components. The Issaquah Basin Plan, of which this conditions report is a preliminary analysis, will provide substantial new information and analysis to quantify the magnitude of area-wide flooding and other basin problems. The King County Building and Land Division (BALD) and Issaquah Planning and Public Works Department also play key roles in preventing the worsening of existing problems by reviewing and conditioning development and by inspecting development projects to ensure compliance with floodplain regulations in both agencies.

Non-structural programs are currently in place in both jurisdictions to reduce flooding damage. These programs include development regulations limiting floodplain and floodway development, federally sponsored flood insurance programs for properties already developed, and emergency response programs. In addition, the city provides sand and bags to residents of flood-prone areas.

6.2.2 King County SWM CIP Program

The King County Council has adopted a six-year 1990 - 1996 SWM capital improvement program which is updated annually. Currently, there is one SWM CIP project constructed in the Issaquah basin.

a) Project 047017 - Mirrormont Drainage Improvement. Pipe and a detention pond were installed in 1988 to reduce flooding of houses and roads. Total Cost - $225,843.

In addition to this completed construction project, the following "projects" allocate funds county-wide for small drainage problems. A portion of these funds can be made available to solve problems in the Issaquah Basin.

b) Project 047055 - Small SWM CIP. Project to address small drainage problems anywhere in the SWM service area, including the unincorporated portion of the Issaquah basin. Ongoing program. Annual budget - $100,000 County-wide.

c) Project 047043 - Opportunity Projects Fund 318. Provides funds to use with other agencies or developers for projects with mutual benefits. Funds can be

used anywhere in the SWM service area, including the unincorporated portion of the Issaquah basin. Ongoing program. Annual Budget - $125,000 County-wide.

d) Project 045250 - Bank Stabilization - County-wide. Provides funds to stabilize stream and river banks to repair bank erosion resulting from flood events. This fund is not allocated to projects in a specific location, but is spent on projects determined annually by the SWM Division based on benefits, needs, matching funds, and permit requirements. The revetment project at the Four Creeks Ranch area, approximately River Mile 7.3 to 8.3 of the mainstem, is an example of this type of project. Ongoing Program. Annual budget - $100,000 County-wide.

6.2.3 City of Issaquah Drainage-Related Projects

The City of Issaquah has no drainage projects currently planned in this basin. The City is currently preparing a Comprehensive Facilities Management Plan that would include a drainage management element. This plan is to be coordinated with the basin plan.

6.2.4 Privately Financed Projects

At least one development proposal presently before the City of Issaquah would significantly impact the stream system in the basin. This proposal would increase the channel conveyance of Tibbetts Creek between SR 900 and I-90, with the intent of limiting flood damage on the east bank in order to allow construction of an office park there. Construction of an upstream sedimentation pond is included in this proposal.

6.2.5 King County Roads Division

Several road improvement projects have been proposed by the King County Roads Division and the City of Issaquah in the Issaquah basin. These road construction projects and design studies, may be important in addressing problems discovered while preparing this problems analysis. The project locations and current status are listed below for reference.

<u>County-wide</u>

a) Project 000389 - County-wide Bridge Redeck. Reserves funds for replacement,repair, and widening of County-maintained bridges. Ongoing. Estimated cost (1991 through 1995) - $3,005,000 County-wide

b) Project 300178 - Countywide [Road] Drainage Projects. Improve roadway drainage where potential hazards are revealed during heavy rains. Ongoing. Estimated cost (1991 through 1995) - $2,129,381 County-wide

Localized

c) Project 200690 - East Lake Sammamish Parkway. Widen to five lanes from SE 56th St. to Vaughn Hill Road. Includes a portion of SE 56th Street. Design to begin in early 1991 with construction in 1994. Estimated cost - $1,724,000

d) Project 200187 - East Lake Sammamish Parkway. Widen to 4 lanes from SE 56th St. to SE 43rd Way. Completed 1990. Total cost - $3,809,166

e) Project 200195 - Issaquah-Fall City Road. Widen to 4 lanes. Design to start in 1995. Estimated cost - $100,000 (1995 design costs only)

f) Project 200588 - Issaquah-Hobart Road. Improve the intersections with SE May Valley Road and SE Mirrormont Blvd. In design, with estimated construction in 1991. Estimated cost - $849,295

g) Project 201089 - Issaquah-Hobart Road Phase II. Improve the intersections with Donlon Road, Tiger Mountain Road, and Cedar Grove Road. Construction in 1991. Estimated Cost - $1,047,327

(Note: no project for the overall expansion of the Issaquah-Hobart Road has yet been adopted; however, such a project is anticipated in the years following completion of the two phases listed here.)

6.2.6 City of Issaquah Roads Projects

SE 56th Street Improvement:

Widen to up to six lanes from 17th Avenue NW to the City limits. The City is lead agency and is coordinating with the County. Includes reconstruction of the bridge over Issaquah Creek. Construction in 1992.

3rd Avenue NE Bridge:

Construct a bridge over the East Fork of Issaquah Creek to connect Gilman Blvd. with 3rd Avenue NE. In design, with possible construction in 1993.

In general, it appears that the Roads Division and SWM Division CIP projects will have little opportunity to deal with system-wide problems. However, localized problems, such as bank erosion and habitat loss, may be resolved with input from the Basin Planning Program. The three projects listed from the City are closely connected with major problem areas and close coordination with the Basin Plan will be needed to avoid exacerbating existing problems.

6.2.7 King County SWM Drainage Investigation Studies

Drainage Investigation (DI) received approximately 1600 drainage complaints in 1990 from citizens throughout King County (Davies, Personal Communication, 1990). About ten percent of these complaints typically result in enforcement actions. Others may form the basis for later County CIP projects. The remaining complaints are directed to agencies with jurisdiction or the citizen is advised on how to solve the problem themselves.

Drainage Investigation received at least 650 complaints related to the January, 1990, storm event alone. For the week of January 8, 318 complaints were filed county-wide, compared to only 60 complaints filed during the week of December 4th in 1989, during which another significant, but slightly smaller, storm occurred. For the January, 1990, storm, thirty-nine complaints were received from the Issaquah basin. County-wide, damage to public facilities from this storm was as much as $3.4 million. The Federal Emergency Management Agency reimbursed only about ten percent of the cost of the damage county-wide.

In addition to processing complaints, DI performs small-scale drainage studies to analyze flood problems and develop retrofit designs for existing retention/detention ponds. At the present time there is one special drainage study being conducted on flooding problems along McDonald Creek. Basin plan hydrologic data and floodplain models are being used in this study, which will be completed during fall 1991.

6.2.8 King County Basin Reconnaissance Recommendations

The King County Basin Reconnaissance Program, completed in 1987, recommended 14 projects, estimated at approximately $3.5 million (1987 dollars), for construction in these basins to address problems uncovered during the field investigations.

The projects recommended for the Issaquah Creek basin included the Mirrormont Drainage Improvement, constructed in 1988, and four wetland or instream detention facilities. Also recommended were an instream sediment trap on tributary 0200 and a channel realignment on tributary 0203. The later two projects were described as independently justifiable, but have not yet been scheduled for construction.

In the East Fork, three wetland regional detention ponds were recommended. On the North Fork, two instream regional detention ponds and a culvert replacement were proposed. An instream sedimentation/detention pond was proposed for Tibbetts Creek.

The conditions and project recommendations in the Reconnaissance reports were based on field reconnaissance only and not a comprehensive modeling of the stream system. A complete assessment of system needs could not be made under these conditions. The recommendations made will be updated and superseded by this Conditions Analysis and by the Final Basin Plan. Based on the more comprehensive investigation, and on hydrologic and hydraulic modeling results, additional projects will likely be recommended in the basin plan and some projects currently on the CIP program list may be recommended to be dropped.

6.3.0 DATA COLLECTION

Existing information about the drainage system was collected and reviewed by Basin Planning staff. Background data included the 1987 SWM Basin Reconnaissance Program reports, proposed City and King County projects and studies, drainage studies from private consultants, field observations, and anecdotal information from City and County staff and citizens. Drainage complaints submitted to the King County SWM Drainage Investigation (DI) Unit were reviewed. Patterns of complaints were analyzed to identify systemic problems in the basin. Reconnaissance program field notes, made in 1986 and 1987, were updated in the summer and fall of 1990 by Basin Planning staff who walked the stream system to update hydraulic, biologic, and geologic conditions in the stream system.

6.4.0 PREVIOUS FLOOD STUDIES

6.4.1 Federal Emergency Management Agency (FEMA)--1979

The Federal Emergency Management Agency published the "Flood Insurance Study, City of Issaquah Washington", dated November, 1979. This study was based on modeling done by Tudor Engineering in 1977. An additional study of areas in unincorporated King County was modeled by the U.S. Army Corps of Engineers, Seattle District, in August, 1976. Included in this study were the mainstem of Issaquah Creek from the mouth to SE May Valley Road and portions of Tibbetts, North Fork Issaquah, and East Fork Issaquah Creeks.

These studies are typical of flood insurance studies performed for FEMA nationwide. The standards by which the studies are done are uniform throughout the nation. Stream gage data, or hydrologic models based on current land use, are used for these studies. Hydraulic modeling is performed by a study contractor using a water surface profile model, most commonly the HEC-2 model developed by the U.S. Army Corps of Engineers. These studies are used by FEMA to prepare Flood Insurance Rate Maps. These maps are then used by the public for

determining flood insurance categories, and by local agencies to regulate development in floodplain areas.

6.4.2 Pickering Farms

In 1987, a study was performed by Horton Dennis and Associates to identify historic flooding and recommend corrective actions at the Pickering Farms Corporate Park, located on the west bank of Issaquah Creek between SE 56th Street and I-90. The study advanced the opinion that the stream reach between the Lake Sammamish State Park and SE 56th Street had experienced increases in water surface elevation of up to 1.5 feet due to sedimentation. Inadequate capacity of the SE 56th Street bridge and lack of channel dredging of the creek were cited by this consultant as the primary factors affecting increased flooding (Horton Dennis and Associates, 1987). The results of this study were used to set the design elevations for the buildings and drainage system for the Pickering Farms Corporate Park.

6.4.3 John Norman Study

Concurrently with the Horton Dennis study described above, John E. Norman, P.E., prepared a study of the lower mainstem of Issaquah creek from the mouth to I-90. This study focused on the overflows occurring on the west bank at SE 56th Street (study river mile 1.204) and on the east bank at study river mile 1.69. The study determined that flows in the main channel were significantly reduced as a result of this overflow. Results of the flooding on November 23, 1986, were incorporated into this study. (Norman, 1987)

6.4.4 FEMA Restudy--1987-88

In 1986, FEMA contracted with CH2M-Hill, Northwest, Inc. to revise portions of the 1977 Flood Insurance Study (FIS) and added several new stream reaches to the study. Included in this study were the mainstem of Issaquah Creek from approximately SE May Valley Road to SR-18, and MacDonald Creek from Issaquah Creek to approximately 128th Way SE (FEMA, 1988). The HEC-2 floodplain models for Upper Issaquah Creek and MacDonald Creek used for the present basin plan study were originally set up for this study.

This study was used to prepare the latest overall King County floodplain map revision.

6.4.5 SE 56th Street

This study was performed as a design study for the SE 56th Street Improvement project, for which the City of Issaquah is the lead agency. The study was performed by CH2M-Hill

Northwest, Inc. (City of Issaquah, Washington, 1990a) The HEC-2 model was based on the King County 1989 survey and was supplemented with additional cross-sections near the SE 56th Street bridge. The study determined that encroachment on the floodplain by development immediately downstream of the bridge was a more significant factor on the floodplains of the creek than was the existing bridge itself.

The SE 56th Street widening project will include a new bridge structure. The hydraulics study for the design determined locations and elevations for a flood protection berm at the Pickering Farms Corporate Park required as a part of Phase III of that development. The study also recommended floodplain excavation to increase the conveyance capacity of the floodplain downstream of SE 56th. The net effect of the bridge would be to slightly reduce floodplain elevations upstream of the bridge and slightly increase elevations downstream. A flow rate of 4373 cubic feet per second for the 100-year event was used for design. Based on HSPF modeling for the basin plan, which predicts a flow of 5471 cfs for a 100-year future conditions event, the capacity of the bridge would be adequate to pass the predicted future 25-year flow of 4210 cfs.

6.4.6 Klohn Leonoff Study

This study was performed by Klohn Leonoff, Inc., in August, 1990, for the City of Issaquah, using survey data and a HEC-2 model of Tibbetts Creek provided by King County. The purpose of the report was to study alternatives for limiting flooding in the light industrial area downstream of Newport Way. Although HSPF simulated flows were available from the King County Basin Planning Program in October, this study used a Log-Pearson Type III distribution of existing gage data to estimate flows. While the correlation with existing condition HSPF flows is good, the channel improvements based on this modeling may not have sufficient capacity to convey the unmitigated future 25-year flows as modeled by King County. The report included habitat mitigation design and a recommendation that a sedimentation pond be constructed upstream of Newport Way to control sediment deposition in this portion of the creek. The final report has been issued (City of Issaquah, 1990b).

6.4.7 Evaluation of Previous Flood Studies

When evaluating these studies, differences in flows used and the long time span over which the different studies were done make a direct comparison a somewhat dubious exercise. Basin Planning staff compared the model results for the lower portion of Issaquah Creek below I-90 and found a general agreement in flood profiles after accounting for differences in stationing and reference datums. In general, the flooding elevations computed in these studies correlate well with those observed in the field during flood events smaller than those modeled. Comparison of the surveyed cross section data was useful in comparing trends in Issaquah Creek stream bed profile changes discussed in Chapter 7.

6.5.0 SPECIAL FLOOD HAZARD AREAS

Since the passage of the National Flood Insurance Act of 1968,the Federal Emergency Management Agency (FEMA) has identified many floodplain areas nationwide on Flood Insurance Rate Maps (FIRMs). These "Special Flood Hazard Areas" (areas within the mapped "100-year" flood boundary) have been identified on the City of Issaquah and King County FIRM's in this area (Federal Emergency Management Agency, 1988).

The remainder of the basin area has been designated as "Zone X" or "Zone D" by FEMA for insurance purposes. These designations apply to all areas that lie outside the mapped "500-year" floodplain or where no flood hazard has been determined. Zone X is considered an "area of moderate or minimal hazard from the principal source of flood in the area". Zone D is an area for which flood hazards have not been determined. This does not exclude the possibility of flooding caused by severe, concentrated rainfall generating a volume of runoff larger than the design capacities of the existing local drainage systems. Local stormwater drainage systems are not normally considered in flood insurance studies. However, the "failure of a local system creates areas of high flood risk within these rate zones" (Federal Emergency Management Agency, 1987b).

6.6.0 EXISTING LOCAL FLOODPLAIN REGULATIONS

King County's Sensitive Areas Ordinance 9614 (SAO), adopted by the County Council on August 29, 1990, provides for setbacks and buffers to protect the habitat and storage functions of stream corridors. The ordinance also includes design criteria and standards for flood hazard areas. In many cases, the floodplain widths modeled in the Issaquah Creek basin exceed the required buffer widths from streams and wetlands. Thus, the floodplain provisions of the SAO may be an important tool in regulating development in these areas.

The SAO specifies a "Zero-Rise Floodway" in King County. The "Zero-Rise Floodway" concept does not generally allow development activities within the floodplain, such as grading, filling, or building of structures, that would cause a perceptible rise in the floodplain elevation. The computation of floodplain elevations is based on future land use condition flows, where available. While this provision can prohibit filling and construction of buildings or other structures within the floodplain, it does not by itself limit clearing or activities that may damage other functions of the stream system. Compensatory storage is also allowed if it can be shown to be hydraulically equivalent to the volume of floodplain storage displaced by filling or structures. In combination with buffer requirements in the SAO, these floodplain regulations will provide the major regulatory tools for protecting the stream corridor and safeguarding health and safety in these areas of unincorporated King County.

In 1991, the City of Issaquah adopted an interim Critical Areas Ordinance, which will be in effect until September, 1992. The floodplain management provisions of this ordinance closely

follow those of King County's SAO. Issaquah and King County (prior to the SAO) stream protection and floodplain regulations formerly allowed a one foot rise above the base flood elevation. The computation was based on existing historic flows. These former regulations closely followed FEMA's minimum requirements to qualify for the federal Flood Insurance Program.

6.7.0 OTHER SOURCES OF INFORMATION

The most valuable source of information on flooding conditions in the basin were the January and November storms of 1990, and the April 5, 1991, storm. Flows at SE 56th Street are summarized in Table 6-1 for these events. The flow estimate for the January, 1990, storm is based on high water marks upstream of the I-90 bridge, since a significant portion of the water in the creek overflowed and crossed SE 56th Street west of the main channel, bypassing the United States Geological Survey (USGS) gage just downstream of SE 56th Street. Flow estimates are provisional and may change slightly after review by the USGS (Fuste, 1990). The recurrence interval is based on the flow frequency distribution modeled by King County for the 1989 land use condition.

Table 6-1

Summary of Recent Storm Flows in Issaquah Creek at SE 56th Street

Event	Time	Flow	Approximate Recurrence Interval
1/9/90	-	3800 cfs	40 years
11/10/90	1345	1850 cfs	2 years
11/24/90	1045	3170 cfs	15 years

The City provides sandbags and sand to residents, which, when properly placed, can reduce property damage. Even so, residents were evacuated from two houses during the November, 1990, storm. County-wide, thirty residences were destroyed and 633 were damaged. According to press reports, many homes were damaged along Issaquah Creek (Seattle Post-Intelligencer, 1990).

The 1990 storms were first-hand demonstrations of how the existing stream systems function under severe flood conditions. During the storms, City of Issaquah and King County SWM staff members observed and photographed much of the flooding. Photos were taken at numerous locations and are on file in the Basin Planning office. These data were used to verify HEC-2 and culvert hydraulics modeling.

The City of Issaquah Public Works Department lists 28 significant flooding problems within the City limits that regularly occur during major storms. Twenty-six of those problems appear to relate directly to the stream system. Problems reported include flooding of roads, commercial properties and both single and multiple family residences. Also reported were erosion and landslide problems. Problems located in the County and City are shown on Figure 6-1.

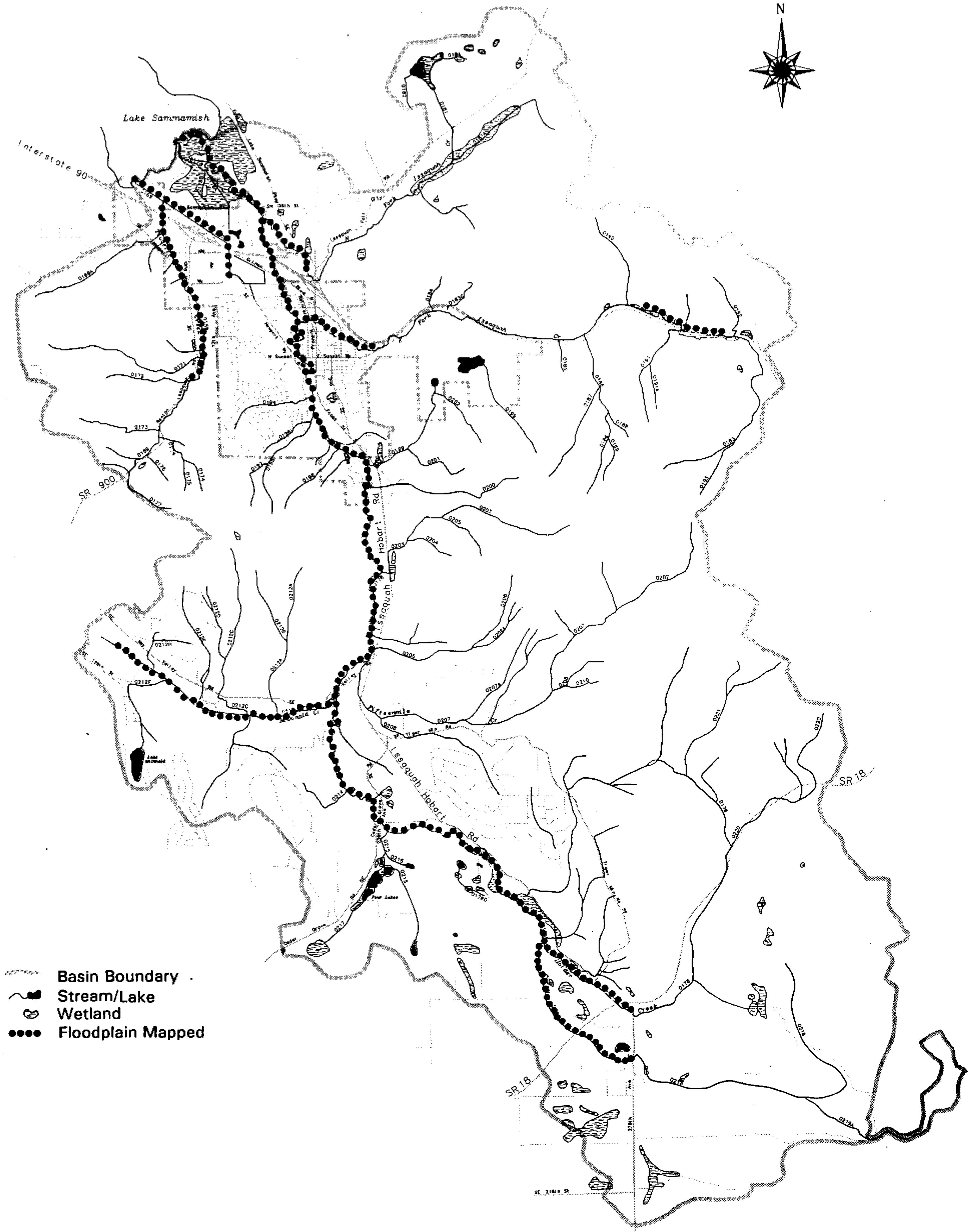
6.8.0 HEC-2 FLOODPLAIN MODEL

The floodplain was modeled for the portions of the Issaquah stream system shown in Figure 6-2 using the 2-, 10-, 25-, and 100-year flows computed by HSPF. Reaches selected for modeling were those most prone to flooding: streams having relatively flat gradients and broad overbank areas. Reaches modeled also had been selected based on the intensity of development or potential development adjacent to the floodplain area. Localized drainage problems, involving failures of maintenance or design of constructed drainage systems, such as found in developed subdivision streets or developed commercial areas, were not studied.

The hydraulic model used in this study is the US Army Corps of Engineers HEC-2 Water Surface Profile computer program (Corps of Engineers, 1984). This model simulates the hydraulics of the stream system in great detail. Using flows generated by the HSPF model as input, HEC-2 computes water surface elevations and other hydraulic parameters for stream reaches whose cross sections have been surveyed and coded into the model. The effects of bridges, culverts, weirs, levees, and dams are also computed by coding in the surveyed and measured geometry of these hydraulic structures.

Data for setting up the floodplain model consist largely of surveyed stream cross sections, both in the valleys and at bridge or culvert crossings, and estimates of the roughness coefficient, Manning's "n". Generally, about seven to eight cross sections per stream mile have been sufficient. Additional data came from topographic mapping (at two foot contour intervals and 1" = 100' horizontal scale), and from field notes and photographs of vegetation and bank conditions. Roughness coefficient was estimated using roughness values tabulated by Chow (1959) and Righellis (1988) and compared with photographs of channels of known resistance values (Barnes, 1967).

The principal use of the HEC-2 program is to determine water surface elevations of the floodplain for various flood frequencies. The output from the program can also be useful in



FLOODSTUDY REACHES

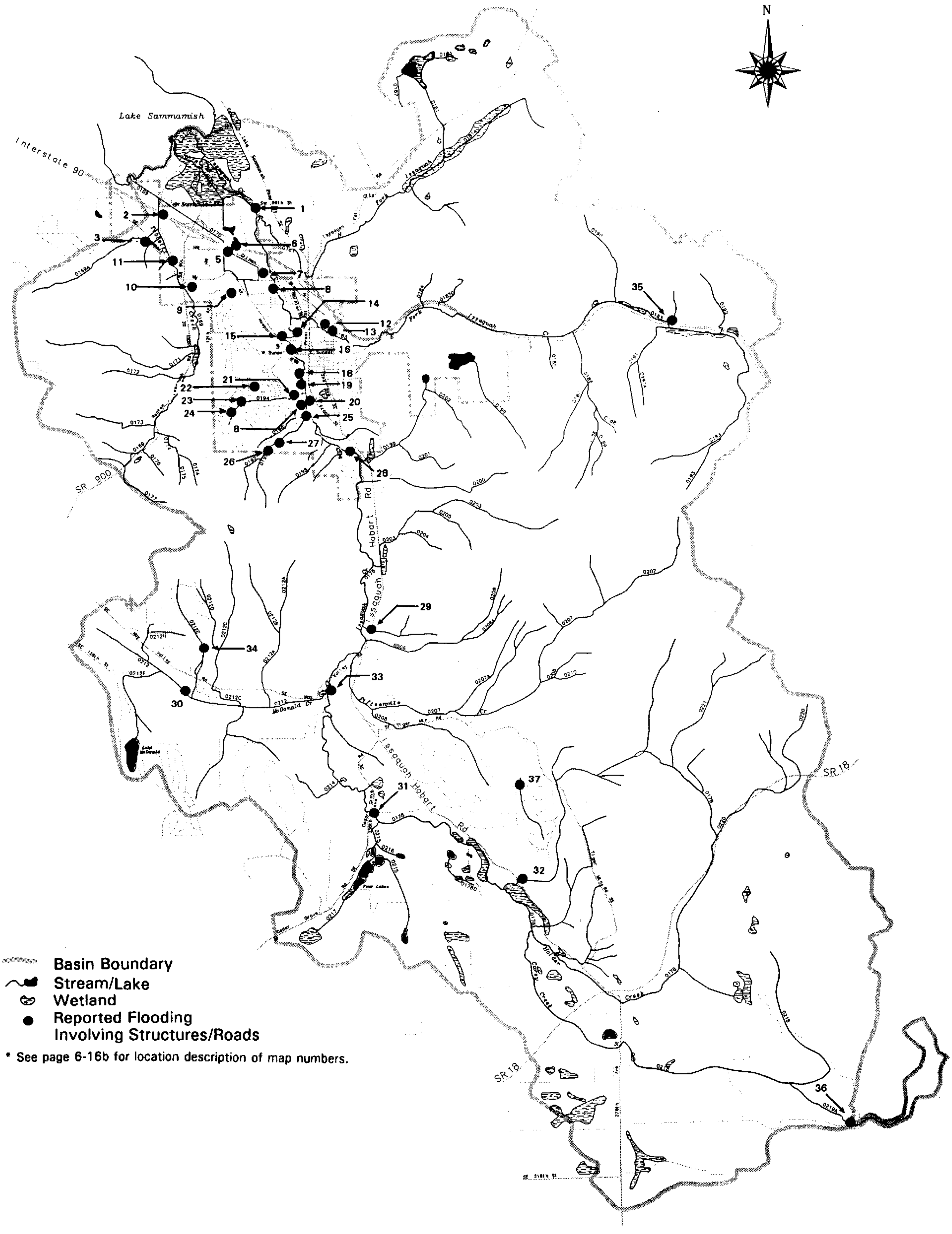
Issaquah Creek Basin Planning Area

Figure

6-1

FIGURE 6-2 LOCATION DESCRIPTION

Map #	Location and description of observed flooding problems
1.	Issaquah Creek at SE 56th St.- Water over roadway west of creek, water surface above lower chord of bridge during heavy storms.
2.	Poplar Way at 19th Avenue NW - Tibbetts Creek backs up from I-90 culverts, berm built without permits, commercial area and roads flood.
3.	Summerhill (Anti-Aircraft Creek) - Sediment deposited on Newport Way. Creek floods five homes and migrates during heavy rains.
4.	Tibbetts Creek from Tibbetts Manor to I-90 - Sedimentation in stream channel reduces capacity. Pasture areas flooded.
5.	Gilman Boulevard - Floods, leaving only two lanes available during heavy storms.
6.	Storm Drain outlet from I-90 - Capacity insufficient for flow. Restaurant floods during heavy rains.
7.	Hi-Lo shopping Center - Floods during heavy rainfall events.
8.	Issaquah Creek floods residences.
9.	Detention pond overflows, contributing to flooding of 12th and Newport intersection. Flow continues to Gilman Boulevard.
10.	Tibbetts Creek - Overflows right bank, flooding 12th and Newport intersection.
11.	Sediment deposits clog culvert.
12.	Issaquah Creek overflows banks.
13.	Issaquah Creek overflows banks.
14.	Issaquah Creek overflows banks.
15.	Issaquah Creek overflows banks, floodwalls constructed adjacent to creek.
16.	West Sunset Way and senior citizen housing floods. Overbank flows come through fish hatchery.
17.	Fish hatchery floods when creek overflows. Loss of fry and bank erosion problems.
18.	Overbank flows flood Clark Street and residences, floodwalls constructed adjacent to creek.
19.	Issaquah Creek overflows banks, flooding residences; floodwalls constructed adjacent to creek.
20.	Issaquah Creek overflows banks, flooding residences.
21.	Mine Hill Creek at Wildwood Boulevard - Sediment clogs culvert and overflows road.
22.	Landslide activity contributing to sediment load.
23.	Landslide activity contributing to sediment load.
24.	Stream downcutting has exposed a sewer pipe below channel, contributes to sediment load.
25.	Sediment from Cabin deposited in Issaquah Creek. Contributes to sedimentation behind hatchery dam.
26.	Offstream erosion problems contributing to Cabin Creek Sediment loads.
27.	Cabin Creek has high flows during heavy rainfall events and carries a significant sediment load.
28.	Issaquah Creek and tributaries 0199 and 0200 overflow flooding numerous homes, Issaquah-Hobart Road, and 238th Way SE.
29.	Nudist Camp Creek culvert plugs with sediment, overflows on to Issaquah-Hobart Road.
30.	Sunset Valley Farms - MacDonald Creek floods frequently due to flat gradient and sediment from side tributaries. Residences flooded.
31.	SE 156th St. - Issaquah Creek out of banks, road under water.
32.	Pheasant Creek (0213A) - Culvert overtopped, flooding road and houses.
33.	Four Creeks Ranch area - Bank and abutment erosion and flooding.
34.	High Valley - Stream flows over banks, flooding yards.
35.	I-90 at East Fork Issaquah Creek - Westbound Lanes flooded, 1990
36.	Taylor Road at Carey Creek - Water over road, culvert capacity exceeded.
37.	Un-numbered tributary to Pheasant Creek (0213A) at SE 152nd Street - Flooding of road and houses.



FLOODING LOCATIONS

Issaquah Creek Basin Planning Area

Figure 6-2

studying sediment transport and habitat, and in setting up stage-discharge-volume-area relationships (F-tables) needed for channel routing in the HSPF model. Ninety-five different variables may be calculated including flow velocities, water surface elevation, stream cross sectional area, and the horizontal extent of the floodplain for a given flow.

A new HEC-2 model was set up for those portions of the Issaquah system that had not been revised since 1977 (David Evans and Associates, 1990). This model of Issaquah Creek is based on 1989-90 survey data and is the most recent floodplain model currently in existence. This model does not, however, consider any changes in channel geometry which may have occurred during three large events in January and November of 1990, and April of 1991. The largest changes are likely to be in the location and size of sediment bars and in additional bank erosion. Flood insurance studies could be based on this model if the channel geometry were first verified by field survey. Depending on the amount of resurvey required, between 75 and 90 percent of the work required to complete the flood insurance study modeling has been done.

The modeling completed thus far for the Issaquah Basin Plan is satisfactory to determine relative changes between current and future conditions, but not absolute floodplain boundaries and elevations. Final calibration to high water marks and gaged flows, and final flows based on Basin Plan recommendations are required before floodplain and floodway configurations could be finalized.

6.9.0 MODELING RESULTS

Modeled flows from HSPF were input into the HEC-2 model. The resulting areas of inundation and floodplain profiles were computed. The results are summarized in Table 6-2. Table 6-2 lists the major road crossings in the reaches of the stream system for which floodplain modeling was done. Six roadway crossings in the basin are predicted to fail more frequently than once in 25 years on average. Ten crossings would overtop during events with return periods between 25 and 100 years. Private drives and roads were not listed. Modeled floodplain elevations are available from the Basin Planning program for these private crossings and other locations along the reaches modeled.

The increases in floodplain elevation between the 1989 Flood insurance study and the basin plan floodplain modeling range from 0.3 to 5.2 feet. The maximum difference occurs at one location near Sycamore Drive. The model used for the FEMA study was not available to determine the reason for the differences at this location.

King County uses a "25-year" design standard to determine the adequacy of all new bridges and road culverts (King County, 1990). The City of Issaquah requires the same standard. Since emergency vehicle access may be hampered during flooding conditions, this criteria is an important consideration in bridge and culvert design.

Table 6-2

Future 100 - Year Flood Elevations at Major Road Crossings

Location	Modeled Floodplain Elevations (Feet Above NGVD Datum)		Road Elevation (Feet)	Road Flooding Frequency (Years)
	FEMA	Basin Plan		
Issaquah Creek				
Access road	N/A	34.09	31.4	25-100
SE 56th	49.1	50.99	48.2	>100(1)
Interstate 90	60.3	60.80	63.7	>100
Gilman Blvd	61.7	64.68	65.4	>100(2)
Juniper Street	66.6	68.88	68.3	10-25
Dogwood Street	78.8	79.07	79.0	25-100
W Sunset Way	88.1	89.74	89.5	25-100
SE Clark Street	94.4	97.11	94.9	10-25(3)
Sycamore Drive	125.5	130.69	125.1	2-10
113th St SE	N/A	165.72	159.8	10-25
SE May Valley Road	225.6(4)	224.14	226.9	>100
229th Drive SE	245.3(4)	243.20	251.9	>100
Cedar Grove Road	292.8(4)	290.93	294.7	>100
SE 156th Street	294.2	294.75	294.2	25-100
252nd Avenue SE	334.4(4)	332.92	335.6	>100
SR 18 Access Road	N/A	478.95	485.8	>100
Carey Creek				
SR - 18	N/A	438.02	450.5	>100
MacDonald Creek				
229th Dr. SE	234.6	233.36	239.6	>100
217th Ave SE	314.9	317.57	317.2	10-25
208th Ave SE	322.6	323.58	323.1	25-100
Tibbetts Creek				
SE 56th St.	39.5	38.6	40.6	>100
Interstate 90	N/A	43.2	42.8	<2
Poplar Way	43.3	43.3	42.8	<2
Gilman Blvd. (Dwy)	N/A	56.5	55.2	2-10
Newport Way	77.7	78.3	75.5	>100
SR 900	78.0	78.8	79.3	>100
North Fork Issaquah Creek				
RR Xing	N/A	56.93	56.2	25-100
64th Place	N/A	64.28	64.81	>100

Table 6-2 (cont.)

Future 100 - Year Flood Elevations at Major Road Crossings

Location	Modeled Floodplain Elevations (Feet Above NGVD Datum)		Road Elevation (Feet)	Road Flooding Frequency (Years)
	FEMA	Basin Plan		
East Fork Issaquah Creek				
Rainier Blvd	N/A	85.16	82.6	25-100
RR Xing	N/A	85.19	83.4	25-100
Front St.	N/A	89.21	92.7	>100
Dogwood St.	N/A	103.91	102.8	25-100
SE High Point Rd.	N/A	473.49	472.5	25-100
Private Landing Strip	N/A	482.99	480.3	<2 year
Interstate 90	N/A	492.92	498.5	>100

N/A - FEMA floodplain elevations not available.

Notes:

(1) Flooding of SE 56th Street occurs approximately 1000 feet west of the river crossing. The cause of this flooding is flow that spills over the left (west) bank of Issaquah Creek and travels west along the south side of SE 56th.

(2) Flooding of Gilman Boulevard occurred near the crossing of Tributary 0170. At high flows, this tributary carries water from Tibbetts Creek. Additional flows spilling over the left (west) bank of Issaquah Creek at I-90 combined to exceed the capacity of culverts crossing I-90, resulting in flooding of several parking lots and at least one business.

(3) Flooding of Clark Street occurs approximately 100 feet east of the river crossing. Flow spilling over the right (east) bank is the cause of this frequent road closure.

(4) FEMA modeled elevations are higher apparently due to stream bottom elevations surveyed higher than the County's survey in 1989-90.

Table 6-4, at the end of the chapter, compares the flooding conditions for current and future land use conditions. This table is a complete listing of all cross sections modeled with HEC-2. Flows from the HSPF model were used to determine the one percent chance ("100 year") current and future floodplain elevations and their horizontal extent. Changes in elevation and width are averaged over the reaches between major landmarks as listed.

6.10.0 CURRENT FLOODING PROBLEMS IN THE ISSAQUAH BASIN

Several types of flooding and drainage-related problems occur in the Issaquah area. Topography and geology as well as development patterns determine the character of these problems.

Riverine flooding with broad valley floodplains, also seen in the adjacent Snoqualmie River basin, is the most notable flooding phenomenon in the Issaquah basin. A recent publication, prepared for the Federal Interagency Task Force on Floodplain Management, that summarizes the status of floodplain management activities nationwide also applies to conditions in the Issaquah basin.

> "Human settlements and activities tend to use floodplains, frequently interfering with the natural processes and suffering catastrophe as a consequence. As human activities encroach upon floodplains and affect the distribution and timing of drainage, flood problems typically increase. The built environment also creates localized flooding problems outside of natural floodplains. Development often requires that runoff be controlled and confined in open or enclosed channels. Particularly in rapidly urbanizing areas,these drainage systems often have proven inadequate to control this runoff." (L. R. Johnson Associates, 1989)

Along the mainstem of Issaquah Creek, residential development has been extensive in some reaches. The most intense development is found within the City of Issaquah south of I-90. Based on mapping done in 1987 and 1989, development in the City has resulted in 118 single family structures being located in the current 100-year floodplain. Nine residential structures have been located in the floodplain in unincorporated King County. Additional construction has occurred within the 100-year floodplain in several locations since this mapping was completed, and so these numbers are minmum estimates.

The Federal Emergency Management Agency reports that of approximately 75 residences in the City with flood insurance, over 40 had filed claims during the flooding in 1990 (Cook, 1991). Throughout the basin, at least 127 residential and 31 commercial structures shown on Basin Planning mapping are subject to flooding. This count is lower than the actual number because additional residential and commercial buildings have been constructed since the count was based on maps made in 1987 and 1989.

In several other locations in the basin, construction has occurred in the recent past under previous floodplain management regulations that allowed construction in flood hazard areas. The plat of Sunset Valley Farms, on MacDonald Creek at approximately 208th Avenue SE, was approved under former regulations requiring lot layout and culvert design based on the 25-year floodplain. Flooding of roads and residences occurred during the two large storms in 1990. Erosion damage has also occurred on the south side of the subdivision. The channel gradient in this area is unstable due to sedimentation from side tributaries. Long-time residents of the valley report that this stream was dredged frequently when the area was farmed.

Since the January, 1990, storm, at least two property owners have constructed floodwalls around structures in or near the floodway of Issaquah Creek within the City. The floodwalls were built at an apartment at 220 Newport Way SW and 130 NW Cherry Street in the City. A third floodwall has been reported at a residence on Front Street south. Permits or engineering review for these walls have not been required, since they do not meet minimum criteria for building permits. Based on FEMA Flood Insurance Rate Maps, it is possible that one or both are in the floodway and thus do not comply with the City's former floodplain management ordinances. At a minimum, there is a chance that both floodwalls will deflect high flows and accelerate erosion on the opposite river bank and may cause additional increases in the water surface elevation during high flows.

Flooding or flood related problems were observed by City and SWM Division staffs in at least 35 locations in the basin during the 1990 storm events. Figure 6-1 shows these observed flooding locations. Many of these flooding problems involved one or more habitable structures. Residents of at least two houses in Issaquah are evacuated during each major storm. At least ten of the flooding sites involved road crossings of the stream system. Several road crossings, such as Clark Street and Sunset Way, have low elevations away from the creek. Although these bridges were not completely overtopped, overbank flow closed these roads in the floodplain area away from the bridge itself. Damage to City roads and utilities was $169,000 for the two 1990 storms (Heath, 1991). Figures are not available for private sector damage, although it is believed to be considerably higher.

Flooding of commercial buildings and channel manipulation have been observed in the lower portion of Tibbetts Creek as well. A berm has been constructed along the east bank of Tibbetts Creek between SE 65th Street and NW Poplar Way to contain high flows. While the effects of this berm have not been modeled, it should be expected to raise water levels in the creek and may cause additional flood damage to unprotected areas. This berm was apparently constructed without permits.

Roadway flooding can be caused by several factors. Culverts or bridges may be underdesigned for the flows experienced. Sedimentation during storms or over long periods of time may reduce the culvert or bridge opening size, and thus the capacity to convey flows. Roadways in floodplain areas may be lower than the flooding elevations of the river or stream. In the case of road crossings in the Issaquah basin, all of these causes are apparent. Stream crossing

designs based on basin plan flooding and sedimentation analyses should reduce the occurrence of similar flooding problems in the future.

Flooding in the steeper upland portions of the basin is largely due to sediment clogging culverts during storm events. Surface flows increased by runoff from impervious or cleared land surfaces erode sensitive outwash soil deposits. Small culverts tend to clog easily with sediment and other debris. Culvert design capacity is exceeded because the volumetric increase, or bulking, of the flow by debris or sediment is not usually considered in culvert design. During large storm events, roads and channel banks are overtopped at low points. Debris may be spread over roads and adjacent properties. The effects of this type of flooding are usually very localized.

Examples of this type of hydraulic problem may be seen along Issaquah-Hobart Road where tributaries from the west slope of Tiger Mountain cross the road, at Sunset Valley Farms on the north and south valley sides above MacDonald Creek, and in the Summerhill development on the west end of Issaquah above Newport Way. In each of these instances, control of sediment sources is also necessary to solve these flood-related problems.

In the Issaquah basin, the sources of the sediment are either stream channels or slope failures adjacent to stream channels. This problem is most severe in soils derived from glacial outwash deposits on steeply sloping ground. Compounding the hazard, many flood damage problems occur when structures are built on alluvial fans and deltas formed by long-term deposition of sediment. Channels in these areas may be unstable, changing location with each major storm. These structures are also subject to damage by mudflows and increased peak flows. Sediment may also build up in culverts or bridge openings and channel bottoms, decreasing the conveyance capacity of the stream and resulting in increased flooding. Frequent maintenance is required to maintain capacity through bridges and culverts. Dredging of channels may also temporarily restore capacity of channels. However, this practice is highly disruptive of stream beds and may destroy salmonid eggs or alevins if done without considering timing of fish runs. A more complete discussion of erosion and sedimentation problems can be found in Chapter 7.

In designing culverts, sediment loading can be accounted for by increasing design flow volumes using a "bulking factor", however, this is not a common practice in the engineering community. This factor can be used to compensate for the effects of debris and sediment on the flow through the culvert and provide a more conservative design (ASCE, 1969). The magnitude of this bulking factor may vary with locality. As far as can be determined there are no recommended bulking factors for the conditions found in the Issaquah basin area.

Urban areas may also experience numerous localized drainage problems. Typical problems are ponding at low points along gutters or parking lots, clogged catch basins inlets, or unmaintained private driveway culverts. These drainage problems can occur throughout the winter or during large storm events during the year, but they are not necessarily related to the stream system. These local, nonsystemic problems are typically solved by localized improvements, maintenance

to the constructed drainage system, or enforcement actions. They are not analyzed in this report.

6.11.0 ANTICIPATED FUTURE FLOODING PROBLEMS

6.11.1 Unmitigated Scenario

Increased development within the Issaquah basin is predicted to result in increased peak flows, as described in Chapter 5. Unless mitigated by onsite detention or controls on the amount of impervious surface, increased flows will cause flooding in previously flood-free areas. Larger peak flows will also occur with increased frequency. Therefore, overbank flooding will occur more often. Increased flows and frequencies will result in greater amounts of property damage, more frequent maintenance, and a higher risk to public safety.

Table 6-4, at the end of this chapter, shows the changes in flooding elevation and floodplain width for the reaches of the Issaquah system modeled using HEC-2. Increased floodplain widths of up to five hundred feet are predicted. Areas showing particularly significant increases in floodplain width include:

North Fork Issaquah Creek - Issaquah Creek to SE 64th Pl.

MacDonald Creek - upstream of 208th Avenue SE

Issaquah Creek - SE 56th Street to I-90

- Juniper to Clark Street

- Upstream of Sycamore Drive

- Cedar Grove Road to 252nd Ave SE

These increases in floodplain width will result in greater costs for flood protection and repair of damage to public and private property.

The number of structures affected by flooding in the reaches modeled under unmitigated future land use conditions will increase dramatically due to expansion of the floodplain. Within the City of Issaquah, the number of single family residential structures flooded by the mainstem of Issaquah Creek during a 100-year flood is predicted to increase from 118 to 214. The number of commercial and multifamily structures affected would increase by 88 percent from 31 to over 50. Public facilities impacted by flooding will increase from 1 to 3. In the basin, the total number of single family residences affected by flooding would be nearly 250. In the recent past,

there has been a trend of converting single family land uses to multifamily within the City. If land uses continue to intensify from single family to multifamily within the existing and future floodplain areas, even more people will be exposed to flood hazards in the future.

6.11.2 Mitigated Scenario

Recent adoption of the King County Surface Water Design Manual (King County, 1990) should reduce the impact of future development in the basin by requiring improved retention/detention (R/D) facilities at new developments. As a result, actual flow rates are not likely to be as high as predicted for the future unmitigated case, discussed in the previous subsection. However, they are likely to be higher than under current conditions, even with mitigation applied through the on-site detention requirements of the 1990 Design Manual. This will occur because:

(1) R/D facilities do not always operate as intended, due to clogging by debris, poor maintenance, or surface flows that bypass the drainage system;

(2) The storage capacity of R/D facilities designed to these requirements are not adequate for large storms or for storms that occur in sequence; and

(3) R/D facilities are not usually required for new impervious surfaces of less than 5,000 square feet.

To estimate the potential damage of future flooding, a preliminary analysis of potentially inundated property was made. Because future mitigated flows will not be simulated by the HSPF model until the solutions analysis for the Basin Plan is further developed, the current flow rate and the future unmitigated flow rate were averaged to approximate the future mitigated peak flows. These peak flow rates were determined for the 25-, 50-, and 100-year events. It is interesting to note that the future 25-year future mitigated flow is roughly equal to the current 40-year event. The January, 1990, flood was approximately a 40-year flood. The 25-, 50-, and 100-year future mitigated flows were used to determine the floodplain boundaries for the three flood events.

To determine the value of property in the floodplains, assessed valuations were obtained from the King County Assessor's records and noted on Assessor's maps, which show property lines. The Assessor's maps were overlain with the floodplain maps to determine which structures and parcels were within the assumed 25-, 50-, and 100-year future mitigated floodplains. Tabulated results of analysis are shown in Table 6-3. The values in Table 6-3 were determined by including values of land and improvements (buildings) for occupied land only, but only if the building encroached on the specified floodplain. Thus, lawn or pasture areas being flooded would not appear in this value unless habitable structures were also flooded.

Table 6-3 does not include the assessed valuations for property in the Pickering Farms office complex. The topographic maps used for the analysis were not recent enough to include the newly constructed buildings, and so the total assessed value of flooded property would be even larger if these properties were included as well.

Several cautions should be noted when considering the results shown in Table 6-3. First, the HEC-2 modeling has not been calibrated sufficiently for use in defining absolute floodplain boundaries; the results are intended for use in comparing relative changes under different scenaria. This calibration process is a likely recommendation of the final basin plan. Second, HSPF models have not yet been completed to accurately determine the future mitigated flow cases. Instead, flows were approximated from the current and future unmitigated cases. Third, several inconsistencies were apparent in the modeling results, particularly where the Issaquah and Tibbets Creeks joined under high flow conditions. Fourth, in some cases determination of the location of buildings relative to floodplain boundaries was very subjective. None of these cautions should invalidate the comparison, however, because most of the same uncertainties apply in each case and because these uncertainties do not significantly affect the overall patern of flooding.

Table 6-3

Assessed Value of Property within the 25-, 50-, and 100-year Floodplains, by Type of Structure and Location (in millions of dollars).

	Floodplain Frequency 25-year	50-year	100-year
City of Issaquah			
Single Fam. Res. Only	18.0	20.8	24.4
Mult. Fam. Res. and Comm./Indust./Public	108.0	136.8	139.8
Total	126.0	157.6	164.2
King County			
Single Fam. Res. Only	4.2	5.0	5.4
Mult. Fam. Res. and Comm./Indust./Public	0.9	0.9	1.1
Total	5.1	5.9	6.5
Grand Total	131.1	163.5	170.7

6.12.0 SUMMARY OF FLOODING PROBLEMS BY SUB-BASIN

Flood damage problems reported or modeled are summarized below geographically by sub-basin. In many cases overbank flow occurs during storm events, but only where roads or habitable structures, single- or multi-family residential and commercial buildings, are involved is the flooding specifically described as a problem.

6.12.1 Carey Creek (0218)

Only one specific instance of flooding has been observed in this sub-basin. The crossing of a tributary to Carey Creek under Taylor Road (SE 208th Street) flooded during the November,

1990, storm. This crossing is a double CMP culvert. Some erosion damage was also reported at the bridge crossing of Issaquah-Hobart Road during the same storm.

Out-of-bank flows have been modeled in the reach below SR 18; however, no roads or habitable structures are affected.

6.12.2 Holder Creek (0178)

No roads or structures are reported to have been damaged in recent flooding in this sub-basin. Streambank erosion and pasture flooding occurs in the reach between SR 18 and the confluence with Carey Creek.

6.12.3 Middle Issaquah Creek (0178)

Both lowland flooding and localized flooding of upland culverts have been reported in this sub-basin. Localized flooding problems have occurred in the Mirrormont and Pheasant Creek areas. The Mirrormont CIP project improved a local drainage system in the plat of Mirrormont that had caused localized flooding. This project was constructed in 1988. An undersized culvert under SE 152nd Street was replaced by Roads Maintenance after it flooded in 1986, following construction of the plat of Mirror Lake Estates immediately upstream. This road, together with the residence just downstream, has continued to flood and is the subject of a Drainage Investigation study that is scheduled for completion in December 1991. Farther downstream, near the base of Mirrormont and close to the confluence with Pheasant Creek, sediment derived from the upstream channel filled culverts and blocked a private access road in January, 1990. During that same storm, sediment blocked a culvert near the mouth of Pheasant Creek, resulting in the washout of a private road. This culvert was replaced by the residents.

The crossing of SE 156th street over the mainstem of Issaquah Creek is predicted to flood during extreme events under existing land use conditions. Stream bank erosion and minor flooding have been reported in 1990 and 1991 in the Four Creeks Ranch area. Streambank erosion and pasture flooding occurs in places along the entire reach of Issaquah Creek in this sub-basin.

6.12.4 Fifteenmile Creek (0207)

No flooding complaints have been filed with the SWM Division in this sub-basin. A resident of the area did relate to SWM staff members that a house had been flooded at the SE May Valley Road bridge but the exact circumstances were not reported. Historic washouts of the Issaquah-Hobart Road by Fifteenmile Creek were also reported. Most reported problems in this sub- basin have been related to sediment and debris. The stream channel gradient is relatively steep throughout the sub-basin and there has been little development.

6.12.5 MacDonald Creek (0212)

Two significant flooding problems have been reported in the MacDonald Creek sub-basin. The subdivision of High Valley has experienced localized culvert problems . At least one residence in the plat of Sunset Valley Farms has been flooded twice in 1990 and again in April 1991. The apparent cause of this flooding is a combination of low gradients and broad floodplains. Portions of this stream are predicted to have increases in the 100-year floodplain width of over 450 feet under future land uses.

6.12.6 East Fork Issaquah Creek (0183)

In the East Fork Sub-basin, there are two distinct areas of flooding. The upper portion of the East Fork, above High Point Road, experienced overbank flow in pasture areas during the two 1990 storms. In addition, a portion of the westbound roadway of I-90 experienced water over the roadway during the November storm. The lower portion of the creek, below the Sunset Way entrance to I-90, flooded roads and yards during both 1990 storms.

Floodplain modeling on the East Fork predicts that as many as 27 residential and 1 commercial buildings could be at least partially flooded by the future conditions 100-year flood. Depth of flooding could increase by as much as 0.7 feet and the floodplain width is predicted to increase by as much as 180 feet in the lower portion of the stream under future land use conditions without mitigation.

6.12.7 North Fork Issaquah Creek (0181)

Flooding problems in the North Fork Sub-basin are largely confined to the lower portion of the channel below East Lake Sammamish Parkway SE. The gradient in this portion of the stream is relatively flat and residences are constructed close to the banks of the channel. The roads and buildings in the area have been built close to the natural grade and many may be affected by beaver activity in this lower reach.

In this reach, three residences are potentially flooded during the 100-year flood under future conditions. Commercial buildings recently permitted along 221st Place SE will be constructed above the 100-year future floodplain elevation for this creek, also known locally as Jordan Creek.

6.12.8 Lower Issaquah Creek (0178)

The Lower Issaquah Sub-basin experiences the most severe flood damage of any in the Issaquah basin. Property losses due to flood damage from Issaquah Creek are among the most severe in the County. Pasture and yard flooding as well as bank erosion occur during large storms from the confluence of MacDonald Creek to SE Sycamore Place. Culverts carrying Nudist Camp Creek under Issaquah-Hobart Road clogged with sediment twice during 1990, closing the road. Other stream culverts in this portion of the sub-basin require frequent maintenance.

Front Street South frequently floods at 2nd Avenue SE, as the creek overflows the right bank and floods several houses. Single- and multi-family residences from SE Sycamore Place to Gilman Boulevard are sandbagged during major storms to minimize flood damage. The City provides materials to residents for this purpose. The worst damage occurs in the reach between Clark Street and NW Holly Street. The Washington State Department of Fisheries Hatchery at Sunset Way has sustained both property damage and loss of fry at least three times since January of 1990. Channelization of the creek has confined flows once allowed to spread over the floodplain. It has been reported that the Fish Hatchery formerly lowered the weir elevation during the winter months, but has since discontinued this practice.

At least two private property owners along this reach have constructed floodwalls around individual properties. While these floodwalls have not been modeled in the Issaquah Creek HEC-2 model, there is a chance that the floodwalls may result in accelerated bank erosion and a rise in water surface elevation during high flows. This is especially true if the floodwalls have been built in the floodway, or high velocity portion of the floodplain. Permits and engineering review have not been required for these floodwalls.

Sediment transported down Mine Hill Creek (0194) clogs the culvert under Wildwood Boulevard, causing overflows at that location. Erosion also occurs in the upper reaches of Cabin Creek (0195).

Buildings in new commercial developments on Gilman Boulevard have been damaged by flooding several times during recent years. This is particularly the case of a restaurant adjacent to Interstate 90. Flows from Issaquah Creek spill out of bank and travel along a drainage ditch beside the freeway. A restaurant and auto parts store west of Issaquah Creek on the South side of Gilman have also been flooded and parking areas on the East side are susceptible to flooding as well. A filled area adjacent to tributary 0170 has been a source of complaints of increased flooding of nearby properties.

The existing bridge at SE 56th Street experiences pressure flow during flows on the order of 40-year or greater return intervals. The major cause of this backup of flow is a constriction in the floodplain caused by past filling downstream of the bridge. A flow split occurs just upstream of the bridge, diverting a portion of the creek flow several hundred feet to the west, where it crosses under the roadway in a culvert. When the capacity of this culvert, which also carries

runoff from the Pickering Farms office park development is exceeded, the roadway can be overtopped. The office park has constructed ponds that can provide a limited amount of flood storage for flows which go overbank between I-90 and SE 56th Street.

The elevation of Lake Sammamish affects the floodplain elevations in the lower portion of the mainstem. Prior to completion of the dredging and straightening of the Sammamish River by the U. S. Army Corps of Engineers in 1966 the lake level was free to fluctuate to a limited amount. The current weir at Marymoor Park results in a 100-year water surface elevation of 33 feet per the current FEMA Flood Insurance Rate Map. Initial conditions in the HEC-2 model for this reach of the mainstem were revised to test the effects of lowering the lake. Lowering the water surface elevation of the lake by 3 feet would result in a drop in the 100-year floodplain elevation of approximately one-half inch at the park access road bridge at RM 0.27. In the short term, until the stream channel gradient had adjusted to the new conditions, all flooding elevation reduction would occur very low in the State Park, and would not affect the urbanized area of this sub-basin. Over the longer term, it is unlikely that any significant lowering would be seen above SE 56th Street at RM 1.69. Lowering the lake elevation would require major modifications to the Sammamish River channel and bridges, and would likely impact existing moorage facilities on the lake.

6.12.9 Tibbetts Creek (0169 and 0170)

The Tibbetts Creek sub-basin has experienced flooding in recent years both due to loss of channel capacity and floodplain storage in the lower reaches below Newport Way and due to interaction with Issaquah Creek in the area below SE 56th Street. Pastures and a nursery above Newport Way flooded during the 1990 storms when flow from Tibbets Creek overtopped its natural channel and was diverted into tributary 0170, a drainage channel built by a former drainage district in the area. No structures were involved in this flooding. The main channel in this area is a deposition zone for sediment from the upper reaches of this basin; sediment deposited in the early portion of the storms reduced the channel capacity. As this sediment is transported downstream, the channel capacity may be partly restored, until filled again in subsequent storms.

North of Newport Way, the channel runs adjacent to a commercial and light industrial area. The stream at this point has been extensively channelized alongside an access road. Since the fall of 1990, a gravel berm has been constructed to keep water away from the industrial area during high flows. The HEC-2 model of Tibbetts Creek has not been revised to determine the effects of this berm on adjacent properties.

Tributary 0170 crosses Gilman Boulevard and Interstate 90 before rejoining the mainstem flows. Water from this tributary is partially responsible for flooding of the commercial experienced during the 1990 storms. Flood-related damage along tributary 0169A has also occurred in the Summerhill subdivision.

Downstream of SE 56th Street, the Lake Sammamish State Park and undeveloped land experience overbank flows but no major property damage during large storms.

6.13.0 KEY FINDINGS

- Construction has been allowed in the past within the 100-year floodplain in both the County and City. Serious flood damage problems exist along portions of Tibbetts, Issaquah, and MacDonald Creeks and the North and East Forks of Issaquah Creek. Residents have been evacuated several times during recent years and sandbagging of homes and businesses occurs annually.

- The City of Issaquah Public Works Department reported 28 significant flooding problem locations within the City limits. Twenty-six of those problems appear to relate directly to the stream system. An additional eight flooding problem locations were identified in unincorporated King County. Problems reported include flooding of roads, commercial properties and both single and multiple family residences. Also reported were erosion and landslide problems.

- Flooding is predicted to increase when the basin is completely built out to the maximum allowable zoning. The number of single family residences flooded during a "100-year" flood is predicted to increase from 118 to nearly 250. Flooding of commercial buildings is predicted to increase from 31 to over 50. Additional construction has occurred since the maps on which these numbers were based were made. Conversion of existing single family land uses to multifamily would increase the number of people exposed to flood hazards.

- Construction of floodwalls and other flood protection measures on individual properties along Issaquah and Tibbetts Creeks could cause increased damage to other properties and accelerate bank erosion during high flows.

- Six roadway crossings are predicted to overtop more frequently than once in 25 years in the basin. Ten crossings would overtop during events between 25 and 100 year return periods.

- According to the Federal Emergency Management Agency, of approximately 75 residences in Issaquah with flood insurance, over 40 had filed claims during the flooding in 1990.

- Increased floodplain widths of up to five hundred feet are predicted. Areas showing particularly significant increases in floodplain width are:

  North Fork Issaquah Creek - Issaquah Creek to SE 64th Pl.

MacDonald Creek - upstream of 208th Avenue SE

Issaquah Creek - SE 56th Street to I-90

- Juniper to Clark Street

- upstream of Sycamore Drive

- Cedar Grove Road to 252nd Ave SE

These increases in floodplain width will result in greater costs for flood protection and repair of damage to public and private property.

o While they may effectively deal with localized flooding, none of the current plans and anticipated projects will be effective in dealing with the systemic flood damage problems occurring in the basin.

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Table 6-4
Comparison of 100 - Year Modeled Floodplains
Current to Future Unmitigated

HEC-2 Section Number	Landmarks	Flow Rates (cfs) Current	Future	Modeled Elevations (Ft. Above NGVD Datum) Current	Future	Change	Average Change	Modeled Widths (Feet) Current	Future	Change	Average Change
Lower Issaquah Creek											
2		4424	5471	31.43	32.50	1.07		192	192	0	
27		4424	5471	32.75	33.77	1.02		1450	1450	0	
27.2		4424	5471	32.87	33.85	0.98		1450	1450	0	
27.a3		4424	5471	33.18	34.07	0.89		1450	1450	0	
27.4	Access Road	4424	5471	33.20	34.09	0.89	0.97	1450	1450	0	0.00
93		4424	5471	37.30	37.61	0.31		113	114	1	
136		4424	5471	43.95	44.99	1.04		462	712	251	
169		4331	5360	48.49	49.32	0.83		100	100	0	
169.2		4331	5360	48.64	49.46	0.82		49	49	0	
169.3		4331	5360	49.04	49.96	0.92		49	49	0	
169.4	SE 56th St	4331	5360	49.77	50.99	1.22	0.86	120	120	0	42.06
184		4331	5360	51.24	52.52	1.28		530	530	0	
210		4331	5360	53.35	54.12	0.77		120	140	19	
233.1		4331	5360	58.53	59.42	0.89		106	339	233	
233.2		4331	5360	59.40	60.32	0.92		68	98	30	
233.3		4331	5360	59.52	60.47	0.95		68	98	30	
233.4	Interstate 90	4331	5360	59.61	60.57	0.96	0.96	68	98	30	57.17
234.1	Westbound	4331	5360	59.61	60.58	0.97		68	98	30	
234.2		4331	5360	59.70	60.68	0.98		80	98	18	
234.3	Interstate 90	4331	5360	59.80	60.80	1.00	0.98	98	98	0	15.96
234	Eastbound	4331	5360	60.43	61.66	1.23		265	273	8	
253.1		4331	5360	62.11	63.16	1.05		65	68	3	
253.2		4331	5360	62.62	63.73	1.11		66	69	3	
253.3	Gilman Blvd.	4331	5360	62.89	64.57	1.68	1.27	67	72	5	4.87
253		4331	5360	63.03	64.68	1.65		67	72	5	
277.1		4331	5360	66.65	67.91	1.26		107	109	2	
277.2		4331	5360	67.29	68.39	1.10		69	69	0	
277.3	Juniper St	4331	5360	68.34	68.88	0.54	1.14	69	69	0	1.74
277		4331	5360	68.77	69.54	0.77		199	199	0	
292		4331	5360	69.95	70.87	0.92		505	601	97	
315		3499	4369	73.10	73.83	0.73		70	71	1	
327.1		3499	4369	76.21	77.13	0.92		60	62	2	
327.2		3499	4369	77.78	78.75	0.97		63	64	1	
327.3	Dogwood St	3499	4369	77.92	79.07	1.15	0.91	63	64	1	16.98
327		3499	4369	78.49	79.67	1.18		87	89	2	
353		3499	4369	82.67	83.68	1.01		111	248	137	
381		3499	4369	86.80	87.78	0.98		295	355	60	
381.2		3499	4369	87.26	88.13	0.87		85	86	2	
381.3		3499	4369	87.91	89.61	1.70		85	90	5	
381.4	Sunset Way	3499	4369	88.06	89.74	1.68	1.24	86	90	4	34.78
386		3499	4369	88.69	90.26	1.57		93	204	111	

Table 6-4 (continued)

HEC-2 Section Number	Landmarks	Flow Rates (cfs) Current	Future	Modeled Elevations (Ft. Above NGVD Datum) Current	Future	Change	Average Change	Modeled Widths (Feet) Current	Future	Change	Average Change
387		3499	4369	89.12	90.46	1.34		258	495	237	
389		3499	4369	91.11	91.20	0.09		286	287	1	
414.1		3431	4326	94.97	95.88	0.91		396	412	15	
414.2		3431	4326	94.74	95.60	0.86		203	210	7	
414.3		3431	4326	95.38	95.57	0.19		341	341	0	
414.4		3431	4326	96.16	96.59	0.43		350	374	24	
414.5	Clark St	3431	4326	96.55	97.11	0.56	0.74	341	341	0	49.43
414		3431	4326	96.28	96.70	0.42		95	95	1	
438		3431	4326	100.36	101.63	1.27		73	79	6	
453		3359	4241	102.94	104.08	1.14		104	107	2	
455		3359	4241	111.06	111.76	0.70		155	166	12	
456.1		3359	4241	113.00	113.81	0.81		175	177	3	
486		3359	4241	116.19	117.02	0.83		251	265	14	
505		3359	4241	119.37	119.95	0.58		698	707	8	
515		3359	4241	121.56	121.98	0.42		688	759	72	
528		3359	4241	124.98	125.79	0.81		101	120	19	
528.2		3359	4241	126.61	127.18	0.57		64	64	0	
528.3		3359	4241	126.62	127.19	0.57		64	64	0	
528.4	Sycamore Dr.	3359	4241	127.47	128.45	0.98	0.76	160	160	0	11.36
544	SE	3276	4136	129.76	130.69	0.93		502	736	234	
561		3230	4070	132.96	133.48	0.52		123	126	3	
588		3230	4070	139.50	140.59	1.09		86	90	4	
610		3230	4070	146.19	147.10	0.91		315	340	24	
631		3230	4070	150.44	151.09	0.65		186	193	7	
667		2991	3855	159.08	159.85	0.77		164	177	13	
667.2		2991	3855	159.52	160.28	0.76		75	79	3	
667.3		2991	3855	160.17	160.28	0.11		78	79	0	
667.4	SE 113th St.	2991	3855	160.59	161.05	0.46	0.69	265	363	98	42.96
684		2991	3855	165.18	165.72	0.54		280	299	19	
710		2991	3855	173.38	173.91	0.53		356	409	53	
726		2991	3855	181.12	181.18	0.06		974	982	8	
747		2991	3855	186.96	188.29	1.33		77	445	368	
765		2991	3855	194.40	194.69	0.29		135	146	11	
780		2866	3765	198.66	199.75	1.09		73	76	3	
780.2		2866	3765	200.03	201.02	0.99		76	79	3	
780.3		2866	3765	200.04	201.02	0.98		77	79	3	
780.4	Pvt. Dwy	2866	3765	200.47	201.49	1.02	0.76	78	81	3	52.17
787		2866	3765	203.35	204.16	0.81		71	76	5	
787.2		2866	3765	205.23	206.19	0.96		82	88	6	
787.3		2866	3765	205.23	206.20	0.97		82	88	6	
787.4	Pvt. Dwy	2866	3765	205.53	206.52	0.99	0.93	84	141	57	18.32
808		2422	3252	211.87	213.20	1.33		69	115	46	
830		2422	3252	220.83	221.67	0.84		265	314	49	
841		2422	3252	223.52	224.34	0.82		140	162	22	
841.2		2422	3252	224.14	224.91	0.77		53	53	1	

Table 6-4 (continued)

HEC-2 Section Number	Landmarks	Flow Rates (cfs) Current	Flow Rates (cfs) Future	Modeled Elevations (Ft. Above NGVD Datum) Current	Modeled Elevations Future	Modeled Elevations Change	Average Change	Modeled Widths (Feet) Current	Modeled Widths Future	Modeled Widths Change	Average Change
841.3		2422	3252	224.14	224.92	0.78		53	53	1	
841.4		2422	3252	224.17	224.96	0.79		53	53	1	
841.5		2422	3252	224.17	224.96	0.79		53	53	1	
841.6	SE May Valley Road	2422	3252	227.92	228.42	0.50	0.83	170	170	0	14.85
Middle Issaquah Creek											
41918	SE May Valley	2422	3252	221.71	222.28	0.57		227	258	32	
42318	Road	2422	3252	222.96	223.49	0.53		40	40	0	
42345		2422	3252	223.19	224.14	0.95		40	40	0	
42370		2422	3252	223.70	224.89	1.19		40	40	0	
42380		2422	3252	223.96	225.33	1.37		40	40	0	
42430		2422	3252	225.56	227.33	1.77		255	290	35	
43030		2422	3252	228.19	228.73	0.54		153	159	6	
43380		2105	2763	229.74	230.22	0.48		124	133	9	
44180		2105	2763	234.02	234.87	0.85		55	61	6	
45180		2105	2763	240.25	241.11	0.86		94	153	58	
45380		2105	2763	240.91	241.92	1.01		36	44	8	
45413	229th Dr. SE	2105	2763	241.70	243.21	1.51	0.97	23	27	3	13.06
45446		2105	2763	244.07	246.13	2.06		29	43	14	
45463		2105	2763	245.54	247.30	1.76		44	44	0	
45543		2105	2763	245.66	247.56	1.90		161	210	50	
46743		2105	2763	248.64	249.76	1.12		113	139	27	
47543		2105	2763	255.76	256.83	1.07		79	104	25	
48943		2105	2763	265.07	265.67	0.60		185	189	5	
49993		2105	2763	269.47	270.01	0.54		485	496	11	
50943		2105	2763	275.48	276.05	0.57		335	345	10	
51783		2105	2763	281.07	281.99	0.92		205	337	131	
52783		2105	2763	287.88	288.17	0.29		329	333	5	
52983		2105	2763	288.99	289.44	0.45		42	42	0	
53001	Cedar Grove	2105	2763	290.06	290.93	0.87	1.01	40	40	0	23.10
53027	Road SE	2105	2763	291.53	292.64	1.11		40	40	0	
53042		2105	2763	291.59	292.71	1.12		42	42	0	
53092		2105	2763	293.21	294.67	1.46		360	385	26	
53199		2105	2763	293.33	294.75	1.42		534	625	91	
53222	SE 156th St	2105	2763	293.31	294.89	1.58	1.34	222	640	418	107.01
53384		2105	2763	294.54	295.07	0.53		714	781	66	
54584		2105	2763	300.23	300.61	0.38		644	672	28	
55344		2047	2671	305.13	305.66	0.53		261	287	26	
55994		2047	2671	308.91	309.48	0.57		251	295	44	
56289		2047	2671	310.64	311.29	0.65		329	374	46	
56299	Pvt Dwy	2047	2671	310.26	310.47	0.21	0.48	38	60	22	38.62
56309		2047	2671	310.54	313.21	2.67		70	411	340	

Table 6-4 (continued)

HEC-2 Section Number	Landmarks	Flow Rates (cfs) Current	Future	Modeled Elevations (Ft. Above NGVD Datum) Current	Future	Change	Average Change	Modeled Widths (Feet) Current	Future	Change	Average Change
56319		2047	2671	312.13	313.42	1.29		421	623	202	
56414		2047	2671	311.98	313.40	1.42		298	543	245	
56614		2047	2671	312.68	313.30	0.62		138	171	33	
57934		2047	2671	321.45	322.20	0.75		280	389	109	
59674		2047	2671	331.86	332.36	0.50		151	169	17	
59794		2047	2671	332.49	333.00	0.51		45	45	0	
59804	252nd Ave SE	2047	2671	331.99	332.92	0.93	1.09	36	37	1	118.44
59827		2047	2671	334.27	337.31	3.04		39	376	337	
59837		2047	2671	336.10	337.58	1.48		671	688	17	
59877		1999	2604	336.12	337.59	1.47		644	659	15	
61037		1999	2604	340.21	341.03	0.82		91	94	3	
62517		1999	2604	351.92	352.37	0.45		239	242	3	
63577		1814	2294	359.58	360.03	0.45		155	170	15	
65107		1814	2294	375.38	376.17	0.79		73	76	3	
66537		1814	2294	388.19	388.88	0.69		82	181	99	
67967		891	965	403.83	403.98	0.15		85	88	3	
69337		891	965	424.75	424.84	0.09		42	42	0	
70127		891	965	437.84	438.00	0.16		132	133	1	
70967		891	965	453.13	453.21	0.08		114	118	5	
72237		891	965	476.60	476.79	0.19		74	75	1	
72334		891	965	478.57	478.69	0.12		39	39	1	
72344	SR 18 Access	891	965	478.87	478.95	0.08	0.67	34	34	0	33.50
72392	Road	891	965	480.23	480.47	0.24		38	39	1	
72402		891	965	480.34	480.59	0.25		40	42	2	
72445		891	965	480.73	480.94	0.21		68	69	1	
73005		891	965	493.80	494.01	0.21	0.23	36	37	1	1.10
North Fork Issaquah Creek											
1	Confluence w/	259.7	462.8	42.54	43.50	0.96		38	41	4	
22	Issaquah Cr	259.7	462.8	50.15	51.27	1.12		21	26	5	
22.2		259.7	462.8	50.82	52.05	1.23		9	15	6	
22.3		259.7	462.8	50.84	53.77	2.93		9	249	240	
22.4		259.7	462.8	50.88	53.82	2.94		11	251	241	
22.5		259.7	462.8	51.09	54.61	3.52		9	181	172	
22.6	Pvt Dwy	259.7	462.8	51.92	54.70	2.78	2.21	62	352	289	136.65
32.1		259.7	462.8	53.09	54.88	1.79		56	501	445	
32.2		259.7	462.8	53.32	54.95	1.63		22	300	278	
32.3		259.7	462.8	53.32	54.61	1.29		22	212	190	
32.4		259.7	462.8	53.35	54.64	1.29		41	240	199	
32.5	Pvt Dwy	259.7	462.8	53.57	55.65	2.08	1.62	44	319	275	277.19
32		259.7	462.8	53.65	55.71	2.06		188	289	101	
44		259.7	462.8	54.74	56.08	1.34		188	257	68	
44.2		259.7	462.8	54.91	56.18	1.27		190	260	70	

Table 6-4 (continued)

HEC-2 Section Number	Landmarks	Flow Rates (cfs)		Modeled Elevations (Ft. Above NGVD Datum)				Modeled Widths (Feet)			
		Current	Future	Current	Future	Change	Average Change	Current	Future	Change	Average Change
44.3		259.7	462.8	54.91	56.89	1.98		190	284	94	
44.4		259.7	462.8	55.01	56.93	1.92		191	285	94	
45.1		259.7	462.8	55.02	56.93	1.91		241	335	94	
45.2		259.7	462.8	55.07	56.94	1.87		242	335	94	
45.3	RR Xing	259.7	462.8	55.33	57.88	2.55	1.86	244	358	114	91.01
45		259.7	462.8	55.42	57.88	2.46		66	590	524	
46.1		259.7	462.8	55.42	57.88	2.46		66	490	424	
46.2		259.7	462.8	55.61	57.89	2.28		73	490	417	
46.3	Pvt Dwy	259.7	462.8	56.30	58.47	2.17	2.34	124	490	366	432.67
46		259.7	462.8	56.36	58.47	2.11		75	227	152	
56.1		259.7	462.8	57.47	59.12	1.65		27	58	31	
56.2		259.7	462.8	57.79	59.19	1.40		13	18	5	
56.3		259.7	462.8	57.66	61.89	4.23		13	146	134	
56.4		259.7	462.8	57.52	62.86	5.34		12	188	176	
56.5	Pvt Dwy	259.7	462.8	60.02	62.85	2.83	2.93	17	188	172	111.47
56		259.7	462.8	60.45	62.90	2.45		108	128	19	
60		259.7	462.8	60.52	62.93	2.41		61	69	8	
73.1		259.7	462.8	61.77	63.88	2.11		32	51	19	
73.2		259.7	462.8	62.40	64.03	1.63		13	13	0	
73.3		259.7	462.8	62.39	63.98	1.59		13	13	0	
73.4		259.7	462.8	62.57	64.14	1.57		13	13	0	
73.5		259.7	462.8	62.60	64.28	1.68		13	13	0	
73	SE 64th Pl	259.7	462.8	62.94	64.84	1.90	1.92	47	55	8	6.82
East Fork Issaquah Creek											
1	Confluence w/	968	1182.6	73.07	73.60	0.53		68	72	4	
13.1	Issaquah Cr	968	1182.6	81.29	81.77	0.48		32	33	1	
13.2		968	1182.6	82.83	83.46	0.63		67	135	69	
13.3		968	1182.6	82.39	84.22	1.83		40	221	182	
13.4		968	1182.6	84.74	85.16	0.42		272	311	39	
13.5	Rainier Blvd.	968	1182.6	84.75	85.15	0.40	0.71	272	309	37	55.20
13		968	1182.6	84.76	85.15	0.39		127	131	4	
14.1		968	1182.6	84.76	85.16	0.40		127	131	4	
14.2		968	1182.6	84.71	85.08	0.37		33	33	0	
14.3	RR Xing	968	1182.6	84.75	85.19	0.44	0.40	33	33	0	1.94
14		968	1182.6	85.05	85.54	0.49		88	98	9	
20.1		968	1182.6	87.06	87.39	0.33		90	90	0	
20.2		968	1182.6	88.13	88.49	0.36		41	41	0	
20.3		968	1182.6	88.13	88.49	0.36		41	41	0	
20.4		968	1182.6	88.47	89.09	0.62		41	41	0	
20.5	Front St	968	1182.6	88.49	89.21	0.72	0.48	41	41	0	1.58
20		968	1182.6	88.99	89.73	0.74		113	113	0	
40.1		968	1182.6	100.32	100.59	0.27		81	83	2	

Table 6-4 (continued)

HEC-2 Section Number	Landmarks	Flow Rates (cfs) Current	Flow Rates (cfs) Future	Modeled Elevations (Ft. Above NGVD Datum) Current	Future	Change	Average Change	Modeled Widths (Feet) Current	Future	Change	Average Change
40.2		968	1182.6	101.57	101.91	0.34		30	30	0	
40.3		968	1182.6	101.49	101.76	0.27		30	30	0	
40.4		968	1182.6	102.02	102.55	0.53		30	30	0	
40.5		968	1182.6	102.41	103.28	0.87		30	30	0	
40.6	Dogwood St	968	1182.6	102.99	103.91	0.92	0.56	86	86	0	0.24
59		968	1182.6	111.31	111.71	0.40		49	59	10	
72		968	1182.6	122.81	123.36	0.55		41	43	2	
88		968	1182.6	134.76	135.44	0.68		37	85	47	
104	I-90 Onramp	968	1182.6	151.31	151.74	0.43	0.52	35	36	1	15.14
318.1		758	872.3	470.19	470.85	0.66		22	25	3	
318.2		758	872.3	470.37	470.98	0.61		10	10	0	
318.3		758	872.3	472.17	473.10	0.93		10	122	112	
318.4	SE High	758	872.3	472.96	473.49	0.53	0.68	53	55	2	29.32
344	Point Rd	758	872.3	476.76	477.21	0.45		24	26	1	
365		758	872.3	480.98	481.44	0.46		65	68	3	
379		758	872.3	481.91	482.36	0.45		50	53	3	
396.1		758	872.3	482.37	482.82	0.45		156	160	4	
396.2		758	872.3	482.32	482.78	0.46		91	93	1	
396.3		758	872.3	482.20	482.74	0.54		152	156	4	
396.4		758	872.3	482.66	482.95	0.29		156	158	2	
396.5		758	872.3	482.67	482.96	0.29		156	158	2	
396.6	Pvt Landing	758	872.3	482.70	482.99	0.29	0.41	133	134	1	2.40
415	Strip	758	872.3	484.73	484.95	0.22		216	226	10	
440		758	872.3	490.85	491.09	0.24		70	74	3	
444.1		758	872.3	492.03	492.35	0.32	0.26	51	52	1	4.92
444.2		758	872.3	492.13	492.45	0.32		47	47	0	
444.3		758	872.3	492.16	492.48	0.32		47	47	0	
444.4	Interstate 90	758	872.3	492.19	492.51	0.32		51	52	1	
445.1	Westbound	758	872.3	492.19	492.51	0.32		51	53	1	
445.2		758	872.3	492.22	492.54	0.32		47	47	0	
445.3		758	872.3	492.35	492.67	0.32		40	41	1	
445.4	Interstate 90	758	872.3	492.57	492.92	0.35	0.32	46	47	2	0.71
468	Eastbound	758	872.3	493.64	494.00	0.36		440	491	51	
490		758	872.3	495.03	495.35	0.32		149	151	1	
518		758	872.3	501.95	502.21	0.26	0.31	50	51	1	17.92
McDonald Creek											
130	Confluence w/	338	554	231.82	232.65	0.83		62	69	7	
230	Issaquah Cr	338	554	233.34	234.66	1.32		10	10	0	
302	229th Dr. SE	338	554	233.36	234.69	1.33	1.16	10	10	0	2.34
332		338	554	235.03	237.0	72.04		26	44	18	
357		338	554	235.03	237.05	2.02		23	24	1	

Table 6-4 (continued)

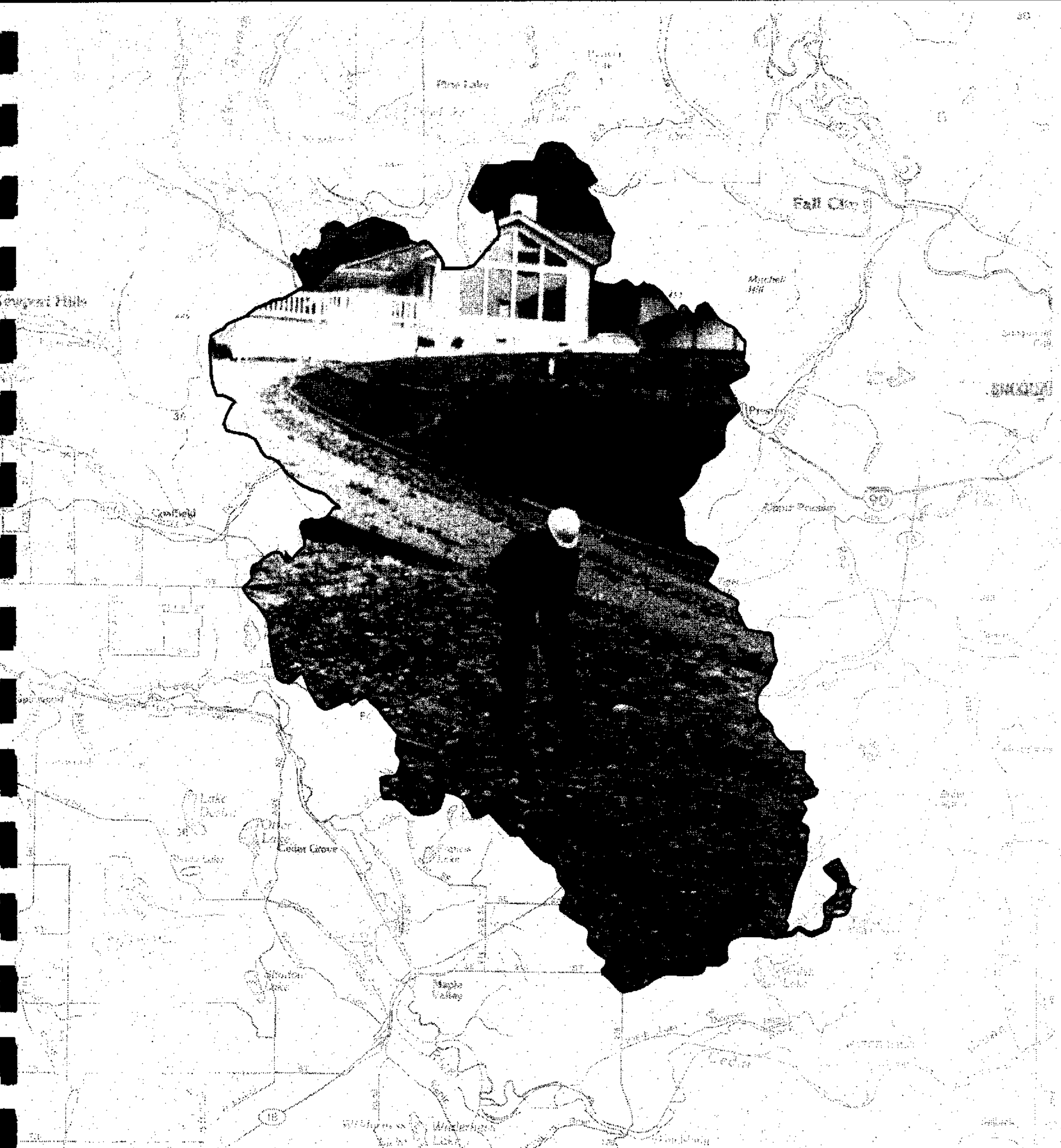
HEC-2 Section Number	Landmarks	Flow Rates (cfs)		Modeled Elevations (Ft. Above NGVD Datum)				Modeled Widths (Feet)			
		Current	Future	Current	Future	Change	Average Change	Current	Future	Change	Average Change
375		338	554	235.23	236.92	1.69		19	24	5	
387	Pvt Dwy	338	554	236.00	237.09	1.09	1.71	22	24	2	6.76
404		338	554	236.49	237.64	1.15		24	24	0	
1304		338	554	255.12	255.60	0.48		69	70	1	
2204		338	554	272.49	273.18	0.69		81	128	47	
3384		272	464.5	304.05	304.75	0.70		25	32	6	
4214		272	464.5	312.48	313.02	0.54		37	70	32	
4394		272	464.5	313.94	314.67	0.73		18	18	0	
4398		272	464.5	317.06	317.48	0.42		88	107	19	
4418	217th Ave SE	272	464.5	317.57	317.93	0.36	0.63	108	118	10	14.42
4428		272	464.5	317.70	318.12	0.42		134	145	11	
4508		272	464.5	317.72	318.16	0.44		120	136	15	
4708		272	464.5	317.75	318.21	0.46		246	261	15	
4718	Pvt Dwy	272	464.5	317.75	318.20	0.45	0.44	254	275	21	15.32
4727		272	464.5	317.75	318.20	0.45		254	275	21	
4737		272	464.5	317.75	318.21	0.46		246	261	15	
4917		272	464.5	317.75	318.22	0.47		446	469	24	
5267		272	464.5	317.76	318.23	0.47		424	479	55	
5285	Pvt Dwy	272	464.5	317.85	318.16	0.31	0.43	206	256	50	32.94
5300		272	464.5	318.16	318.34	0.18		256	275	19	
5310		272	464.5	318.23	318.45	0.22		479	498	19	
5570		117.2	203.3	318.25	318.49	0.24		364	405	41	
6570		117.2	203.3	319.47	319.63	0.16		44	53	9	
7630		117.2	203.3	321.30	322.29	0.99		19	22	3	
7740		117.2	203.3	321.29	322.19	0.90		5	5	0	
7816	208th Ave SE	117.2	203.3	322.51	323.58	1.07	0.54	7	97	90	25.87
7966		92.2	151.3	322.66	323.87	1.21		17	25	8	
8346		92.2	151.3	323.06	324.34	1.28		16	23	6	
8353	Pvt Dwy	92.2	151.3	323.06	324.33	1.27	1.25	21	23	2	5.73
8367		92.2	151.3	323.08	324.39	1.31		21	23	2	
8374		92.2	151.3	323.10	324.47	1.37		16	82	65	
8774		92.2	151.3	323.40	324.69	1.29		18	182	164	
9324		92.2	151.3	323.72	324.75	1.03		143	608	466	
9346		92.2	151.3	323.69	324.74	1.05		66	524	458	
9386	Pvt Road	92.2	151.3	324.00	324.75	0.75	1.13	91	524	433	264.64
9396		92.2	151.3	324.05	324.76	0.71		282	614	332	
9796		92.2	151.3	324.06	324.77	0.71		736	861	125	
10481		92.2	151.3	324.07	324.77	0.70		872	935	63	
10521		92.2	151.3	323.88	324.78	0.90		4	432	428	
10806		29.9	49.2	324.46	324.81	0.35		908	933	25	
11456		29.9	49.2	324.46	324.81	0.35		262	290	29	
11486		29.9	49.2	326.47	327.58	1.11		6	203	197	
11536		29.9	49.2	326.48	327.59	1.11		223	284	61	
12536		29.9	49.2	326.48	327.59	1.11	0.78	700	700	0	139.99

Table 6-4 (continued)

HEC-2 Section Number	Landmarks	Flow Rates (cfs) Current	Future	Modeled Elevations (Ft. Above NGVD Datum) Current	Future	Change	Average Change	Modeled Widths (Feet) Current	Future	Change	Average Change
Tibbetts Creek											
2		427	603	29.19	29.84	0.65		182	182	0	
42		230	230	35.91	36.07	0.16		17	17	1	
51		230	230	38.07	38.10	0.03		31	31	0	
51.2		230	230	38.26	38.29	0.03		39	39	0	
51.3		230	230	38.17	38.19	0.02		39	39	0	
51.4		230	230	38.31	38.34	0.03		28	28	0	
51.5		230	230	38.54	38.56	0.02		28	28	0	
51.6		230	230	41.37	41.37	0.00		111	111	0	
56.1		230	230	41.58	41.58	0.00		111	111	0	
56.2		230	230	41.73	41.73	0.00		34	34	0	
56.3		230	230	41.63	41.63	0.00		32	32	0	
56.4		230	230	42.77	42.77	0.00		32	32	0	
56.5		230	230	43.22	43.22	0.00		32	32	0	
56.6	NW Sammam-	230	230	43.24	43.24	0.00	0.07	900	900	0	0.10
60.1	ish Rd. (SE	334	367	43.24	43.24	0.00		900	900	0	
60.2	56th St)	334	367	43.24	43.24	0.00		600	600	0	
60.3		334	367	43.24	43.24	0.00		600	600	0	
60.4		334	367	43.25	43.25	0.00		600	600	0	
60.5	Interstate 90	334	367	43.25	43.25	0.00	0.00	600	600	0	0.00
60		334	367	43.25	43.26	0.01		1121	1121	0	
82.1		334	367	47.52	47.62	0.10		49	51	2	
97.1		334	367	54.14	54.26	0.12		103	104	1	
97.2		334	367	54.88	55.02	0.14		33	34	1	
97.3		334	367	55.98	56.00	0.02		94	95	1	
97.4		334	367	56.39	56.51	0.12		115	121	6	
97.5	Dwy @ SE 63rd	334	367	56.61	56.72	0.11	0.09	58	58	0	1.67
97		334	367	56.76	56.88	0.12		135	136	1	
107.1		334	367	59.20	59.32	0.12		101	112	11	
107.2		334	367	59.61	59.74	0.13		158	158	0	
107.3		334	367	59.98	60.02	0.04		135	135	0	
107.4		334	367	60.45	60.50	0.05		135	135	0	
107.5	Culvert Xing	334	367	60.59	60.66	0.07	0.09	135	135	0	2.04
107		334	367	61.16	61.29	0.13		22	22	0	
131.1		334	367	73.22	73.46	0.24		24	25	1	
131.2		334	367	73.33	73.58	0.25		25	25	1	
131.3	SE Newport Wy	334	367	78.13	78.33	0.20	0.21	115	116	1	0.59
131		334	367	78.14	78.34	0.20		115	116	1	
133		334	367	78.14	78.34	0.20		115	116	1	
133.2		334	367	78.16	78.36	0.20		177	178	1	
133.3		334	367	78.14	78.34	0.20		176	178	1	
133.4		334	367	78.24	78.44	0.20		177	179	1	
133.5		334	367	78.29	78.49	0.20		178	179	1	
133.6		334	367	78.29	78.49	0.20		239	243	4	

Table 6-4 (continued)

HEC-2 Section Number	Landmarks	Flow Rates (cfs) Current	Future	Modeled Elevations (Ft. Above NGVD Datum) Current	Future	Change	Average Change	Modeled Widths (Feet) Current	Future	Change	Average Change
142		334	367	78.63	78.82	0.19		53	59	6	
142.2		334	367	78.76	78.95	0.19		31	32	0	
142.3		334	367	78.76	78.95	0.19		31	32	0	
142.4		334	367	78.90	79.10	0.20		30	31	0	
142.5		334	367	78.91	79.10	0.19		31	31	0	
142.6	Renton-Issa-	521	740	79.01	79.72	0.71	0.24	23	25	3	1.73
154	quah Rd SE	521	740	85.81	86.39	0.58		111	129	18	
154.2		521	740	86.15	86.86	0.71		21	21	0	
154.3		521	740	88.06	88.26	0.20		263	292	29	
154.4		521	740	88.52	88.73	0.21		330	358	28	
154.5		521	740	88.50	88.68	0.18		325	351	26	
154.6	Tibbetts	521	740	88.64	88.89	0.25	0.36	243	255	12	18.93
167	Manor	521	740	96.52	96.77	0.25		235	271	37	
167.2	Bridge	521	740	98.24	98.38	0.14		654	676	22	
167.3		521	740	98.53	98.66	0.13		701	723	22	
167.4		521	740	98.62	98.77	0.15		717	741	25	
167.5		521	740	98.66	98.79	0.13		655	675	20	
167.6	Kelly Ranch	521	740	98.99	99.16	0.17	0.16	788	790	2	21.33



Chapter 7

Erosion & Deposition of Stream-Channel Sediment

CHAPTER 7: EROSION AND DEPOSITION OF STREAM-CHANNEL SEDIMENT

7.1.0 INTRODUCTION

The Issaquah Creek and Tibbetts Creek basins present one of the most varied stream-channel environments in all of King County. The eastern part of the Issaquah basin is dominated by the bedrock ridges of Grand Ridge, Tiger Mountain, and Taylor Mountain. The streams that flow off these steep uplands, including the East Fork tributaries, Fifteenmile Creek, and upper Holder Creek, form vigorous systems. Similarly, those channels in the west part of the basins that drain off Cougar Mountain, particularly the tributaries to Tibbetts Creek and McDonald Creek, are steep and energetic.

In contrast, some of the other major tributaries of the basins occupy channels previously carved by much more voluminous glacial meltwater. These tributaries include the North Fork Issaquah Creek, the upper East Fork, lower Carey Creek, and the main stem of McDonald Creek. The present-day streams are "underfit," paltry remnants of those much larger prehistoric torrents. Although capable of moving some sediment within their channels, these modern streams are much less energetic than their mountainous counterparts.

The largest of these underfit streams is the main channel of Issaquah Creek itself. Glacial scour and subsequent meltwater flow created the valley now separating Squak and West Tiger Mountains, with postglacial runoff in the area collecting in what is now Issaquah Creek. Although the creek can little affect the overall valley form, its drainage area is sufficiently large that it has created its own zones within that valley where its erosive and depositional activity is evident. For example, broad areas of the Issaquah valley are subject to channel migration, being consumed and redeposited over a period of centuries by the lateral shifting of the creek. Lower in the basin, the valley floor is episodically inundated by flood flows, and the sediment that is then deposited on the floodplain is reshaping the valley bottom. These processes are most evident at the extreme lower boundary of the basin, where deposition of Issaquah Creek into Lake Sammamish at the Issaquah delta is literally creating the basin anew.

7.2.0 DATA GATHERING METHODS AND ANALYSES

Information for this section was collected from a variety of sources. Nearly all of the stream channels were walked in 1988 and 1989; the flood of January 1990 rendered some of that information outdated, and so most of the major channels were rewalked in the summer and fall of 1990. Some additional field review was necessitated by the November 1990 flood. Problem areas were also identified from previous drainage complaints to King County and the city of

Issaquah, from the Basin Reconnaissance studies of the area (King County, 1987), and by notes from, and conversations with, basin residents.

More specific analyses were performed in certain reaches because of specific concerns or availability of specific data. Along the Issaquah Creek mainstem, channel migration was reviewed using sequential aerial photos, following the preliminary results of Blomquist (1987). Review of depositional conditions also relied on data in that report, together with channel cross-sections surveyed for 1977 and 1985 floodplain models. Sediment transport calculations, made in lower Issaquah and Tibbetts Creeks, are based on HEC-2 backwater modelling, field sediment data, and the Bagnold formula for bedload transport (Bagnold, 1980). Potential impacts to the upland channels were largely evaluated from disturbances revealed through air-photo coverage of their drainage areas. Recent area-specific studies by others were also reviewed and their results incorporated as appropriate, including a channel study of lower Tibbetts Creek (Watershed Company, 1990) and a brief review of the Issaquah Creek delta (Northwest Hydraulic Consultants, 1990).

7.3.0 CHANNEL PROCESSES

7.3.1 Introduction

The activity of Issaquah Creek, Tibbetts Creek, and their tributaries is expressed in a variety of ways in the landscape. In broadest terms, erosion in the upper basin generates sediment that is transported through the system and comes to rest in the lower basin. But transport of that sediment can be interrupted by either natural or artificial conditions along the stream system. The passage of that sediment can also affect the behavior of the streams that are carrying it. This section therefore reviews the available information on the dominant channel processes in the Issaquah Creek and Tibbetts Creek basins, particularly the noteworthy zones of erosion, deposition, and channel migration identified in the system.

7.3.2 Upland Channel Erosion and Catchment Disturbance

Introduction

The slopes of Cougar, Squak, and Tiger Mountains have undergone varied recent histories of logging and other development activity. Several areas of disturbance (see below), absent on 1970 aerial photographs but visible on 1989 photos, are noteworthy because they affect substantial percentages of individual catchments of individual streams within the two basins. Such areas have rather good correlation with downstream problems during the January and November 1990 storms.

Cougar Mountain

The largest disturbed area draining into Tibbetts Creek off Cougar Mountain is the "Clay Pit," lying at the headwaters of tributary 0171. It is a stripped, largely impervious area without significant surface-water control and covering about 30 acres. It composes only a few percent of the overall drainage area for tributary 0171, and not surprisingly the lower channel is in relatively good condition. But farther up-basin, the pit generates the predominant source of runoff into the headwater stream. This runoff initiated several large debris flows, involving several hundred cubic yards of sediment, that entered tributary 0171 during the January 1990 storm.

Squak Mountain--Tibbetts Drainage

The west side of Squak Mountain is scarred by three mining sites, one active and the others largely abandoned, that contribute large sediment loads to the downstream system. The lowermost mine, at about RM 2.6 of Tibbetts Creek (the Harris mine), is inactive. The second site is an abandoned clay pit which occupies about 10 percent of the tributary area to 0174 and 0175. Its steepness, abundance of loose mine tailings in erosional contact with the two streams, and complete absence of erosion-control measures guarantees downstream impacts. The upper, active site (Sunset Quarry) occupies over one-half of the tributary area of upper Tibbetts Creek above SR 900. The sediment control pond on the site has failed repeatedly, in part because the entire upstream flow of Tibbetts Creek is routed through it. Impacts to the adjacent May Creek basin have also resulted. Downstream turbidity and sediment loads are frequent testimony to these conditions and have been subject to long-standing enforcement action by the County's Building and Land Development Division. Despite this action, no substantive improvement has occurred, perpetuating what is probably the single greatest impact to Tibbetts Creek.

Westerly drainage off Squak Mountain has also created erosion and deposition problems on the slopes above RM 2.1 on Tibbetts Creek, near SE 82nd Street. Drainage collected by stormwater facilities in the new plat of "Twenty-six Point Five" off Mount Olympus and Mount Logan Drives SW, in part from onsite runoff and in part from unidentified sources farther upstream, is discharged into two unnumbered channels that drop over 300 feet into Tibbetts Creek. Flow from these channels is collected and diverted by a series of private drainage systems near the powerline access road just east of Tibbetts Creek. During the January 1990 storm, this flow overwhelmed the downstream system with water and sediment, severing access roads and threatening to inundate at least two residences.

Squak Mountain--Issaquah Drainage

The south and west slopes of Squak Mountain are remarkably free of recent logging or development. The most significant exception is on the southwest shoulder of Squak Mountain,

where a series of multi-acre lots dot the upper tributary area of tributary 0212E, and to a lesser extent tributary 0212D. Downstream problems on the depositional fan of these streams, just north of McDonald Creek (tributary 0212), are significant on 0212E and largely absent on 0212D. Yet 0212A, with almost no disturbance save a single access road to the relay station on the summit, has had the worst problems with sediment passage through its culvert under SE May Valley Road. Future development in this tributary's subcatchment, therefore, would likely have even more serious effects on the downstream system than seen elsewhere in the McDonald Creek valley to date.

The northeast slopes of Squak Mountain drain very steep terrain at about the southern edge of intense development in the City of Issaquah. Several of these channels (notably tributaries 0194 and 0195) have experienced significant erosion in their upstream reaches, particularly during the January 1990 storm, and commensurate downstream deposition near their confluences with Issaquah Creek.

Tiger Mountain

Recent clearcuts near the eastern boundary of the Issaquah Creek basin occupy the headwaters of several streams in this area. Cuts of only 10 percent or less of the tributary area drain to Holder Creek (tributary 0178), Fifteenmile Creek (tributary 0207), and tributary 0203. In contrast, cuts of about 40 percent of the tributary area on both No Name Creek (tributary 0206) and Nudist Camp Creek (tributary 0203A) in 1976 and 1983 have increased flows by about 10 percent, based on HSPF modelling of the No Name Creek subcatchment (an equivalent analysis was not made of the smaller drainage area of Nudist camp Creek). Some additional sediment load is likely as well. These two channels had severe problems with sediment deposition at the Issaquah-Hobart Road during both the January and November 1990 storms. Any additional clearing on these slopes would likely have increased impacts downstream.

Other channels in this area have a history of erosion and downstream sedimentation. Two, tributaries 020 and 0203, were reported to have had sediment traps installed in 1933. They were washed out during a large flood in 1950, resulting in blockages of the Issaquah-Hobart Road, and were never replaced. Similar road blockages also occurred in January 1990.

Non-Mountainous Upland Channels

In addition to the major uplands of the two basins, two other areas have suffered particularly severe downstream impacts. They are characterized by slopes that, although not as steep or extensive as those draining the mountains, are underlain by particularly erodible deposits of the Vashon advance outwash (see GEOLOGY, Chapter 3). This deposit, non-cohesive and relatively gravel-poor, is implicated in some of the most severe channel erosion problems County-wide (Booth, 1989; King County, 1989).

In these basins, this deposit is exposed in only a few areas, particularly along the south side of the McDonald Creek valley and at the base of Mirrormont, in the middle Issaquah sub-basin along the Issaquah Hobart Road. Above McDonald Creek, only minimal logging and road-building in a portion of the tributary area of an unnumbered stream had previously occurred. However, the downstream plat of Sunset Valley Farms had restricted conveyance at the valley floor by construction of two houses on the alluvial fan of the stream. The flow of water and sediment resulting from the January 1990 storm caused thousands of dollars of damage to these properties. Although improvements to the conveyance system were made that weathered the November 1990 storm, much more intense development is presently proposed for the tributary basin, with an Environmental Impact Statement already in progress for one of them (Emerald Green). Other such channels drain adjacent hillsides, with the potential for similar impacts to future downslope development (see also FLOODING, Chapter 6).

The second such problem area lies at the base of Mirrormont, at two specific locations. One site lies about 0.7 miles southeast of the main entrance road. Here, an unnumbered channel draining a steadily developing area of about 50 acres overtopped its ditch-and-culvert drainage system in both January and November 1990, and then flowed over the steep slope above the Issaquah-Hobart Road, excavating a ravine some 20 feet deep, 40 feet wide, and several hundred feet long. The sediment so derived blocked the highway during both storms.

The second Mirrormont site lies about 0.5 miles farther southeast, where two unnumbered tributaries cross a private road system. The major disruption during the January 1990 storm came from sediment deposition and culvert washout at the crossing of Pheasant Creek (tributary 0178E), which drains the eastern part of Mirrormont and adjacent slopes of Tiger Mountain, at its crossing of 262nd Avenue SE. This pattern was likely augmented by diversion of almost one square mile of tributary area from Holder Creek into this catchment by improper culvert placement on Tiger Mountain. On a western tributary, which drains the central Mirrormont development and originates at the plat of Mirror Lake Estates (see FLOODING, Chapter 6), upstream channel erosion and downstream sediment deposition caused the washout of a smaller road, 261st Avenue SE. Continued development in Mirrormont is likely not only to increase the severity of these existing conditions but also to increase the chances that new such problems will arise, because the advance outwash deposit probably underlies the hillslopes both southeast and northwest of these sites as well.

7.3.3 Valley-Floor Deposition

Once eroded, the sediment that is transported by high-gradient stream channels remains in motion only as long as the flow is competent to transport it. Although flow competence is a combination of several factors, on a basinwide scale it is crudely proportional to both the stream discharge and the channel gradient. Thus if a stream undergoes a reduction in gradient without commensurate tributary inflow, its competence to transport decreases. Under most conditions, this results in a zone of deposition.

In the Issaquah Creek basin, such depositions zones are widespread. They line the valley walls of Issaquah Creek and McDonald Creek, where steep lateral tributaries off Tiger, Cougar, and Squak Mountains reach the valley floors. In these areas, stream-channel activity since deglaciation has constructed broad alluvial fans covering tens to hundreds of acres, reflecting the thousands of years in which lowered gradients have resulted in reduced competence and a deposition of the sediment load.

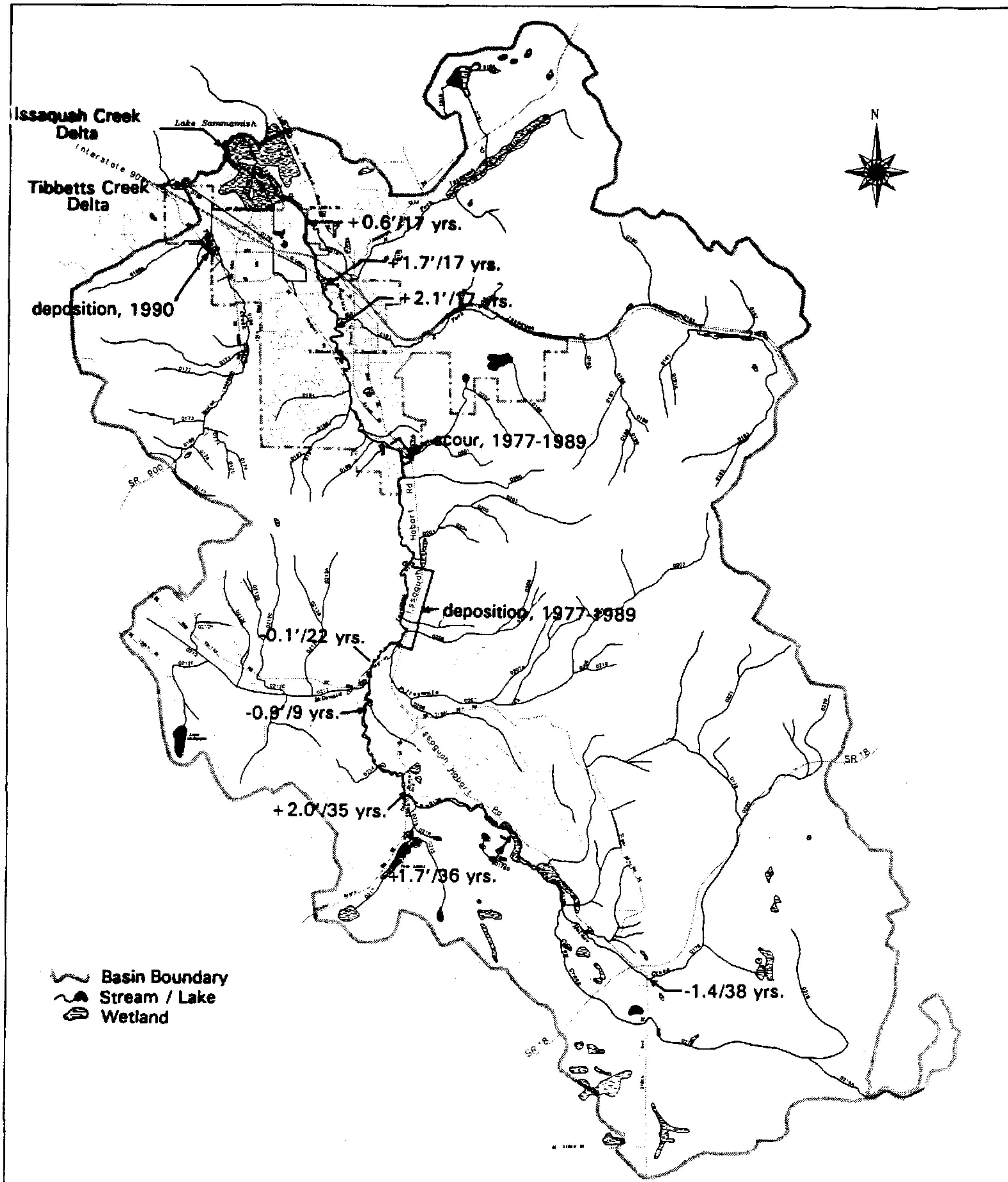
Several additional factors help determine the rate and the impacts of this deposition. Clearly, an increase in the sediment load from upstream will result in an increase in the volume of material deposited downstream. But even an increase in flow rate from development activities can make a disproportionately larger increase in sediment load, because the balance between erosivity of the flow and the erosional resistance of the channel bed and banks is disrupted. As a result, greater sediment is mobilized from the channel perimeter itself. Once on the alluvial fan, deposition of transported sediment becomes more problematic and damaging if (and where) it becomes more localized. Flow constrictions, particularly culverts, locally reduce competence and offer a locus for deposition. As a result, sediment preferentially drops out at these points, initiating a vicious circle of reduced conveyance, reduced competence, and increased deposition. Where the volume of sediment is sufficient, as during the January 1990 storm, blockage of ill-placed roadways with susceptible culverts is the ultimate result. At another locality, the sediment load of Cabin Creek (tributary 0194 off of Squak Mountain) has contributed to multiple partial blockages of the water intake to the State fish hatchery, just downstream of the tributary's confluence with Issaquah Creek.

A second, related type of depositional zone results from the unavoidable flattening of stream gradient where the flow enters its receiving waters and transport capacity drops to essentially zero. In this basin, Lake Sammamish provides that final gradient control. As a result, deltas are formed by the sediment transported by Issaquah and Tibbetts Creeks. Their rates of expansion are discussed in a later section.

7.3.4 In-Channel Deposition--Bridge and Channel Surveys (Figure 7-1)

<u>Variability of Deposition</u>

Deposition in a stream system as varied as Issaquah is a complex process. Not only are zones of erosion and deposition distributed unevenly along the channel system, but also the changes can vary over time as well. Spatial variability results from changes in the channel gradient, such as where the profile of a stream flattens downstream and the competence of the flow to carry its sediment load decreases. Variability can also reflect the location at which new sediment loads enter a stream, such as where a steep lateral tributary joins with the main stem. Temporal variability occurs in response to the annual variability in storm intensities and flood flows. It also is imposed by the rate at which bedload sediment moves down a stream system--a large slug of sediment deposited in a channel reach may be transported out of that reach (and into the



LOCATION OF SCOUR AND DEPOSITION

Issaquah Creek Basin Planning Area

Figure 7-1

next), but it may take years or even decades for that process to be completed. Finally, temporal variability in erosion or deposition can reflect changes in the basin or to the channel itself. Such changes can be as simple as a newly constructed undersized bridge or culvert crossing that constricts the flow at high water, resulting in locally reduced competence and thus deposition. They can also be as pervasive as the net increase in discharge accompanying urbanization, or the increase in sediment load caused by land clearing or construction.

Data Sources

Although theoretical models of sediment transport ideally can predict both the spatial and temporal variability in channel erosion and deposition, more concrete methods are generally more reliable. In the Issaquah Creek basin, several such data sources are available. Information on past conditions was provided from the 1977 FEMA floodplain study of Issaquah Creek, which surveyed the bed elevation of Issaquah Creek from the mouth upstream to about the confluence of Carey and Holder Creeks. These data are supplemented at a number of bridge crossings, between SE 56th Street and the Issaquah-Hobart Road crossing of Holder Creek, where bed elevations relative to the bridge structures were first measured during their construction. Those data cover an interval between 1949 and 1978, depending on the year of a particular bridge's construction.

More recent data are available to compare with this historical information. The most complete data set is provided by 1989 Issaquah Creek floodplain surveying, performed by David Evans and Associates for this basin plan. Owing to differences in its elevation datum relative to the FEMA survey, the 1989 information is used only upstream of the Fish Hatchery weir, a fixed elevation reference for both surveys, to the limit of this survey at about the junction of Issaquah Creek with McDonald Creek. More site-specific changes were determined by remeasuring, in 1987, the bridges for which historic information was available, selecting only those (eight in total) for which correlation with the old data appeared reasonable (Blomquist, 1987).

Results--Issaquah Creek

Although no universal trend of erosion or of deposition emerges for the whole of Issaquah Creek, several zones show significant changes. The most dramatic is in the 1.3-mile reach starting immediately below the confluence with Fifteenmile Creek. The 1977 and 1989 floodplain surveys suggest that up to several feet of deposition have occurred during these 12 years. Interestingly, aerial photos taken in 1961 show that this same reach of channel, particularly from No Name Creek (tributary 0206) downstream (i.e. the lowermost 1 mile of this reach), was the most heavily braided of any reach in the Issaquah system, with broad unvegetated point bars at every bend. By 1970, the upstream end of this intense braiding had shifted downstream about 3000 feet; the downstream end had also shifted downstream, but only 1000 feet. Thus the zone of braiding had contracted as it moved, suggesting the passage of a

slug of sediment down the system. Above this zone, previously braided reaches had been reconfined to a single channel. By 1989, nearly all sign of braiding had disappeared from the active channel, with all once-fresh bar surfaces now revegetated. Based on both the upstream limits of 1961 braiding and the zone of maximum changes in bed elevation between 1977 and 1989, No Name Creek and possibly Nudist Camp Creek (tributary 0203A) are the primary sources of sediment into this reach of Issaquah Creek, and they are capable of supplying sufficient sediment to affect the morphology and channel-bed elevation of the main stem for many years or decades.

Other zones of significant deposition are scattered along Issaquah Creek but are of lesser magnitude. The impact of that deposition, however, may actually be greater in places because of more intense adjacent land use that cannot tolerate even slight increases in water-surface elevation at flood stage. This is particularly true in the city of Issaquah, where the bridge surveys indicate 0.59, 1.72, and 2.13 feet of deposition at Dogwood Lane, Gilman Boulevard, and SE 56th Street between 1970 and 1987. In part, these deposition zones probably reflect the constrictions on flood flows imposed by these road crossings, with similar conditions likely at the other bridges where survey data were not available (particularly SE Clark Street). As the basin continues to urbanize, both water discharges and sediment discharges are likely to increase, and so the response of the channel system to such constrictions is likely to increase also. As a result, continuation or even acceleration of the rate of deposition (presently about a foot, on average, per decade) is likely.

Other deposition zones are indicated by available data at the bridge crossings of Cedar Grove Road and Getschman Road in the Middle Issaquah sub-basin, but only at rates of a fraction of an inch per year (about 2 feet total in 26 years). Eventually, however, bridge capacity could be compromised.

Significant degradation of the channel bed is indicated in only one reach, about 3000 feet of channel in the area of the Sycamore development. This lies about one mile downstream of the area of maximum deposition discussed above; it includes a portion of the channel that was relocated in 1933. The data are insufficient to determine whether the zones are actively migrating downriver, and thus whether the deposition now being seen upstream will eventually reach this lower area. If so, the rate of migration is likely to require several decades to traverse the necessary distance to this developed area, in which flooding is already a significant problem. Loss of channel capacity through future aggradation would add to this flooding problem, but it is unlikely to make conditions materially worse than they are already.

Bed degradation is also indicated by bridge surveys at the upstream and downstream ends of the Four Creeks Ranch area, in the vicinity of the confluence of McDonald Creek with Issaquah Creek. At the Four Creeks Road Bridge (229th Drive SE), the channel has degraded 0.9 feet from 1978 to 1987. At the SE May Valley Road crossing, 0.3 miles downstream, that degradation reduces to a near-negligible 0.1 feet in the 22 years to 1987. Thus aggradation does

not add to the severe impacts of channel migration, which is particularly active in this reach (see later section).

Deposition in Lower Tibbetts Creek

Physiographically, Tibbetts Creek is a "compressed" version of Issaquah Creek. Like its larger neighbor, the Tibbetts basin is basically a low-gradient trunk stream fed by high-gradient tributaries flowing off the surrounding uplands. But whereas the Issaquah Creek basin extends 12 miles as it falls from its upland divide to Lake Sammamish, the Tibbetts Creek basin covers a nearly equivalent elevation drop in less than one-third of that distance. Thus gradients here are much steeper overall.

The contrasts between upper and lower parts of the basin are particularly strong along Tibbetts Creek. The mainstem enters its central valley near the south basin boundary at about elevation 400 feet (RM 3.6) and falls to elevation 100 feet over the next 1.9 miles (RM 1.7), for an average slope of 3 percent. The lowermost 1.9 miles of Tibbetts Creek, from just above Tibbetts Creek Manor to Lake Sammamish, declines in gradient almost 5-fold, to 0.7 percent. In comparison, Issaquah Creek has an average gradient of 0.8 percent between elevation 400 feet (Carey-Holder Creek junction) and elevation 100 feet (Sycamore Street crossing), reducing less than 3-fold to 0.3 percent downstream to Lake Sammamish. Sediment transport in Issaquah Creek is therefore less intense (because of the lower gradients overall) and deposition much less localized (because of the more gradual downstream change in gradient) than for Tibbetts Creek.

These physiographic conditions have several consequences for deposition in lower Tibbetts Creek. The most abrupt decline in channel gradient, in the few thousand feet above and below SE Newport Way, includes no significant lateral tributary inputs to the main flow. Thus sediment transport through this reach should decline dramatically. Indeed, the entire broad lowland surface from the vicinity of the Tibbetts Creek Manor to at least I-90, and probably all the way to Lake Sammamish, is mantled by relatively recent alluvial-fan and floodplain deposition of Tibbetts Creek as it progressively loses its competence to transport the sediment load from upstream. Efforts to confine the channel to a single thread have been thwarted, particularly near the manor, by abundant in-stream deposition of several feet of gravel during the January and November 1990 floods. This inherent propensity of the stream system for deposition here has been enhanced by increased flows from basin development, adding to instream channel erosion farther upstream, and by the noteworthy contribution of sediment to the channel near the head of Tibbetts Creek by the Sunset Quarry and another, now-abandoned clay-mining site about 3000 feet downstream.

Transport competence in lower Tibbetts Creek is also affected by recent alterations to the stream system. Most relevant here are the constrictions on flood flow imposed by undersized road crossings, which impound water on their upstream side and so further reduce the ability of the flow to transport sediment. Coincidentally, the crossing at SE Newport Way, in the middle of

the zone intrinsically most favored for sediment deposition, also imposes the greatest single constriction on flood flows of any in the system (Watershed Company, 1990). In contrast, small fish-habitat structures, installed near the manor in the summer of 1990, were buried under several feet of sediment in this deposition zone and obviously had no effect whatever on the ultimate pattern of deposition in the lower basin.

7.3.5 Delta Growth into Lake Sammamish

In addition to deposition within the channels of Issaquah and Tibbetts Creeks, sediment that is transported all the way to their mouths deposits in Lake Sammamish. The finest size fractions move out into the lake and eventually settle to the bottom. Near to the shore, the slightly coarser deposited sediment forms a delta, whose rate of growth can be followed through sequential aerial photos.

The prehistoric Tibbetts Creek delta extends as a largely forested lobe into the southwest corner of Lake Sammamish. Its shape is crudely rectangular, about 400 to 500 feet on a side. Tibbetts Creek presently empties off the northeast corner of the delta lobe. Using 1970 and 1989 airphotos, Tibbetts Creek has extended its delta about 60 feet to the northeast. The sediment does not encroach on any docks or other structures, although such improvements are located a few hundred feet west along the shoreline, out of the path of likely future deposition. Any future development in this area, however, would need to take this process into account.

The prehistoric Issaquah Creek delta is a much broader form, extending about 1000 feet into the Lake Sammamish basin and forming the pronounced "dimple" along the southern shoreline of the lake. The creek presently enters the lake at the northwest corner of the delta, where a relatively recent lobe, some 200 feet in length and width, extends off the main body of the delta and into the lake. Between 1970 and 1989, a sediment plume of an additional 200 feet in length has built out on both sides of the creek and extends directly into the lake. No structures are affected by this growth, and none lie within several thousand feet of it.

7.3.6 Channel Migration--Zones and Rates

<u>Introduction</u>

Issaquah Creek, and to a lesser extent Tibbetts Creek, is a migrating river. As such, they display the same basic process of channel migration common to all such systems--zones of long-term stability, and zones where channel shifting is a near-annual event. The locations of such zones can be crudely predicted from sediment transport patterns, but sequential aerial photographs provide the most reliable method of displaying the past sites of migration and thus the most likely future zones of activity. These historical data also provide the past rates and

amplitudes of migration, and thus they provide the basis for identifying areas of particular concern, either present or future.

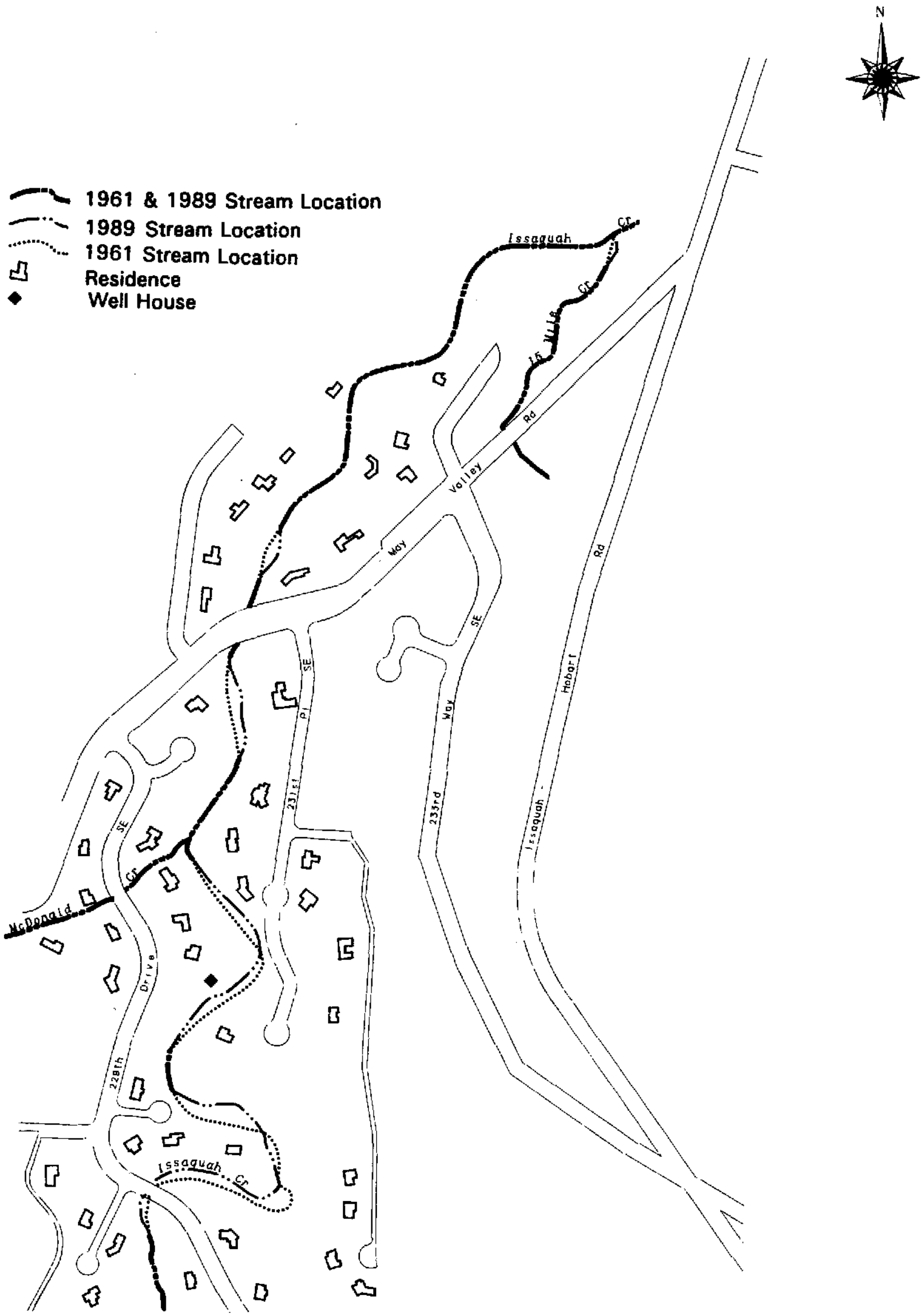
The two data sources were 1:4,800-scale orthophoto transparencies taken in September and October of 1961 and 1:7,200-scale stereo-paired photos taken during the early spring of 1989. Comparative coverage was limited to the lowermost 9.6 miles of Issaquah Creek by availability of the older set. Coverage was further limited by the percentage of channel obscured by late-summer tree canopy in 1961. Despite these restrictions, over 80 percent of the main channel was successfully compared over this 28-year period. The precision of the method is estimated at about 0.05 inches on the photos or 30 feet on the ground, about 1 channel width, which accounts for enlargement, alignment, and drafting errors. Precision is somewhat better, however, where roads or houses provide closer controls.

Results--Major Zones of Migration

Two major zones of migration, with channel shifts in excess of 150 feet over the 28-year interval of the air photos, were recognized. The first lies in the one-half mile immediately downstream of the Cedar Grove Road crossing, where the channel has shifted to the west as much as 200 feet. The area so affected is entirely undeveloped pasture. An additional zone of equal or greater magnitude is reported by area residents. It covers an area just upstream, between Cedar Grove Road and SR 18, and so is beyond the coverage of the older air photos.

The second major zone, with channel shifts almost as great as the first, lies downstream of SE 56th Street in an undeveloped part of the State Park. Here, the amplitude of meander bends in 1961 had expanded considerably by 1989. At the documented rates of migration, at least one ox-bow lake could be formed in the next 10 years.

A third zone of migration is also significant, but less for its absolute magnitude of change than for the proximity of developed land in its vicinity. It lies just upstream and downstream of the confluence of Issaquah Creek with McDonald Creek, and as such it encompasses nearly all of the Four Creeks Ranch development (Figure 7-2). This zone probably reflects a more subdued downstream continuation of the first major zone discussed above, namely that below the Cedar Grove Road. Through Four Creeks Ranch, the migration is at most 75 feet, and typically only one-half that value, over the 28 years. Yet even this reduced migration has locally consumed half or more of the setback of houses from Issaquah Creek, particularly those on 231st Place SE and SE 139th Court. The effects of the two 1990 storms, although not covered by these sets of airphotos, have only furthered the action of the stream in the same fashion that had been accomplished in the preceding 3 decades. There is no indication that any of these processes are abating. Localized armoring of the bank at a few select locations through this reach will tend to distort the pattern of meander migration, potentially increasing the impact on those banks remaining unprotected.



CHANNEL MIGRATION: 4 Creeks Ranch Area

Issaquah Creek Basin Planning Area

0 500 1000
Feet

Figure 7-2

Results--Downstream Sequence of Migration Zones

Although the three zones of channel migration described above are significant for their rates or for their impacts, migration affects many reaches in the study area to varying degrees. Within the area of air-photo coverage, their conditions are as follows:

Mirrormont to Upper Four Creeks Ranch (RM 9.6-8.3)--This reach includes the most intense zone of channel migration in the study area, with average rates of nearly 6 feet per year. The upstream-most 2000 feet was completely stable during this time, however, and the lowermost 3000 feet shows a few short reaches of near-stability separated by zones with shifts of about 50 to 100 feet.

Four Creeks Ranch (RM 8.3-7.3)--See above discussion and Figure 7-2. Channel migration rates average one to two feet per year, with the pattern dominated by the downvalley translation of entire meander loops.

SE May Valley Road to Nudist Camp Creek (tributary 0203A) (RM 7.3-6.5)--Tree cover obscured about 30 percent of this reach in 1961, but the remainder showed no measurable shift in the 28-year period.

Below Nudist Camp Creek (RM 6.5-5.6)--Migration in this reach is characterized mainly by a change in channel pattern, from intensely braided in 1961 to single-thread in 1989. Nearly all of the channel shifts during this period were accommodated within a broad "active-channel" zone, readily identifiable on the 1961 air photos by alternate unvegetated gravel bars. They define a band 100 to about 150 feet wide where the flow has occurred in the past and probably will move into again in the future. Since 1961, a few structures have been constructed immediately adjacent to this active zone, particularly in its uppermost 2000 feet, and the likelihood of future encroachment by the stream on these structures is high.

Lower Issaquah-Hobart Road (RM 5.6-4.3)--Migration by the channel here is low. Only one area, just downstream of SE 104th Street, shows significant movement in the 28-year period. This area also exemplifies the often unintended effects of bank protection. Immediately upstream of 5 structures, constructed on the left bank at the outside of and just down-valley of a meander bend, the channel has shifted at most 40 feet. As of 1989, a revetment had been constructed to limit migration of the channel in the immediate vicinity of these structures, particularly the last one which lies directly in the path of the downvalley translation of this meander bend. But because of this interruption of the migration pattern, flow immediately downstream has been disrupted, and here the channel is shifting over twice as fast, with displacements of up to 100 feet between the time of the two photo sets.

Sycamore Area (RM 4.3-4.0)--A portion of the channel here was relocated in 1933; since 1961, channel migration through this area has been moderate. Shifts average up to 40 feet, although one zone of meander cut-offs moved the active channel 150 feet, probably in a single flood event. By 1989, houses along SE Sycamore Creek Lane had seen the creek consume one-half of the distance between its 1961 position and the footprint of these structures; elsewhere in this reach, the adjacent land is undeveloped.

Sycamore to Clark Street (RM 4.3-3.5)--Trees obscured the 1961 view of the channel in this reach and so no measurements are possible.

Hatchery Area (RM 3.5-3.0)--The channel has migrated a few tens of feet downvalley just below the SE Clark Street bridge, but otherwise it has been stable through this reach.

Lower Issaquah City Area (RM 3.0-1.4)--The channel here is generally stable, anchored in position by multiple bridges, culvert crossings, and armored banks. A few short areas of migration occur; only one, between Northwest Dogwood Street and NW Holly Street, exceeds a few tens of feet of movement in the last 28 years.

State Park (RM 1.4-mouth)--See above discussion. Meandering below the SE 56th Street bridge is active and affects over 80 percent of the channel length. The absence of development in this area is fortunate, because the zone of affected area defines a broad band up to 300 feet wide.

7.3.7 Sediment Transport Analysis

Introduction

The movement of sediment along the stream system in the basins depends on both the supply of sediment to the channels and the competence of the flow to move that material. These two factors are not wholly independent: increased sediment loads tend to steepen the gradient of the channel, increasing competence, and increased competence will tend to increase the sediment supply, by scouring the channel bed and banks. This interaction complicates any effort to make a precise determination of sediment movement; on the other hand, it provides a self-regulating mechanism that allows data developed from one river system to be applied to an entirely different location with some confidence.

The most useful quantification of sediment movement in basins such as these is the rate of transport of the "bedload," namely the sediment that defines the channel form and that moves by sliding, rolling, or hopping along the bed. This omits the finer sediment that travels in suspension with the water flow, and which typically constitutes well over half of the total sediment yield from a drainage area. This finer fraction, however, does not affect channel shape

or deposition as profoundly as the bedload fraction unless deposition into large standing water bodies (such as large wetlands or lakes) is of major concern.

Bedload Transport Calculations

A large number of predictive equations have been developed over the last 100 years to calculate bedload sediment transport. All depend on identifying a threshold flow to initiate motion, and then each calculates the rate of transport as a function of the flow in excess of that threshold. Different flow parameters are used by different formulas to calculate that rate, and different methods are used to predict the initial threshold of movement.

In general, the prediction of different formulas on the same stream are wildly different, with results differing by 10, 100, or more. Gomez and Church (1989) analyzed ten such formulas on the same data set (where the true transport rate had also been measured directly) and concluded that the formula of Bagnold (1980) was most suitable for gravel-bedded rivers, such as those in the Issaquah Creek and Tibbetts Creek basins. Predictions of this formula were typically within a factor of 2 of the actual measured values. This range of imprecision, low by engineering standards but very high by sediment-transport standards, should be remembered throughout the discussion that follows.

Methods

The Bagnold formula correlates the movement of bedload with the "unit stream power," or rate of energy expenditure of the flowing water per unit area of the bed. To calculate this value, the flow depth, slope, and active channel width are needed. The threshold of sediment movement is determined from the size of the sediment awaiting transport, which for this formula is characterized by the median grain diameter of the bed sediment.

Flow parameters for this analysis were derived from HEC-2 model outputs. Cross-sections in natural channels were selected, and relationships between discharge and depth, and discharge and width, were determined. These relationships were then used to define a depth and width of flow at any discharge, necessary because the values used in the transport analysis (see below) were not exactly those modeled with HEC-2, requiring some interpolation (but not extrapolation). Water-surface slope was also determined from the HEC-2 model; variation of slope with changing stage was judged not significant here and so a single value was used for all discharges. Sediment sizes were estimated visually from the grains below the surface pavement on gravel bars; a more rigorous determination is planned when stream stages decline in late spring 1991.

The Bagnold equation returns instantaneous rates of transport, in units of kilograms (or cubic meters) per second. To convert this value to net transport, this rate of transport must be

multiplied by the duration of the flow (see HYDROLOGY section) producing this rate. The total transport is then the sum of all such individual values. As discharges increase, the two factors change in opposite directions--the rate of transport increases, but the duration of that flow (over the simulation period of 41 years) decreases. Their product thus peaks at some intermediate value, which will vary for each stream but is normally expected to be about the bankfull, 1.5-year event (Leopold and others, 1964).

These relationships are shown in Figure 7-3, using lower McDonald Creek as the example. The instantaneous transport rate depends only on the width, depth, and slope of flow acting on the prevailing sediment. The flow durations graphed here are for current land use--future land use would show longer durations for a given discharge, and forested land use would show shorter durations. The net bedload transport is the annual average rate, expressed here in units of kilograms per year for a given discharge. It peaks at about 50 cubic feet per second, midway between the current 1.5-year and 2-year flows. The total annual transport is the annualized sum of all such annual rates; for this channel, it equals about 80 tons (about 50 cubic yards) per year (see next section). These results are averaged over the simulation period; individual floods could deliver even more than an average year's amount during a single event.

Results

Analyses were made for four locations in the two basins: lower McDonald Creek, two sites on lower Issaquah Creek, and mid-Tibbetts Creek. A fifth site, farther upvalley on McDonald Creek, was attempted and abandoned because the channel behavior was too different from those channels used in initial set-up of the Bagnold formula. A sixth site, on lower Tibbetts Creek, may be added once HEC-2 modeling is completed and verified and additional sediment data are collected.

On McDonald Creek (Figure 7-4), sediment transport has increased modestly from fully forested conditions but could nearly triple under future land use without mitigation. A change of that magnitude probably could not occur; instead, such an imbalance between sediment supply and transport capability would be expressed by rapid downcutting in the lower canyon. To a lesser extent this is already occurring, because the supply of sediment from the upper, low-gradient valley is low already. Increased sediment transport capacity in the lower canyon would simply amplify this existing trend. The annual rate of transport under either forested or current conditions is quite similar with regional data on bedload sediment yield (on the order of 10 tons per square mile per year; see Nelson, 1971).

Two stations in lower Issaquah Creek (Figures 7-5 and 7-6), downstream of the city and above and below the confluence with the North Fork, were analyzed. Both show similar bedload sediment transport rates of a bit over 5 tons per square mile per year (equalling about 500 cubic yards per year at these sites), suggesting this reach is in general balance (barring artificial channel constrictions). Moderate increases in transport have already occurred relative to forested

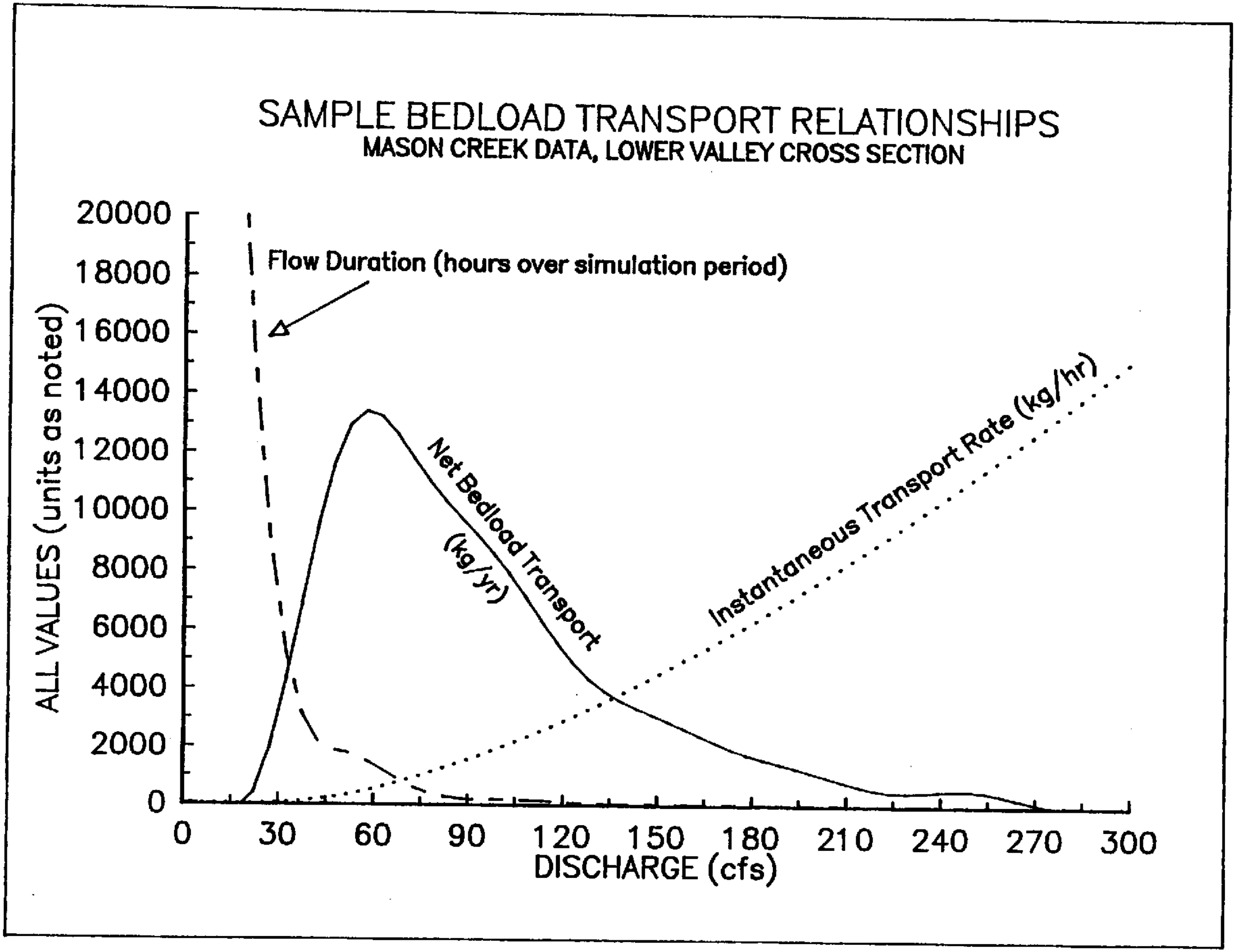

SAMPLE BEDLOAD TRANSPORT RELATIONSHIPS
MASON CREEK DATA, LOWER VALLEY CROSS SECTION
Flow Duration (hours over simulation period)
Net Bedload Transport (kg/yr)
Instantaneous Transport Rate (kg/hr)
ALL VALUES (units as noted)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
30
60
90
120
150
180
210
240
270
300
DISCHARGE (cfs)

Figure 7-3

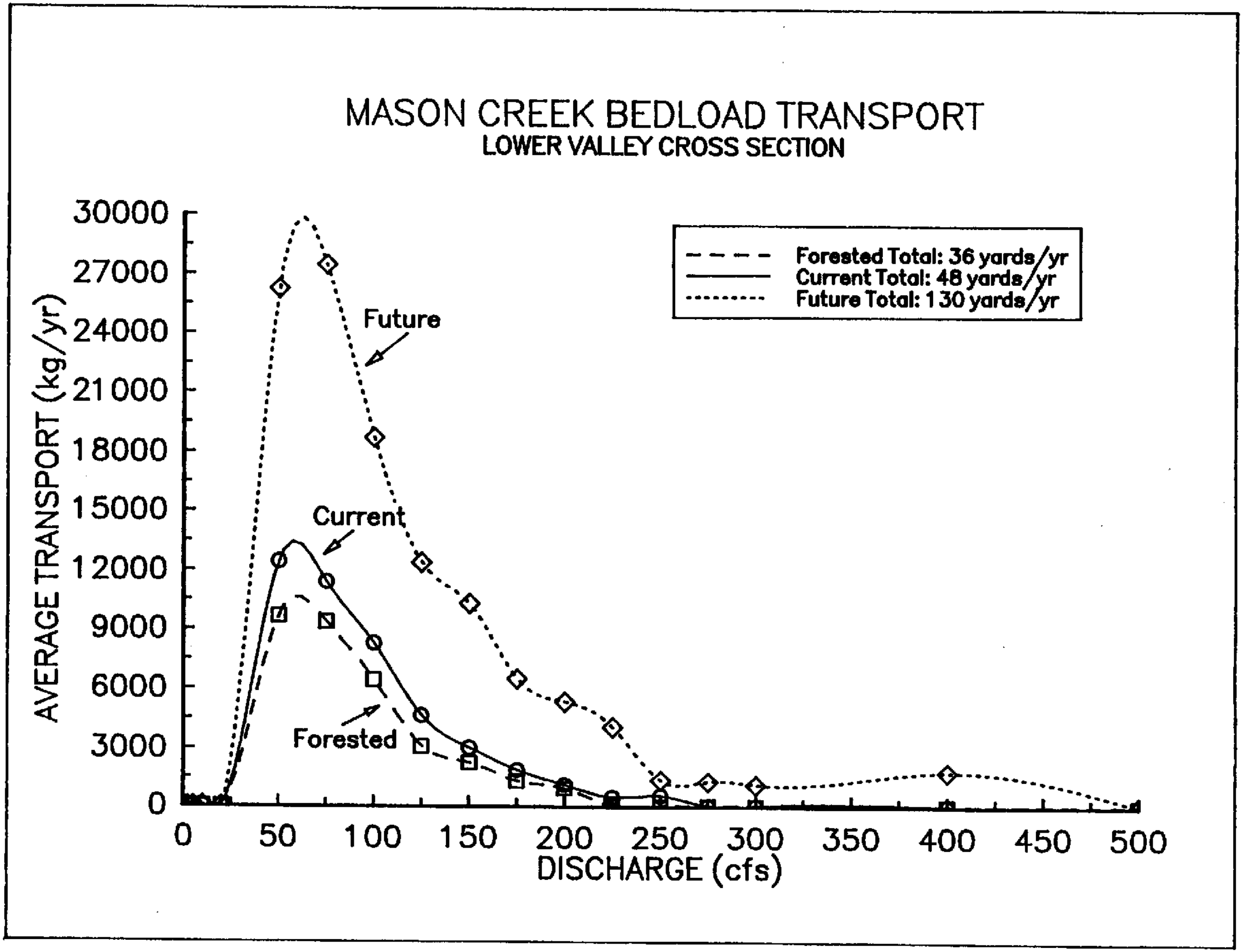

MASON CREEK BEDLOAD TRANSPORT
LOWER VALLEY CROSS SECTION
Forested Total: 36 yards/yr
Current Total: 48 yards/yr
Future Total: 130 yards/yr
Future
Current
Forested
AVERAGE TRANSPORT (kg/yr)
DISCHARGE (cfs)
0
3000
6000
9000
12000
15000
18000
21000
24000
27000
30000
0
50
100
150
200
250
300
350
400
450
500

Figure 7-4

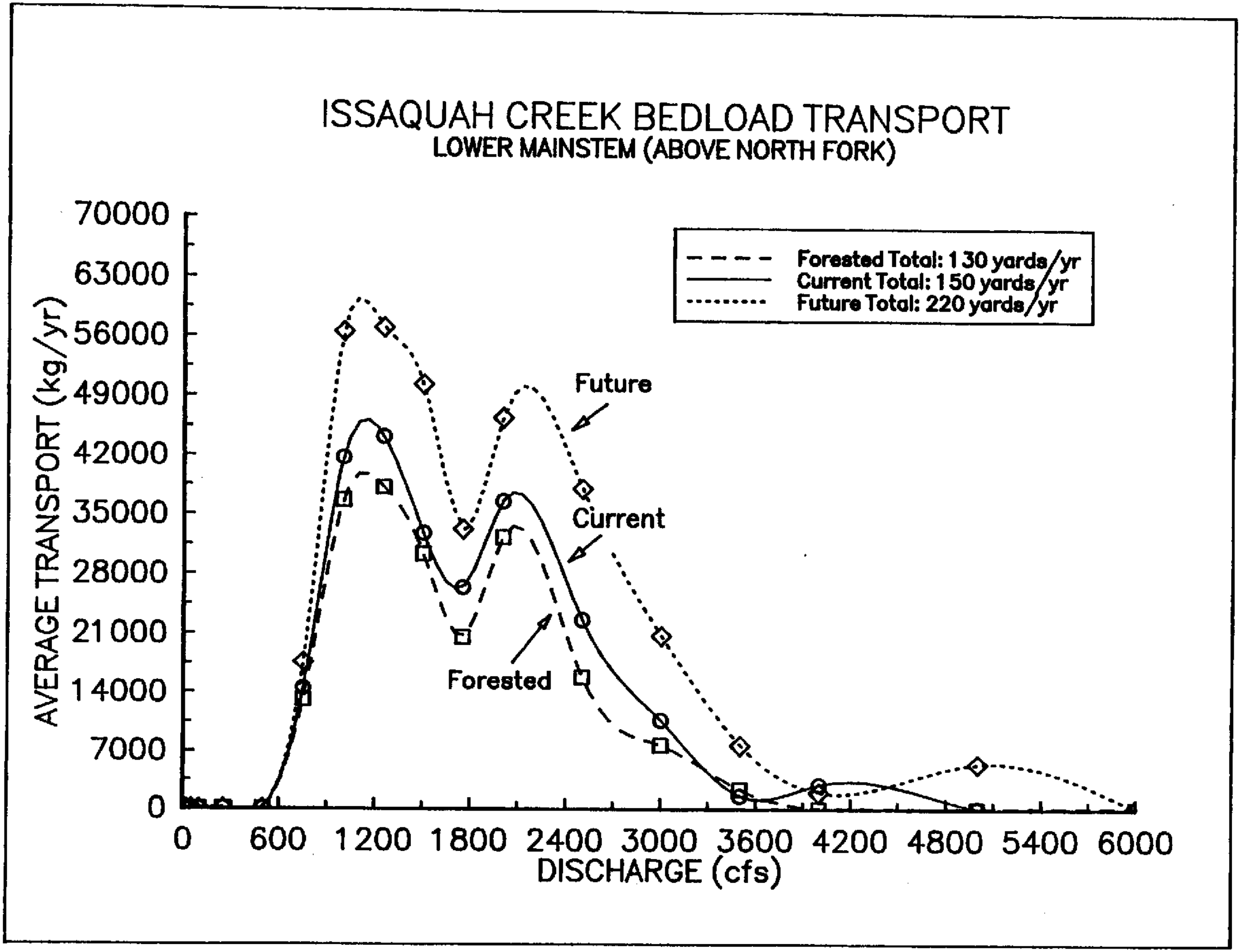

ISSAQUAH CREEK BEDLOAD TRANSPORT
LOWER MAINSTEM (ABOVE NORTH FORK)
Forested Total: 130 yards/yr
Current Total: 150 yards/yr
Future Total: 220 yards/yr
Future
Current
Forested
AVERAGE TRANSPORT (kg/yr)
70000
63000
56000
49000
42000
35000
28000
21000
14000
7000
0
0
600
1200
1800
2400
3000
3600
4200
4800
5400
6000
DISCHARGE (cfs)

Figure 7-5

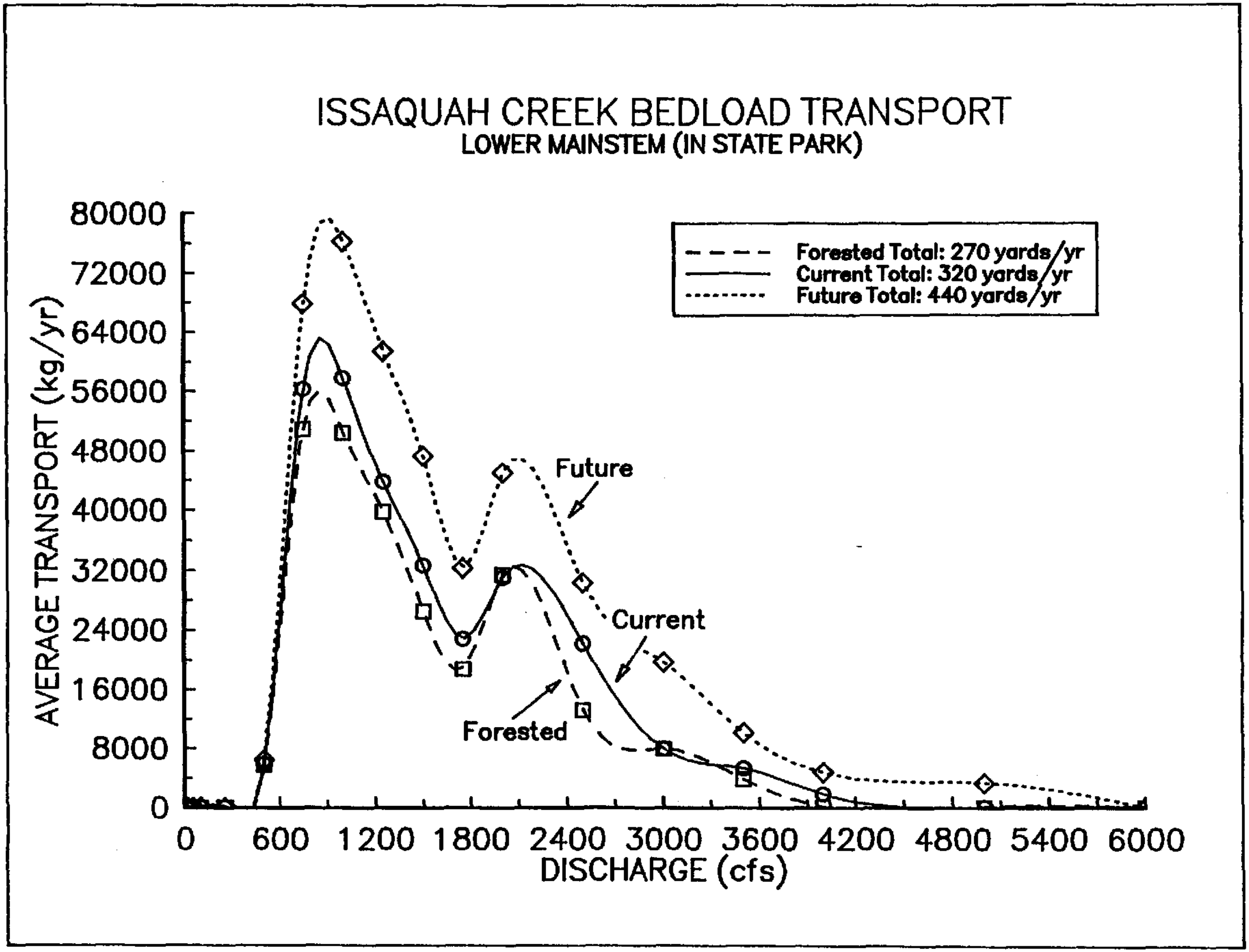

ISSAQUAH CREEK BEDLOAD TRANSPORT
LOWER MAINSTEM (IN STATE PARK)
Forested Total: 270 yards/yr
Current Total: 320 yards/yr
Future Total: 440 yards/yr
Future
Current
Forested
AVERAGE TRANSPORT (kg/yr)
80000
72000
64000
56000
48000
40000
32000
24000
16000
8000
0
0
600
1200
1800
2400
3000
3600
4200
4800
5400
6000
DISCHARGE (cfs)

Figure 7-6

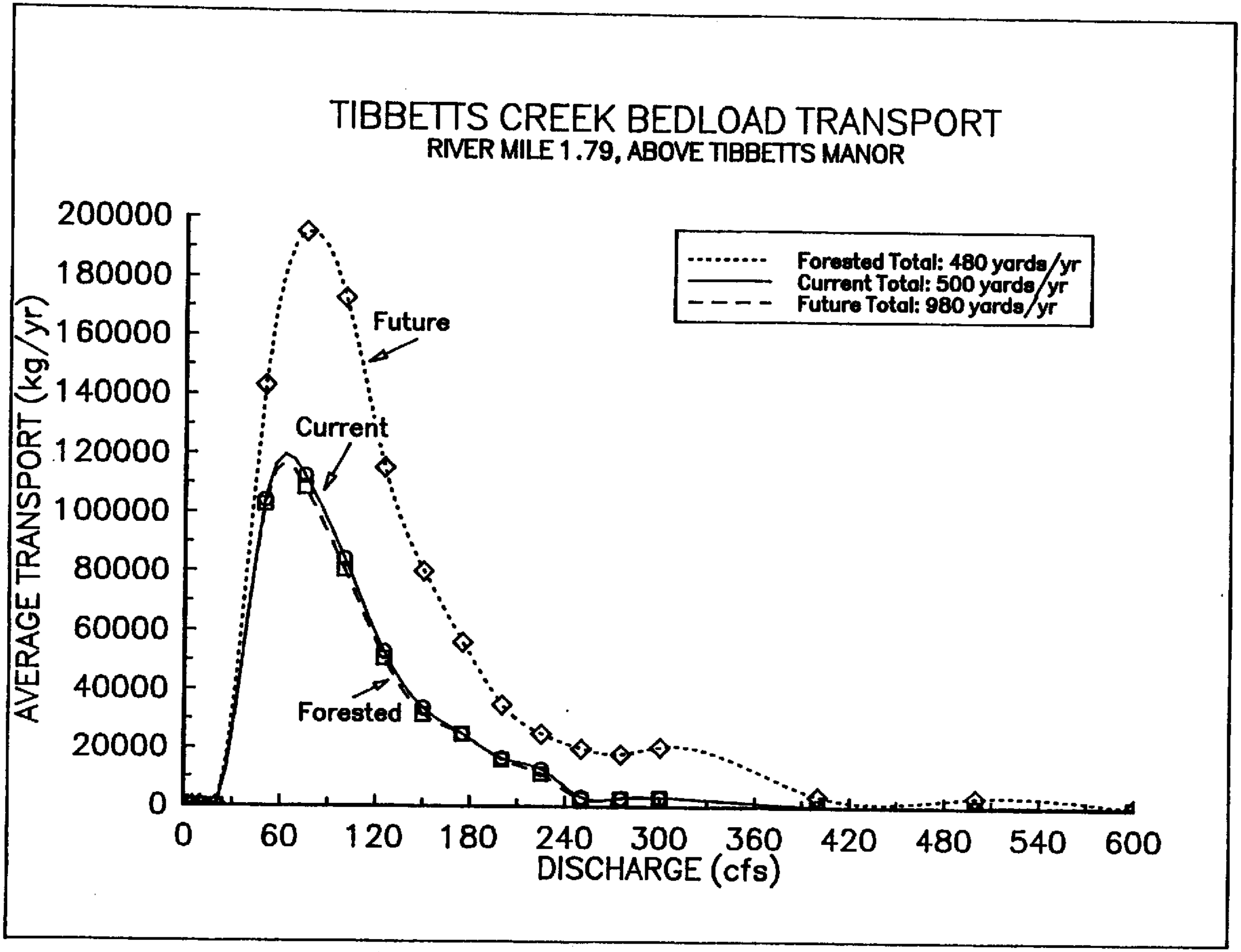

TIBBETTS CREEK BEDLOAD TRANSPORT
RIVER MILE 1.79, ABOVE TIBBETTS MANOR
Forested Total: 480 yards/yr
Current Total: 500 yards/yr
Future Total: 980 yards/yr
Future
Current
Forested
AVERAGE TRANSPORT (kg/yr)
200000
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
0
60
120
180
240
300
360
420
480
540
600
DISCHARGE (cfs)

Figure 7-7

conditions; without mitigation, future flow increases could add another 30 to 40 percent. This degree of change does not bespeak a catastrophic alteration of the stream channel, but it does emphasize that existing sedimentation problems through the city (where channel constrictions render the transport calculation unreliable) will increase in severity. Thus existing problems and trends will worsen as flows increase.

The results from Tibbetts Creek (Figure 7-7) are unusual, probably reflecting both imprecision in the bedload transport model as well as the character of the basin. Calculated transport rates are an order of magnitude greater than those seen elsewhere, although the peak in the annual rate still occurs where anticipated, midway between the 1.01-year and 2-year flows. The volume represented by these rates is about 850 cubic yards per year; if extrapolated to the entire basin upstream of I-90, the rate is 1100 cubic yards per year (remarkably close to the Washington State Department of Transportation estimate of about 1000 cubic yards annually removed from the I-90 culverts). Changes between forested and current conditions are minimal, but without mitigation the future transport rate is predicted to double. Existing sedimentation problems in the vicinity of Newport Way would thus worsen dramatically. Although some additional sediment modeling is warranted to confirm and elaborate these results, the basic implications are clear: Tibbetts Creek is a far more energetic stream than its larger neighbor to the east, and potential land-use changes could increase an already-problematic condition to dimensions that would dwarf other problems basin-wide.

7.4.0 STREAM CHANNEL PROBLEMS BY SUB-BASIN

7.4.1 Introduction

The variety of processes active in these two basins make for a complex pattern of channel conditions. In this section, the general expression of these processes in combination are discussed geographically, with reference both to earlier sections of this report and to field evaluations during 1990.

7.4.2 Sub-basin Processes and Problems

Carey Creek (0218)

With one exception, no significant sediment problems have been reported in Carey Creek, either from the Basin Reconnaissance or during field work for the basin plan. Recruitment of gravel in the upper sub-basin is followed by progressive deposition and downstream fining of the bed sediment as the channel reaches the valley floor. As the channel reaches its confluence with Holder Creek, the bed is largely sand. The absence of significant development along the channel and in its tributary area has maintained an overall balance between water and sediment discharge, with the result that problem conditions are absent and aquatic habitat is excellent.

The one problem in this sub-basin was noted following the November 1990 storm, at the extreme southeast corner of the basin. Here, the channel now diverting flow away from Walsh Lake (tributary 0219A) showed significant bed and bank erosion from recent high flows. The material so eroded has been transported varying distances downstream, infilling portions of the channel of Carey Creek with sand and gravel. The source of the flow is larger than what the previously mapped tributary area upstream would suggest; field review indicates that Webster Creek overflows into the diversion channel at high discharges (see HYDROLOGY section).

Holder Creek (0178)

In contrast with its neighboring sub-basin to the south, Holder Creek shows significant signs of sediment imbalance. These effects are localized, and they are largely concentrated high in the sub-basin where the impacts of logging and SR 18 affect a proportionately greater amount of the tributary area. The channels here display zones of local incision and deposition, which in turn initiate bank failures from either oversteepened slopes or lateral channel migration.

Below the confluence of tributaries 0178 and 0220, the impacts of the upper basin are progressively modulated by the increase in drainage area and the largely intact forested corridor, which contributes copious woody debris to the channel to help stabilize its form. These conditions depend on a coherent corridor and limited flow increases, both of which were becoming less certain as of 1990. In contrast, only one erosion problem in this sub-basin was noted in the Basin Reconnaissance in 1987, localized bank erosion just downstream of the Issaquah-Hobart Road crossing. This problem site appears to be a direct consequence of artificial channel constriction and consequent increase in flow depth and velocity.

Below the Issaquah-Hobart Road, the channel follows a pattern not unlike Carey Creek, with progressive downstream fining. On Holder Creek, however, the gradient change is not as abrupt, and so the degree of fining is less and the bed is predominantly gravel all the way to the confluence with Carey Creek. Lateral migration of the channel is significant in this zone of progressive fining (and thus of progressive deposition of coarser sediment); as a result, localized bank erosion is common.

Fifteenmile Creek (0207)

With an average slope approaching 10 percent, this sub-basin is the steepest of the entire basin plan area. As a result, the sediment transport within the channel is also most vigorous. Scour of the channel down to bedrock is ubiquitous in the upper half of the basin; only as the channel moves out over its lower slopes, depositional remnants of torrential late-glacial flow, do zones of both deposition and erosion become common.

Specific problems in this sub-basin are a direct result of the high energy of this stream. High flow during the January 1990 storm washed out a private culvert on 252nd Place SE that provides sole access to 15 houses. Localized areas of channel erosion, common throughout the system, are problematic in a few areas in the vicinity of 240th Avenue SE where development is encroaching on the stream corridor.

The most immediate threat to a residence occurs at the mouth of Fifteenmile Creek, where the channel flows through backyards and adjacent to a house. Anywhere that a steep channel, such as Fifteenmile Creek, meets a lower gradient flow, such as Issaquah Creek, deposition of some part of the sediment load and consequent channel shifting is almost unavoidable. At this site, bank armoring has been largely but not completely successful at minimizing that tendency and protecting the structure and the yard around it. The November 1990 storm, however, resulted in additional channel migration and the need for further bank protection.

Middle Issaquah Creek (0178)

In this sub-basin, the main channel of Issaquah Creek meanders over a plain of glacial outwash and has begun creating its own, smaller floodplain within the wider valley. As a result, flooding is limited to a relative narrow zone adjacent to the creek. Yet channel migration can affect a broader region, for the present flow is competent enough to erode modern and glacial sediments alike. The lateral tributaries of this sub-basin are both flat, such as tributary 0217 in Cedar Grove, and quite steep, such as Nudist Camp Creek (tributary 0206). They are thus subject to dramatically different types of problems, ranging from flooding in low-gradient, low-lying areas to upstream erosion and downstream deposition on the steeper tributaries.

The main channel actively migrates throughout much of this sub-basin, with numerous examples of lateral channel shifts from the two 1990 storms of a few feet up to several tens of feet. Although examples of such movement are scattered throughout this reach, the most damaging have occurred where development has encroached upon the zone of active or potential channel migration, in the Four Creeks Ranch development. The most severe erosion problem here shifted the active channel to within a few feet of a house foundation during the November 1990 flood, following a pattern of channel migration evident over the preceding decades. Slightly upstream, longer term channel migration has left steep embankments along the right bank, a portion of which failed catastrophically in March 1991 and temporarily dammed the main channel. Future landslides in this area are quite possible.

Sediment movement along Middle Issaquah Creek is relatively consistent throughout. The largest gravel contributed by Holder Creek does not travel much past the 252nd Avenue SE (Getschman Road) bridge, as the channel drops off one glacial-age terrace on to a lower surface with a flatter gradient. Beyond that point, however, bed sediment does not vary systematically, although the effects of agriculture and suburban development are reflected by an increasing sand and silt load in the downstream direction. The channel again steepens as it approaches and

passes through the Four Creeks area, primarily as the flow accommodates the additional sediment load delivered by lateral tributaries. In this area, the floodplain of Issaquah Creek is confined by a terrace that is only a few feet higher than the level of relatively frequent inundation. Indeed, the channel has degraded almost 1 foot in the last 15 years at the Four Creeks bridge (229th Drive SE). Thus this "terrace," upon which a number of houses are built, may be a floodplain only recently abandoned by the river.

The lateral tributaries in this sub-basin displayed several problems sites as a result of the January and November 1990 storms. Most were associated with drainage from the slopes of Tiger Mountain, particularly as concentrated by road drainage systems. These included a few minor blockages of SE Tiger Mountain Road by sediment, water and sediment over 230th Avenue SE above Cedar Grove, and sediment on the road at the entrance to Mirrormont. More severely, a large ravine was apparently initiated during the January 1990 storm and expanded again in November, adjacent to the Issaquah-Hobart Road just southeast of 252nd Avenue SE. The water originates in a road-ditch and culvert system along SE 159th Street in Mirrormont and then drains down an easement to the Issaquah-Hobart Road. In both storms, the system on the upper roadway overtopped, and the runoff was then sufficiently energetic to erode the steep hillside downslope. Deposition at the base of that slope blocked the Issaquah-Hobart Road during both January and November. Farther southeast, drainage off the eastern end of Mirrormont caused two other sites of sediment deposition that severed a private road system.

McDonald Creek (0212)

The McDonald Creek sub-basin is a study in contrasts. The main channel of McDonald Creek, along 90 percent of its length, is a grossly underfit stream flowing the wrong way up a valley carved by glacial runoff. The ability of the modern water flow to alter this valley is almost nil. Only where the channel reaches the eastern edge of its valley, with its steep drop down to the main Issaquah Creek valley, is the channel sufficiently energetic to move much sediment and so establish a balance between water and sediment flow.

In contrast, the lateral tributaries of McDonald Creek are uniformly steep. Those originating from Squak Mountain locally have gradients of 20 percent or more and move large amounts of sediment to the valley floor. Even those originating on the south side of the main valley, from the Lake McDonald and Cedar Hills upland, can vigorously erode their bed and banks. Development adjacent to these reaches has and will experience the impacts of this activity. But in both cases, the transporting ability of these lateral streams also drops profoundly as they reach the valley flat; as a result, a substantial majority of their sediment load must be deposited.

The north side of the valley displays this process particularly well. The 0212 tributaries have built an alluvial fan almost 1 mile wide and over 2000 feet long between the foot of Squak Mountain and McDonald Creek. This is a zone of pervasive, chronic sediment deposition, because the dramatic change in stream gradient mandates an equivalent change in transporting

ability. Constrictions in the flow path, such as culverts under SE May Valley Road, serve to localize that deposition and amplify the impact of that deposition. Similarly, increased runoff in the upland channels from hillside clearing and development activity does not change the overall processes occurring but can increase their rate, such that a greater load of sediment is delivered to the downstream system.

The results of these conditions are amply demonstrated at the plat of Sunset Valley Farms, which straddles the valley and so receives runoff from both north and south tributary hillsides. From the north, flow down 0212E during the January and November 1990 storms passed through the culvert under SE May Valley Road but could not pass, and so covered, SE 135th Street. From the south, flow down an unmapped but readily recognizable tributary overtaxed a backyard drainage system in January and excavated a trench several feet deep and over 100 feet long, exposing utilities and blocking SE 138th Place. By November, an upgraded system handled a somewhat lower flow adequately. Development activity in the headwaters of both tributaries is not high but is pervasive, with local clearing and road-ditch channelization common.

An additional problem with tributary inputs occurs here. Because of its very low gradients, the main channel of McDonald Creek is particularly sensitive to changes in its balance of water and sediment. The low energy of this system means that channel capacity cannot increase rapidly by bank erosion in response to increased discharges, and the transport of sediment cannot increase rapidly in response to infilling by greater sediment loads. An increase in both water and sediment, such as delivered by 0212E, results in the worst of both worlds--rapid infilling of the channel at the same time that more water is seeking to move downvalley. In most river systems, the active channel can compensate at least in part for these changes, but here the response will be much slower. Chronic flooding is the result, particularly if the floodplain of the creek is only slightly lower than the terrace and fan deposits on which development is now taking place.

Only in the lower canyon of McDonald Creek, as the stream drops down to the main valley, is the flow able to adequately form its own channel. Some channel-bank erosion is evident, probably in response to increased upstream discharge, but the hydraulic buffering of the upper, flooded valley has minimized these impacts and allowed a short reach of relatively high stability and high habitat value to remain. Were the conveyance of the upstream channel increased, this reach would suffer an accelerated rate of erosion, which in turn could add significant new sediment loading to lowermost McDonald Creek and Issaquah Creek downstream to its junction with Fifteenmile Creek. Among the potential impacts, accelerated channel migration is probably most problematic.

East Fork Issaquah Creek (0183)

Like McDonald Creek, the East Fork of Issaquah Creek is an underfit stream, flowing in a relatively narrow channel within a very much broader valley carved by glacial meltwater.

Whereas the valley of McDonald Creek was carved by water leaving the Issaquah area to the west, the East Fork valley carried flow entering the Issaquah area from the east. Gradients are much steeper in this valley, however, and so the East Fork is a relatively energetic stream throughout most of its length. In its middle and upper reaches, this is expressed by numerous examples of bank erosion; as it emerges from this confining valley onto the floor of the main Issaquah Creek valley, much of the sediment so eroded has formed a lobe-shaped alluvial fan covering about 100 acres just west of the E Sunset Way interchange.

The East Fork has also been heavily altered by human activity. Beginning with early logging activity, followed by its diversion and confinement during construction of I-90, and finally by progressive armoring and constriction of the lower channel by adjacent houses and road crossings, this tributary has probably seen the greatest degree of physical alteration of any in the basin. Runoff from I-90, neither detained for water-quantity control nor treated for water-quality control, adds to the impacts on this system.

Despite these conditions, surface-water problems in this sub-basin are not terribly severe. Local bank erosion in the upper reaches is common, particularly where the reconstructed channel has been excessively confined by adjacent roadway fills. Erosion is also evident on many of the northern tributaries that flow steeply off Grand Ridge, particularly from recently logged areas. Landsliding off the steep adjacent hillsides has occurred in the past and continues to be a potential downstream hazard. Deposition of eroded sediment is not presently causing significant conveyance problems, except near the mouth of the creek at the Rainier Boulevard N bridge. Zones of substantial sand deposition are found throughout the system, however, that probably reduce the habitat value of this stream.

<u>North Fork Issaquah Creek (0181)</u>

The North Fork occupies yet another glacial meltwater channel, and the creek flows weakly over much of its length. As with McDonald Creek, its closest analog, the upper channel is very low gradient and is fed by much steeper lateral tributaries. The lower channel, in contrast, cuts down at the edge of the main Issaquah valley, dropping 200 feet at a 10 percent gradient to the valley floor.

The upper channel flows through an extensive riparian wetland. The area acts as a repository for sediment eroded from the surrounding uplands, most notably the Klahanie development around Yellow Lake. In this area, land clearing with poor or nonexistent erosion control since 1986 and continuing as recently as 1990 has almost continuously discharged fine sediment to Yellow Lake and downstream tributaries to the North Fork. Additional clearing on the south side of the valley, on Grand Ridge, has further contributed to the sediment load.

Below about RM 1.6, the channel cascades over a bedrock falls and begins its steep descent to the valley floor below. Bedrock floors the channel for a portion of its length, and large boulders

and logs help anchor and stabilize this reach of stream. As the stream continues past the Lakeside Gravel Pit and continues towards its confluence with Issaquah Creek, some constrictions from road crossings have induced either erosion of the abutments, deposition within the bridge or culvert, or a combination of the two. Major problems, however, are not evident.

One significant problem noted in the 1987 Basin Reconnaissance Report, the overflow of the Lakeside sediment ponds adjacent to the North Fork, has been corrected in the intervening years. Presently, all runoff is pumped to the top of the pit at about elevation 400 and allowed to infiltrate. As a result, no surface discharge of any consequence now leaves the site. The upland settling ponds, however, are perched very close to the hillside leading down to the North Fork valley. Their seepage appears to have initiated at least one significant debris flow into the North Fork at about RM 1.5. Additional failures are quite possible in the future, both because seepage will continue and because the capacity of the ponds is being used up. In particular, the confining berm may not be adequate to withstand seismic shaking and almost certainly would benefit from evaluation and possibly redesign.

Lower Issaquah Creek (0178)

The lowermost 7 miles of Issaquah Creek, together with its local tributaries, include some of the most diverse and active channel conditions in the basin. Channel infilling, bank erosion, and migration are all active in portions of this sub-basin, particularly at the upstream end and also downstream of SE 56th Street in the State Park. Even more significant than the absolute rate of activity, however, is the proximity of developed land uses to the activity that is occurring. In particular, channel migration in the Sycamore development is consuming the setbacks of houses from the stream at a rate that would eliminate them altogether in the next few decades. Infilling of the channel through the city of Issaquah is reducing flood capacity, a growing problem primarily because of the severe encroachment into the floodplain of Issaquah Creek by a number of roads and houses.

Lateral tributaries in this sub-basin provide significant sediment loads into Issaquah Creek, by virtue of numerous sites of localized bank and channel erosion. Flows down the northeast-most tributaries off of Squak Mountain (0194, 0195, and 0196) in particular have caused severe in-channel erosion, probably as a result of significant headwater development with minimal or non-existent detention. Tributaries off of Tiger Mountain, particularly 0200, also suffer bank erosion and downstream deposition, although the process (if not the present-day rates) are to be expected in any such system. For example, where tributary 0203 is diverted for 1000 feet along the Issaquah-Hobart Road, deposition is artificially localized by the abrupt decline in gradient. The narrowness of the ditched channel partly compensates for that decreased gradient, by increasing the depth of flow, but ongoing maintenance is required and overtopping of the channel onto the highway has occurred, most recently during both the January and November 1990 storms. Tributaries 0203A and 0206 share in this history of high sediment loads and substantial downstream deposition.

This sediment load has direct effect on operation at the State fish hatchery. In particular, coarse sediment descending Cabin Creek (tributary 0194) has contributed to partial clogging of the main hatchery water intake, located just downstream of the confluence with Issaquah Creek, several times in the last 5 years. This immediately reduces the water supply to the hatchery, threatening the incubating eggs and juvenile salmon. Although a small settling area at the mouth of Cabin Creek has provided some relief, the volume of sediment transported by that tributary can easily overwhelm the available volume. Continued maintenance is also necessary.

The major sediment load delivered to the valley bottom of this sub-basin's tributaries, however, presently is contributed by No Name and Nudist Camp Creeks. Steep channel gradients, locally augmented by headwater logging, have induced substantial erosion of the channel bed and banks with subsequent deposition at and below the Issaquah-Hobart Road. Even prior to the most recent logging, the historic pattern of stream-channel braiding suggests that one or both of these channels episodically contributes a significant slug of sediment into Issaquah Creek.

A second, more pervasive influence of sediment on the fish hatchery has arisen from the quantity of fine sediment carried by the flood flows of Issaquah Creek and contributed from all upstream sources. Silt-sized particles, generally much too small to be settled out of the flow once they have become entrained, settle on the incubating eggs and can cause suffocation if not washed off. During major floods, this can occur for up to several days at a time.

Tibbetts Creek (0169)

The Tibbetts Creek basin is a miniaturized version of the Issaquah Creek basin--a major trunk stream in a central valley drains its flanking bedrock uplands. But in Tibbetts Creek, although the horizontal distances are shortened, the vertical elevation changes are nearly equivalent. Thus the gradients along Tibbetts Creek and its tributaries are among the steepest in the basin plan area, and the system as a whole is very energetic. For example, whereas Issaquah Creek infilled its channel by a foot or two in 12 years, Tibbetts Creek has nearly obliterated reaches of its channel with sediment twice in one year.

Impacts to the Tibbetts Creek system are also more pervasive. In the Issaquah Creek basin, headwater areas are largely undisturbed and the upland sub-basins of Holder and Carey Creeks provide some of the best aquatic habitat County-wide. In contrast, two quarries at and near the head of Tibbetts Creek seriously damage water quality and affect water quantity from the basin divide all the way to the basin outlet. Thus no part of the system is unaffected by development impacts, and any correction or restoration of the system will be much more difficult.

Increased flow in the main channel of Tibbetts Creek, in addition to increased sediment load, have resulted from basin development. Constrictions to that flow from road crossings and bank armoring have locally amplified the effects of such flows, yielding numerous examples of both bank erosion and channel deposition along the main valley. The most dramatic examples have

been in the vicinity of Tibbetts Manor at about RM 1.5, where a natural deposition zone has been enhanced by constriction from the Newport Way SE crossing and a greatly enhanced sediment load from upstream. In both January and November 1990, infilling of the channel yielded substantial flooding of downstream structures and roadways.

Lateral tributaries to Tibbetts Creek have also been impacted by development. A large debris flow, initiated by runoff from the "Clay Pit" on Cougar Mountain, entered tributary 0171 in January 1990. Elsewhere on Cougar Mountain, a smaller such flow entered tributary 0169A, but here the downstream development had previously diverted the creek to allow construction of additional houses. During the January 1990 storm, sediment from upstream infilled a portion of the diverted channel of 0169A and rediverted the flow towards its original path, now occupied by several residences. Deposition at the base of the channel, in another diverted reach along Newport Way SE, blocked that roadway during both January and November 1990 storms. Across the valley, development-concentrated runoff draining off Squak Mountain caused substantial erosion and deposition to a group of residences on SE 82nd Street just east of Tibbetts Creek.

The most severe problems in the basin, however, are associated with an inactive quarry lying on the northwest slopes of Squak Mountain along tributary 0174. Bare slopes, loose tailings, and non-existent erosion control have combined to yield significant damage to the SR 900 road crossing during the January 1990 storm and massive sediment inputs into Tibbetts Creek. The 1987 Basin Reconnaissance identified a potentially active earth flow in the quarry adjacent to tributary 0174. Although of mainly long-term concern, its evaluation and stabilization if needed should be a high priority for the ongoing, but largely ineffective, enforcement action on this property.

7.5.0 KEY FINDINGS (Figure 7-8)

7.5.1 Upland Erosion

Several sites of upland channel erosion are significant, because they are locally hazardous and also contribute significant sediment to the downstream system. These include:

--Squak Mountain tributaries to McDonald Creek (0212A, B, C, D, and E)
--Tributary 0174 to Tibbetts Creek

Other tributaries may not be of sufficient size to generate significant downstream sediment loads, but conditions along their steep reaches are locally problematic or hazardous:

--Tributary 0169A, where diverted

7.5.2 Valley-Floor Deposition

In addition to the sites of hazardous upland channel erosion, other tributaries are problematic primarily because of their downstream effects, primarily roadway blockage. These include:

--Unnumbered south valley sidewall tributary to McDonald Creek through Sunset Valley Farms
--Tiger Mountain tributaries, including No Name and Nudist Camp Creeks (tributaries 0206 and 0203A), and tributaries 0200 and 0203
--Unnumbered tributary to Middle Issaquah Creek through Mirrormont development

7.5.3 Channel Migration

Channel migration of Issaquah Creek in the Four Creeks Ranch and Sycamore developments poses significant, long-term threats to a number of occupied residences. Piecemeal bank protection is not likely to provide systematic protection for all houses potentially at risk. Even more rapid migration elsewhere in the basin poses little threat to existing structures, but this activity could prove problematic in the future if development occurred without adequate recognition of these active zones.

7.5.4 Channel Infilling

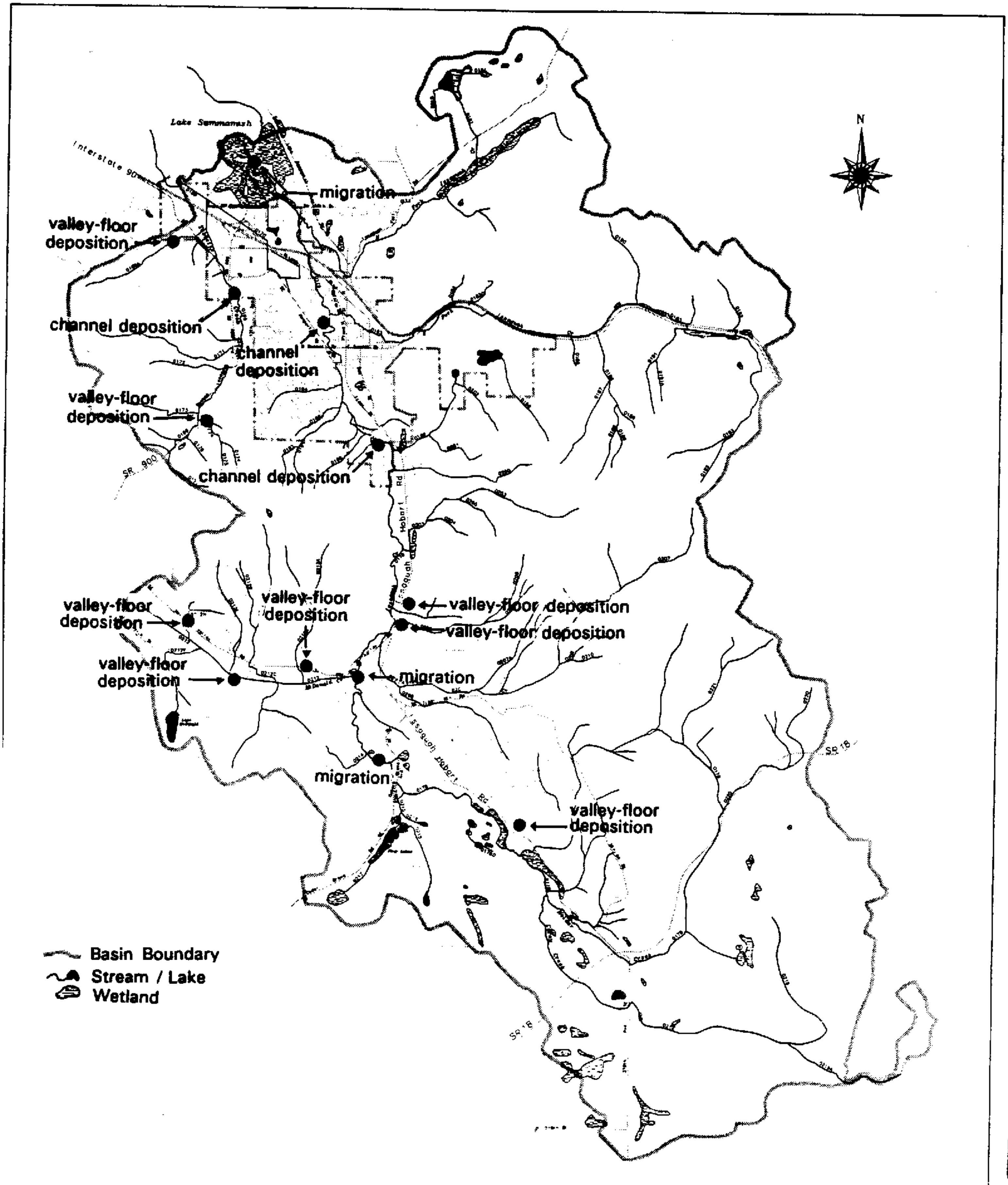
Deposition within the channel of Issaquah Creek through the downtown area is exacerbating, and is in part a result of, flow constrictions caused by under-sized bridges and culverts. Adjacent land use has encroached upon the floodplain, making the impacts of this deposition more severe

than would otherwise be the case. Tibbetts Creek is also experiencing infilling for similar reasons, amplified by an increased sediment load from upstream sources and from erosion of the upstream channel.

7.5.5 Summary of Findings

For a basin of its size and development intensity, Issaquah Creek has remarkably few significant problems and has maintained substantial reaches of high resource value. Existing problems are a result of two general conditions: 1) localized areas of more intense development that in turn have affected the neighboring stream system; and 2) development that has proceeded with little understanding of the natural, ongoing processes that have and will continue to be active in this system. In several cases, this development now finds itself directly in the path of those processes. The trend of future activity in the basin, however, suggests that no area is immune to the effects of land-use changes, particularly deforestation in the upper parts of the watershed and urban development adjacent to the stream channels.

Tibbetts Creek, in contrast, occupies a basin where severe impacts already affect most of the major stream reaches. Preservation of an existing, well-functioning channel system is no longer an option in this basin; instead, the drainage network must now be reclaimed from high loads of both suspended sediment and coarser bedload. The magnitude of this problem is substantial, but it is dwarfed by the future prospects for this basin without appropriate management and mitigation.



CHANNEL MIGRATION AND DEPOSITION AREAS

Issaquah Creek Basin Planning Area

Figure 7-8

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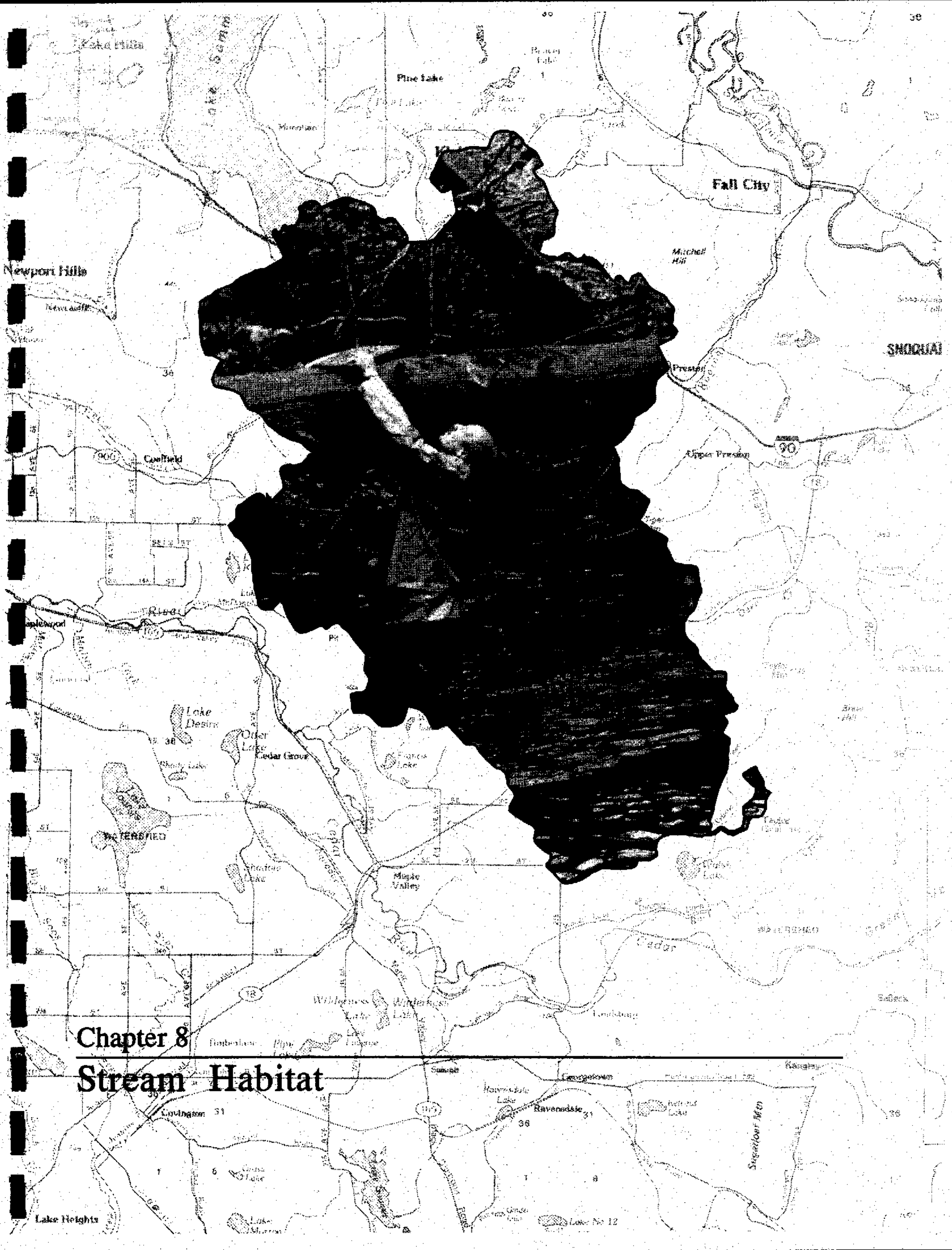


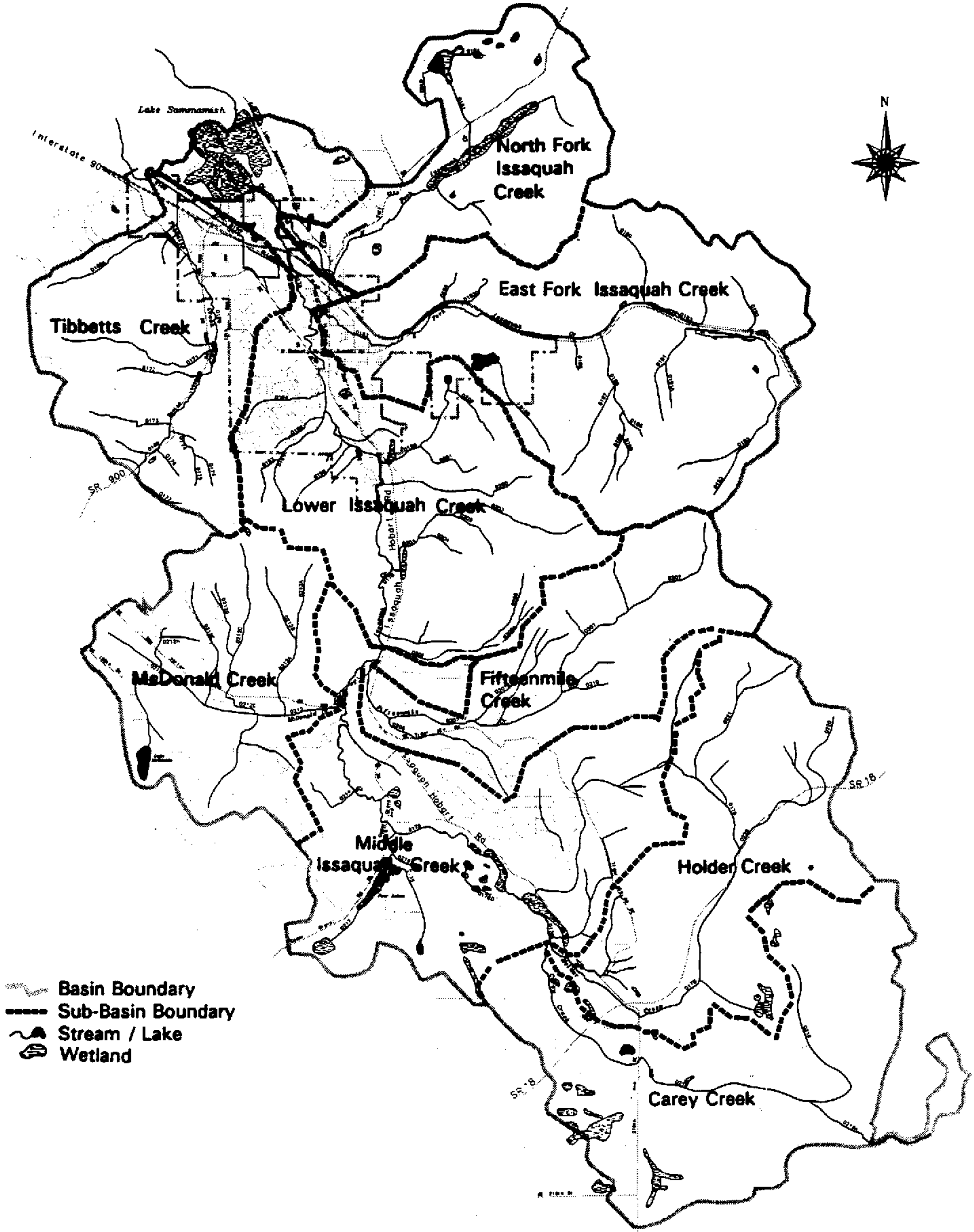
Chapter 8
Stream Habitat

CHAPTER 8: STREAM HABITAT

8.1.0 INTRODUCTION

The Issaquah Creek Basin--including the Tibbetts Creek Basin--covers some 61 square miles and contains over 122 miles of stream, 38 inventoried wetlands, and 4 lakes (Figure 8-1a). These features overlay a diverse geology and topography resulting in a complex system of habitats ranging from high gradient mountain streams and perched wetlands on steep slopes to low gradient meandering streams and a large freshwater delta along the southern shore of Lake Sammamish. A burgeoning urban land use combined with traditional forestry, quarrying and agricultural activities have contributed to a host of habitat problems, some of which are reach specific and others that have created systematic loss of stream and wetland functions and subsequent loss of habitats.

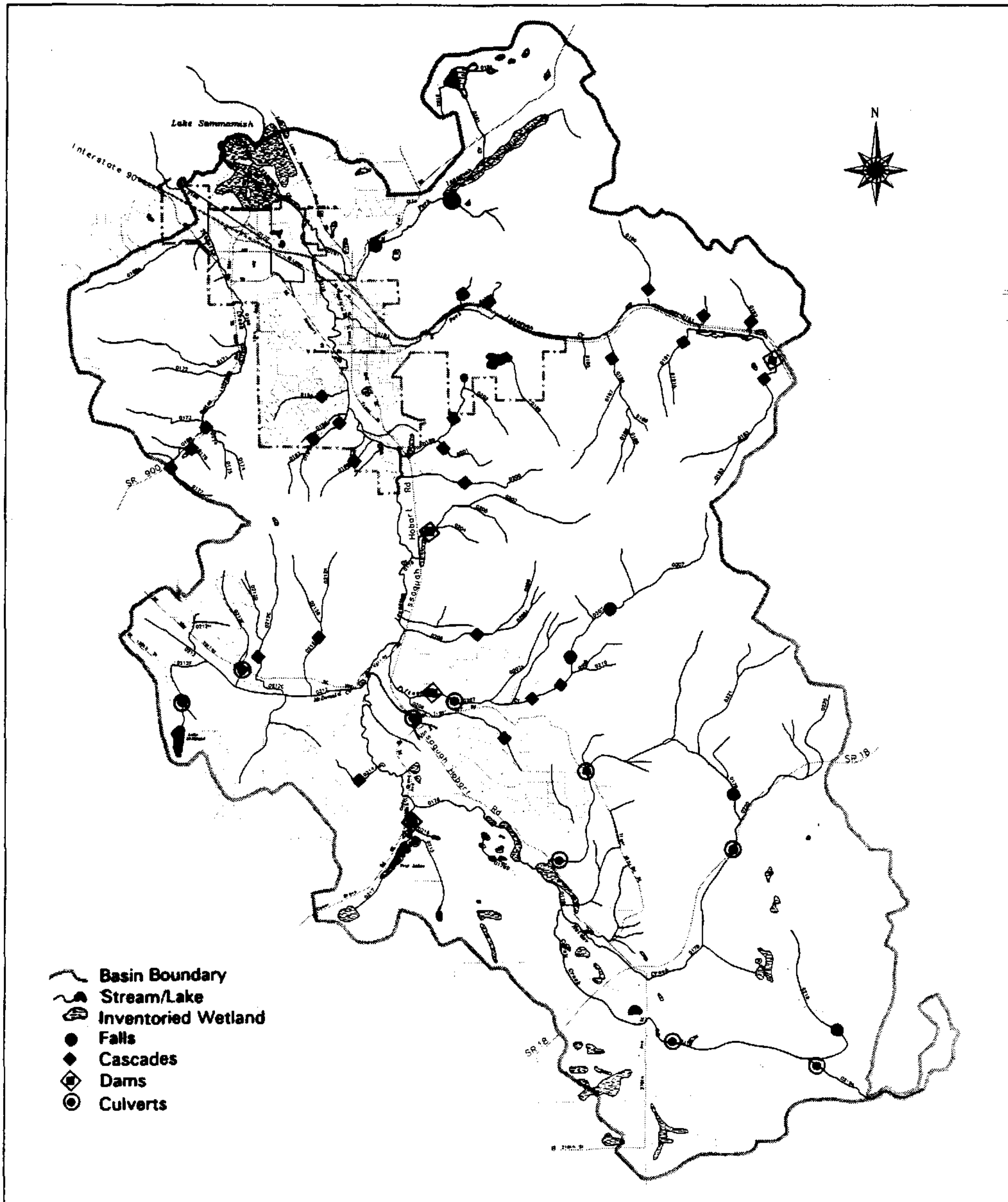
Approximately 30 percent of the drainage is accessible to anadromous salmonids (Figure 8-1b) and supports significant runs of sockeye (Oncorhynchus nerka) and its non-migratory form, kokanee, coho (O. kisutch), and chinook salmon (O. tshawytscha); cutthroat (O. clarki) and steelhead trout (O. mykiss). The upper portion (above RM 3.1) of the drainage of the mainstem Issaquah Creek, however, receives limited use by anadromous salmonids due to a Washington State Department of Fisheries (WSDOF) salmon hatchery at RM 3.1. A weir at this site restricts use of the system by coho and chinook to excess fish beyond hatchery production needs and to escapees during floods. Sockeye salmon, steelhead trout, and cutthroat trout are passed upstream. The hatchery utilizes water from the creek and as a result it is dependent on good upstream water quality. The slower moving lower portion of the creek and its mouth are utilized by a wide variety of exotic cool and warm water species of fish, including smallmouth bass (Micropterus dolomieui), black crappie (Pomoxis nigromaculatis), bluegill (Lepomis macrochirus), pumpkinseed (Lepomus gibbosus), and brown bullhead (Ictalurus nebulosis). These are largely present due to the stream's connection with Lake Sammamish. These exotic fish species were probably introduced to the system in the 1920s in an effort to enhance recreational fishing opportunities in the lake. Bass and crappie can be highly predatory on juvenile salmonids in the lake and lower reaches of the creek. As habitat in the lower reaches becomes marginal for salmonids due to upstream effects on water quality, temperature and dissolved oxygen, these exotic species may become more prevalent.



ISSAQUAH CREEK BASIN AND STREAM SYSTEM

Issaquah Creek Basin Planning Area

Figure 8-1a



NATURAL AND CONSTRUCTED BARRIERS TO MIGRATION

Issaquah Creek Basin Planning Area

Figure 8-1b

8.2.0 HISTORICAL INFORMATION

8.2.1 Fish Use

Chinook and coho were probably the predominate anadromous fish species in the system; Table 8-1 (at the end of the chapter) lists known species use of Issaquah Creek and its tributaries. The WSDOF Salmon Hatchery at RM 3.1 on the mainstem was constructed to supplement these runs and to provide eggs and juveniles for supplementation in other stream systems in the state. This hatchery limits use of approximately 27.1 miles of spawning and rearing habitat for coho and chinook in order to meet hatchery objectives. As a result, production of wild fish above this point has been limited. Significant natural production of coho and sockeye does occur in the East Fork of Issaquah Creek, but less in the North Fork and Tibbetts Creek.

Kokanee (also called silver trout), a non-migratory form of sockeye, reside in Lake Sammamish and use Issaquah Creek and its tributaries for spawning. This particular population appears to be a relict form, the result of sockeye invasion of the lake some 2,000 to 4,000 years ago and is unrelated to the more recent Cedar River sockeye planted in the watershed in the 1930s. The remaining population is a remnant of the historic one and has declined rapidly in recent years. Never abundant, estimates of the present population indicate that as few as 300 individuals may survive, a number too small, perhaps, to prevent extinction.

In addition to the species mentioned above, two other salmonid species that reside in Issaquah Creek are Dolly Varden (Salvelinus malma)--a char, and the mountain whitefish (Prosopium williamsoni).

8.2.2 Land Use Impacts to Habitat

Timber Harvest

Logging was the earliest significant land use to have habitat impacts in the drainage. It began in the late 1860s and focused initially on harvesting trees in the accessible riparian areas along the lower gradient streams. This was accomplished because of the larger sized trees in these areas, the ease with which cut timber could be transported, and the potential for conversion to homesteads. Large scale commercial logging on Tiger Mountain began about 1915 and peaked in the 1920s and 1930s. Many riparian areas within the forestry use zone still lack large coniferous trees. Some locations of old growth and mature second growth can be found in portions of upper Carey Creek, however. Streams in this area exhibit a high degree of stability and channel complexity. Few other streams in the drainage have large conifers still present in the riparian corridor or situated as large woody debris (LWD) in the stream. Where large wood was left (as in Carey Creek), there is evidence of high quality fish habitat and good to excellent stream stability.

Agriculture

Agricultural activities were initiated in the mid-1870s and conversion from forestry uses in low gradient areas of the valley peaked in the early 1900s. Several large and small commercial farms and numerous hobby farms are still in existence throughout the basin. The hobby farms are typically found in the upper valley reaches of the basin where flat land is limited to the valley floor. Many of the stream reaches traversing these areas are impacted by efforts of landowners to reduce site specific problems of flooding and erosion. This has resulted in considerable lengths of armored stream banks, almost complete absence of large channel-stabilizing wood, and straightened channels. These activities have left many stream reaches with little habitat diversity and reduced fish production capabilities. It also appears that, contrary to the intent of these activities, the result has been to reduce stream stability and increase landowner erosion problems.

Urban

The city of Issaquah is located near the mouth of Issaquah Creek. In recent years it has been the focal point for rapid urban growth in the basin. In addition to this core area, areas in the mid- and upper reaches of Tibbetts, MacDonald, and the East and North forks of Issaquah Creek are being subjected to urban growth effects and associated habitat impacts from roads and stormwater runoff. Holder and Carey Creeks, the two upper branches of the mainstem Issaquah Creek, appear to be the only sub-basins that have avoided major urban impacts to date. Urban effects on aquatic habitats are manifested by increasing instability of streams on steep slopes, flooding and erosion due to loss of flood plain, loss of dense streamside vegetation and localized degradation of water quality.

8.3.0 HABITAT CONCEPTS

The ability of the Issaquah Creek basin stream systems to support resident and anadromous salmonid fish is directly related to the quality and quantity of instream and riparian habitat. Before discussing detailed habitat findings, some background information on fish and wildlife habitat is presented.

8.3.1 Stability of Riparian Ecosystems

Riparian ecosystems evolved naturally under conditions of dynamic change punctuated by occasional catastrophic events caused by floods, fires, and impacts from beaver activity. The occurrence of large floods--those that occur during 25-, 50-, or 100-year storms--is the major environmental factor that shapes riparian and instream habitats by causing bank cutting, debris torrents, landsliding, and sediment deposition (Hall, 1988). While periodic natural disturbance

is normal in riparian ecosystems, human-caused impacts from logging, grazing, dredging, and the use of streams as conveyance systems for urban stormwater greatly increases the magnitude and frequency of disturbance in the riparian environment, making it less suitable as habitat for fish and wildlife (Leopold, 1971; Meehan et al., 1977).

8.3.2 Habitat Structure

The two primary fish habitat types are riffles and pools. Riffles are shallow, gravelly, fast-water areas that are the main food production areas of streams. Riffles provide habitat for aquatic insect species that make up most of the diet of salmon and trout, although insects of terrestrial origin falling into the stream also constitute an important source of food. Riffles also provide spawning areas for all salmonids and rearing habitat for early life stages of certain species, such as steelhead. Pools, which form in deeper, slower flowing areas or downstream from obstructions such as logs, rootwads, and boulders, are the main fish rearing and resting areas for most salmonids, including coho (Reeves et al., 1989).

8.3.3 Riparian Vegetation and Large Woody Debris

The value of fish habitat depends to a great degree on the many useful functions of riparian trees, shrubs, and ground cover (Sedell et al., 1988). Root masses along stream banks help prevent erosion and maintain channel stability. As trees die and topple into the water or are dislodged due to windthrow, large woody debris (LWD) in the form of logs and stumps is added to streams. In addition to its role in pool and riffle formation, LWD provides cover, a source of nutrients, and sediment storage sites. Riparian vegetation also helps trap and filter sediments, debris, and pollutants from surface runoff. During high flows, riparian vegetation slows and disperses floodwaters, reducing water velocity and reducing erosion that damages fish spawning and aquatic insect production areas. Riparian vegetation also buffers streams from temperature extremes that are stressful to fish. It also benefits many wildlife species by providing food, cover, migration corridors, and places for nesting and perching that are close to water, an essential habitat requirement for wildlife. Different riparian tree and shrub species support typical groups of terrestrial insect species that are important sources of food for fish; 266 insect species have been recorded from willow, 90 from alder, and 16 from fir (Mundie, 1969, and Mundie, no date). Leaves, needles, cones, and other small woody debris entering streams from trees and shrubs are a principal source of food for many aquatic insects that are in turn eaten by young salmonids (Meehan et al., 1977). Some categories of aquatic insects are very sensitive to disturbance and tend to disappear when streamside vegetation is removed by logging, construction, or landscaping (Newbold et al., 1980). Their disappearance can damage vital links in the food web of stream-dwelling organisms on which fish depend.

8.3.4 Streamflow Maintenance

All juvenile and adult salmonids need adequate flows of clean, cold (50-55 degrees Fahrenheit), well-oxygenated water for migration, spawning, and rearing. Survival of their food supply--mainly aquatic insects found in cold, fast-running water--also depends on adequate streamflows. Different salmonid species vary in their dependence on year-around streamflow, depending on how long they reside in the freshwater environment. Sockeye salmon, for example, spend a relatively short period of time in streams during incubation and development to the fry stage. Upon emergence, sockeye fry move downstream to rear in large lakes--in this case, Lake Sammamish and Lake Washington. Coho salmon, and steelhead and cutthroat trout, on the other hand, spend much longer periods in fresh water and thus may be much more susceptible to the damaging impacts of low flows and high temperatures. Chinook juveniles spend a variable amount of time in fresh water and are highly dependent on estuarine food resources.

Urbanization alters streamflow patterns by increasing flows during storms and decreasing infiltration of rainfall into groundwater, the major source of summer streamflows (Leopold, 1971). Groundwater discharge in turn affects thermal habitat space. The size of fish and benthic invertebrate populations in a stream depends strongly on the amount of near-optimal thermal habitat available during the critical warm periods of summer. Moreover, some salmonid species select groundwater discharge areas for redd (egg nest) construction and rely on relatively stable temperatures for egg and larval development (Meisner et al., 1988). As flows decrease, juvenile fish tend to crowd into upstream groundwater discharge areas, downstream rearing areas, or get trapped and die in pools due to lack of food and/or oxygen. Stream corridors also lose much of their value as wildlife habitat when streamflows disappear.

8.3.5 Effects of Urbanization on Habitat

The effects of development on watersheds are pervasive and generally damaging to fish and wildlife habitats. As discussed in Chapter 5, the magnitude and frequency of flows may be doubled or more by future urbanization within a subcatchment. With increased flows, and especially where protective riparian vegetation is absent, stream channels tend to be widened and stream beds scoured by the erosive forces of high velocity water and transported sediments. Scouring flows also remove much of the habitat-stabilizing LWD within streams, reducing habitat diversity and sediment storage capacity. Urbanization also increases the total amount of sediment, dissolved solids, and pathogenic bacteria entering streams from terrestrial sources (Leopold, 1971). Even in fully developed watersheds, suspended sediment loads are chronically increased by runoff from roads, parking lots, and other impervious surfaces (Whipple et al., 1981; Leopold, 1971). These impacts lead to loss of spawning and rearing habitat for fish due to filling in of pools and siltation and compaction of spawning gravels. Frequent and prolonged high flows also result in replacement of spawning gravels by cobble too large to be used by fish for spawning. In extreme cases, all gravels may be scoured down to bare glacial till or bedrock.

Other effects of urbanization include riparian corridor and channel alterations such as removal of streamside vegetation and instream LWD, channel straightening and dredging, construction of roads and bridges, stream bank armoring, and the loss of off-channel areas that provide refuge for fish during extreme flood events. While these activities may be viewed as necessary for full use of private property or as attempts to protect against flood flows, they also fragment riparian corridors and open them up to disturbances by humans, domestic animals, and influxes of pollutants. They also cause loss of habitat complexity and reduce food-chain support for both fish and wildlife. Some alterations such as bank armoring and channelization decrease the roughness of channels and accelerate flows, while others, such as bridges and culverts can cause local flow constrictions and flooding during storms.

8.4.0 PRESENT AND FUTURE HABITAT CONDITIONS

8.4.1 Present Habitat Conditions

Forests of the Issaquah Basin

The slopes of the foothills that rise alongside Issaquah Creek and its tributaries are covered by second growth forest much changed from the original forest of 200 years ago. That forest was dominated by immense Douglas fir (Pseudotsuga menziesii) with smatterings of western hemlock (Tsuga heterophylla) and western red cedar (Thuja plicata). The forest was a mosaic of trees of various species and uneven ages, interspersed with breaks of maple (Acer macrophyllum), alder (Alnus rubra), salmonberry (Rubus spectabilis), and other shrubs. The forest floor was littered with fallen trees, some sprouting young trunks, acting as nurse logs for the new growth. Huckleberry (Vaccinium parvifolium) sprouted low on broken snags and straggly rhododendron (Rhodonendron macrophyllum) and western azalea (Rhododendron occidentale) provided colorful variations in the deep, green foliage. In the moist, shaded gullies, devil's club (Oplopanax horridum) and creambush (Holodiscus discolor) could be found surrounding the seeps and springs.

The forest floor supported such common plants as foamflower (Tiarella trifoliata), western trillium (Trillium ovatum), trail plant (Adenocaulon bicolor), tiger lily (Lilium columbianum) and wood violet (Viola glabella); and such uncommon plants as the saprophytes (plants that lack chlorophyll and derive nutrition from decaying organic matter) Indian pipe (Monotropa uniflora), pinesap (Hypopitys monotropa) and pinedrops (Pterospora andromedea). Certainly, many of these species remain in the present forest, but in numbers and locations much reduced from the past.

The present forest bears little resemblence to its progenitor. It is composed of typical Puget lowland second growth--mostly dense, even-aged stands of Douglas fir, hemlock, some red cedar and true fir (probably grand fir, Abies grandis). Even-aged stands of hardwoods-big leaf maple and alder-grow on the lower and mid-slopes of Tiger and Squak mountains. A few isolated

stands of old-growth forest with trees over 1,000 years old occur on Tiger Mountain but these stands are small and merely remnants of the old forest. This present forest does not possess the diversity of habitats found in the original.

Nevertheless, some unique areas are do exist in the forest and have been identified by the Washington Department of Natural Resources (DNR) as critical wildlife habitats. The wetlands of Tradition Lake, Round Lake, Otter Lake, Beaver Valley and Double Beaver provide habitats for a variety of wildlife. The riparian areas of Beaver Valley/Silent Swamp, the corridors of Fifteenmile Creek and Preston Creek, the talus caves on northwest Tiger and the cliffs of Yah-er Wall are other important areas.

Wildlife

Elk (Cervus elaphus), black-tailed deer (Odocoileus hemionus columbianus), black bear (Ursus americanus), bobcat (Felis rufus), and, of course, beaver (Castor canadensis) are some of the large mammals that inhabit these areas. In the past, cougar (Felis concolor)--called tigers by the early settlers--were regular inhabitants. Today, some few occupy the adjacent Cedar River watershed and still venture into the upper Carey Creek basin and areas of Tiger Mountain.

Bald eagles (Haliaeetus leucocephalus), barred owls (Strix varia), northern saw-whet owls (Aegolius acadicus), red-tailed hawks (Buteo jamaicensus), pileated woodpeckers (Dryocopus pileatus) and blue grouse (Dendragapus obscurus) are among the more that 100 species of birds that reside in the forests and the clearings. The northern spotted owls (Strix occidentalis) that reside in the Cedar River Watershed probably use the Tiger Mountain complex as a travel corridor and hunting area. They are confirmed visitors to the headwater forests of Carey Creek (Fuerstenberg, 1990, personal observation).

Round Lake provides excellent nesting habitat for a variety of waterfowl including eared grebes (Podiceps nigricollis) and bufflehead (Bucephala albeola); stream corridors are causeways for dippers (Cinclus mexicanus) and belted kingfishers (Ceryle alcyon).

Various amphibians and reptiles are to be found throughout the basin, also. Some, like the rubber boa (Charina bottae) and the pacific giant salamander (Dicamptodon ensatus) provide occasional surprises to hikers and stream biologists.

In 1983, the DNR consolidated various ownerships on Tiger Mountain and created the Tiger Mountain State Forest. This area encompasses some 13,500 acres on the mountain and is managed for a multiplicity of uses. Forestry is, of course, of paramount importance but hiking, nature study, horseback and mountain bike riding, even hang gliding, are among the recreational opportunities. In 1990, approximately 2000 acres on Tiger Mountain were reserved as conservancy areas in which no forestry activities will occur.

Immediately across the Issaquah valley to the west stands Squak Mountain, a state park and natural area that also offers opportunities for forest recreation.

Forest practices--particularly those of the early and mid-twentieth century--have had, and continue to have, dramatic impacts on the watersheds and streams of the Issaquah basin. Observations of channel deterioration in streams flowing from early clearcut (and now reforested) sub-basins such as are found on Tiger and Squak mountains suggest that the current conditions are the result of slope and channel instabilities that were induced during the last wave of harvest (perhaps even earlier). Forest practices during the early to mid-twentieth century were often severe in their effect on the forest environment. Large clearcuts extended across the landscape, covering many sub-basins, particularly in the headwaters of many streams on Tiger and Squak mountains. Logs were dragged across slopes to landings, debris and slash were cleared from the cut, and streams were cleared of logging and other debris, often in consideration of fish passage. Once cut, areas were often burned to prepare the area for reforestation. The result appears to be a landscape modified spatially and temporally such that the magnitude and frequency of disturbances such as landslides and stormflows have increased. This new disturbance regime is focused on slopes and in channels with much reduced volumes of large woody debris, standing and downed, different in composition from the historic condition. This material acted to dampen and diffuse the forces acting on the slopes and channels; the system has been, in effect, "set up" for failure and can be triggered by disturbances that would have had little effect in the old forest.

In some rare cases, as in the East Fork of Issaquah Creek, sections of the streambed were floored with timbers and temporary splashdams were constructed. Logs were stored in the impoundments behind the dams. When a sufficient quantity of logs was assembled, the dam supports were pulled away and the rush of water carried the logs downstream to the mill or to a holding area. The effect on the stream was nothing short of catastrophic as this induced debris torrent traveled down the channel, stripping bed and banks of gravel and vegetation. Evidence of the practice persists in the presence of steep, vertical banks.

Current forest practices, while differing in degree of treatment, are not fundamentally changed from the historic model. Present practice provides for some modicum of protection for streams and wetlands (and only certain of these) but generally neglects steep slopes with sensitive soils and provides virtually no recognition of landscape-level phenomena. (In the Tiger Mountain State Forest, however, innovative forest management techniques are being tested with wildlife and landscape principles as major considerations. Selective harvesting in various areas and provisions for habitat blocks of sufficient size and diversity are attempts to accommodate harvesting while decreasing the deleterious effect on wildlife and their habitats.) In the Issaquah Creek system, headwater clearcuts abound on Tiger and Taylor mountains, subjecting the most sensitive slopes and stream channels (0- and 1st-order channels of Holder, Carey, Fifteenmile and others) to perturbations such as slope erosion, landsliding, and increased stormflow. In some cases, cuts are large enough to cover all headwater catchments (Nudist Camp Creek, for example) and the higher order channels downstream exhibit varying degrees of distress.

Some protection is afforded by the forest practices regulations that require buffers on certain stream channels. Generally, these buffers are inadequate to protect riparian and in-stream resources from the direct effects associated with logging (see Brazier and Brown, 1973; Barton et al., 1985). Given the magnitude of the disturbance relative to the ability of small stream systems to resist and recover from these effects, it is not surprising that such streams exhibit gross instability. Furthermore, these regulations are not mindful of the larger scale, diffuse impacts associated with mass alteration of the landscape. Profound changes occur in plant communities, wildlife habitats, and the hydrologic regime.

8.4.2 Stream Habitat Problems

Stream habitat conditions in the basin range from excellent to very poor. Streams in the lower reaches of the basin have been significantly altered due to construction of early railways, of Interstate 90, and to urban development in and around the city of Issaquah. These activities have resulted in a highly confined channel, loss of riparian vegetation, reduced floodplain capacity, and a reduction in habitat suitabilty for most salmonids. Stream reaches higher in the basin are suffering from significant loss in stability due to increases in sediment loading and concurrent losses in channel form and complexity. These environmental changes have resulted in shifts from stream reaches with an historic mixture of complex pool and riffle habitats to homogeneous reaches of predominantly riffle habitats. Much of the loss in channel complexity and stability appears to be related to the changes in riparian and instream factors, especially in the loss of large channel-stabilizing woody debris in streams. This latter conclusion is supported in part because many of the observed channel changes in the lightly or non-urbanized subcatchments of the Issaquah Creek basin appear to be occuring even in the absence of radical changes in hydrology (i.e. higher peak flows, more frequent high flows, lower summer flows; see Chapter 5) apparent in more heavily urbanized stream systems of the county.

The lack of channel complexity and energy diffusion capabilities has many implications for stream impacts in the basin. On small steep streams, the result has often been mobilization of large sediment loads which ultimately affect private property and fish habitat downstream. Examples of this phenomena include Nudist Camp Creek (tributary 0203A) and upper MacDonald Creek (tributary 0212E). In the first instance, tributary 0203A has transported large amounts of sediment during every recent storm and has overtopped the Issaquah-Hobart Road on five occasions in the past three years. In the latter case, sediments from tributary 0212E, which flows off of Squak Mountain, have thwarted landowner efforts to stabilize the channel adjacent to his home. The cumulative effect of this small stream sedimentation is to destabilize channels and reduce quantity and quality of spawning and rearing habitat in larger fish-bearing streams downstream. Various reaches of Carey, North Fork Issaquah, Fifteenmile and mainstem Issaquah Creek are being degraded by these types of inputs.

Lack of large woody debris in larger channels directly reduces potential for fish production in addition to increasing localized erosion problems. For larger, lower gradient fish-bearing

streams, habitat quality (i.e., size and complexity of pool area) is proportional to the amount of large coniferous wood either in the channel or in adjacent riparian areas, available for recruitment to the channel. When there is a lack of such woody debris, habitat complexity decreases and the effects of small stream inputs and adjacent land uses are further magnified. Specific examples of this are found throughout reaches of the mainstem Issaquah and Holder Creeks, and in portions of Carey, Tibbetts, and the North Fork Issaquah Creeks.

8.4.3 Future Habitat Conditions

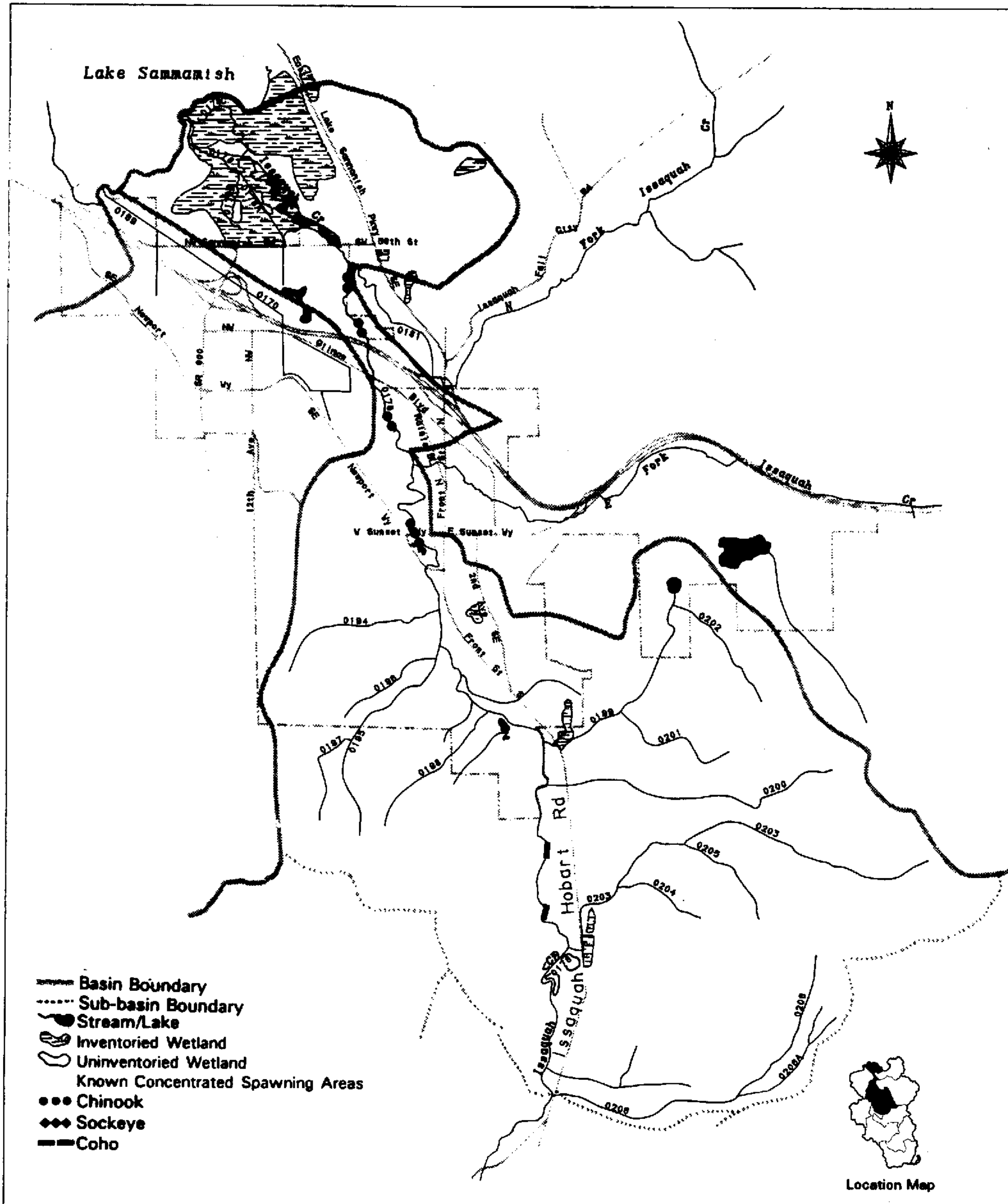
Habitat quality and quantity in the basin will continue to be compromised by stability problems of both mainstem and tributary channels. Upslope and riparian conditions that are contributing to these problems will be exacerbated as intensive logging and urban development continue on steep slopes adjacent to smaller stream systems. In addition, there may be delayed impacts from past timber harvesting activities, particularly on steep headwater areas of the basin. Stream systems particularly susceptable to these effects include drainages from steep slopes on Grand Ridge, Cougar, Squak, Taylor and Tiger Mountains. Unless corrected, these problems will continue to reduce habitat quality by transforming channel complexity from a pool/riffle mixture to a high energy riffle-dominated system. This homogenization of habitats will in turn reduce available habitats for the historic complex of salmonid species. Simplification of habitat complexity reduces both spawning and rearing suitabilty for most species. The implication for salmonid populations is that coho and chinook salmon and steelhead trout most likely will continue to decline in abundance. Sockeye will be affected to a lesser extent since they are not dependent on in-stream rearing habitat. As with many other urban streams in King County, populations of resident and possibly anadromous strains of cutthroat trout will predominate in most reaches of the system. This appears to be related to their ability to utilize "fringe" habitats typified by small patch sizes of pool and riffle, suitable cover and velocities.

Invasion of bass and other exotic warm water species from Lake Sammamish will increase in the lower reaches of Issaquah Creek as the cumulative effects of upstream land uses on water quality, particularly water temperature and nutrient loads, continue to manifest themselves.

8.5.0 STREAMS HABITAT BY SUB-BASIN

8.5.1 Lower Issaquah Creek (Main Stem) Sub-basin

The Issaquah Creek mainstem lies in a narrow valley about one quarter mile wide between the steep walls of Squak Mountain on the west and Tiger Mountain on the east. From its confluence with Lake Sammamish to the forks of Carey and Holder Creeks, Issaquah Creek is 11.4 miles long and has four major and seventeen minor tributaries. The major tributaries are North Fork, East Fork, Fifteenmile, and McDonald (also called Mason) Creeks; all have salmonid populations that use the streams for spawning and rearing (see Figures 8-2 through 8-9). Most of the minor tributaries provide some habitat for salmonids as well, but often fall steeply from



LOWER ISSAQUAH AQUATIC HABITAT FEATURES

Issaquah Creek Basin Planning Area

Figure 8-2

the hillslopes, limiting the useable stream length (Figure 8-1b). The North and East Forks are accessible by all fish when flows are sufficient to allow passage. The state salmon hatchery at RM 3.1 controls all access by salmonids to the upper watershed.

From its confluence with Lake Sammamish to SE 56th Street (RM 1.2), the mainstem winds through Lake Sammamish State Park. The stream is large here, deep and slow moving, as it approaches the lake. Mean stream width is over 30 feet, and pools often exceed six feet in depth and 2,000 square feet in surface area. The bottom is fine sand and silt. The stream flows over glacial material and floodplain sediments of its own deposition; it is quite sinuous, curving back onto itself several times in the first mile. Channel migration is particularly active here (see Chapter 7); one particular bend at about RM 0.5 has been nearly cut off as the stream erodes the thin septum of sediment that separates the curves.

This lower half-mile of the stream serves primarily as transport and rearing habitat for salmonids and provides spawning areas for bass, perch, and suckers from the lake. There is little large woody debris (LWD) in this reach, with the exception of a debris jam near the mouth and a few old submerged snags. The corridor is dominated by red alder, black cottonwood, red-osier dogwood, snowberry, and willow. Evidence of beaver activity and deer is common.

The gradient increases slightly at about RM 0.6 and gravels begin to appear as bed material. The stream flows through mowed fields and there are continuous, high (to ten feet) cut banks in this area that show signs of recent sloughing. Blackberry is the dominant bank vegetation here, interspersed with alder and willow. During the October 1989 survey, chinook and sockeye were observed building redds in the riffle here (Figure 8-2).

Upstream of this reach to Southeast 56th Street, the gradient holds at about 0.5 percent and the channel assumes a pool:riffle character excellent for spawning salmon as evidenced by the number and size of the redds observed during the 1989 survey. Limited electro-fishing carried out in the summer of 1989 showed pools occupied by juvenile chinook, coho, and steelhead, as well as by resident cutthroat and rainbow adults. There is some braiding at low to moderate flows and numerous off channels are formed in this reach. High banks alternate with wide floodplains and signs of deer, beaver, and river otter abound. LWD is sparse and occurs as small debris jams consisting of small material. Since few conifers occur on the banks throughout, it is not surprising that recruitment of LWD depends upon rather small deciduous trees. Where LWD does occur, it is consistently very old--mainly cedar and hemlock--and is both large and well-anchored. This material provides the extensive hydraulic diversity that would otherwise be absent from the channel. It appears to cause the channel to variably deepen, and provides sediment storage that builds bars and riffles. This is consistent with other work in the Pacific Northwest on the role of LWD in streams (Keller and Tally, 1979; Keller and Swanson, 1979; Hogan, 1984).

Above SE 56th Street (RM 1.2), the stream becomes somewhat less sinuous and artificial bank protection becomes more common. The pool:riffle character of the stream continues and salmon spawn in all available riffles. The riparian corridor is reduced in width to less than 100 feet on the average, and residences make their appearance on the banks. LWD is even more sparse than downstream, due mostly to its rapid and continuous removal by residents. The stream varies in width from 20 feet to more than 40 feet and pools average 3 feet in depth. Gravels are generally clean of fine sands (less than 15 % by volume) and are not consolidated. The confluence with the North Fork of Issaquah Creek occurs on the right bank at RM 1.9. During the October, 1989 stream survey, chinook, coho and sockeye were observed spawning throughout this reach.

Upstream of Interstate 90 (RM 2.0) to about SE 96th (RM 4.5), the stream flows through the main portion of the city of Issaquah. It is joined by the East Fork at about RM 2.4 and by four smaller tributaries between RM 2.4 and RM 4.5. Bank protection is common throughout this reach. Large, angular rock, concrete retaining walls and concrete blocks and broken pieces are usual means of bank protection. Much of this material has fallen into the stream and the bankwork is in constant need of repair. Banks are rendered quite sterile with such protection and provide little in the way of habitat for fish or for riparian zone inhabitants. The riparian corridor through this reach is much reduced even from the downstream narrow corridor. Width of the undisturbed riparian zone on either side of the stream rarely exceeds 50 feet and more often is less than 25 feet. The zone that does exist is often manicured and devoid of typical riparian species, exhibiting most often a manucured character. Human debris is more common. Shopping carts, tires, trash and grass clippings are in evidence throughout this reach. Nevertheless, all salmon species using the creek were observed to spawn and rear throughout this reach, upstream to the hatchery weir; brief observations over a two week period in early October, 1989 suggest that the spawning densities are lower in this reach than farther downstream, however. Spawning fish are easily disturbed and the lack of cover in this reach exposes the salmon to predation as well. Spawning success is probably limited by these disturbances to some degree. Gravels are somewhat sandier than downstream, and they are slightly consolidated. This does not seem to interfere with redd-building activity but may reduce egg survuval. LWD is essentially absent from this reach except for a large debris jam at about RM 2.5. Pools are shallower throughout this reach and riffles more extensive. Although the pool:riffle character of the stream remains, the ratio clearly favors riffles.

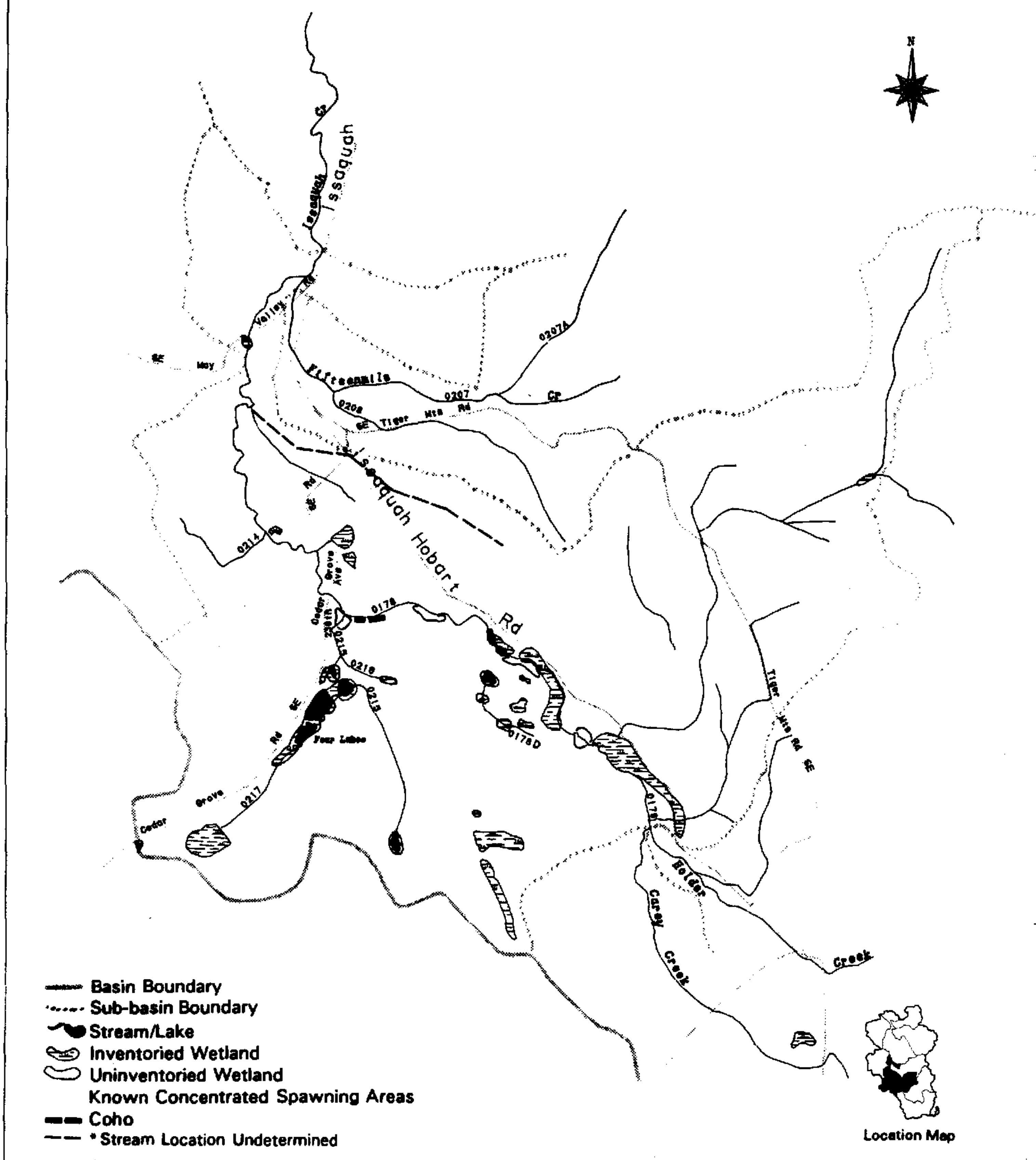
At RM 3.1, the Issaquah State Salmon Hatchery diverts almost all chinook and coho to the facility. Sockeye and other salmonids are passed through the rack and allowed to spawn naturally in the upper watershed. The water supply for the hatchery is diverted from the creek at about RM 3.4. An old and inadequate fishway allows fish to pass this structure. Immediately upstream of this diversion dam, Cabin Creek (tributary 0194) flows into the stream on the left bank. This stream is a source of much fine sediment, due mainly to urban-related stormwater erosion of once-ephemeral swales on the slopes above the creek.

Upstream of the city, the stream flows through the sparse residential area that covers the valley floor up to about the SE May Valley road (RM 7.3). Upstream of the road, Issaquah Creek flows through a predominantly agricultural area below the forks--the confluence of Holder and Carey Creeks forming the mainstem at RM 11.4. The characteristics of the stream and its corridor throughout this 6.9- mile reach are fairly consistent. From the city limits upstream to the SE May Valley Road, the stream flows close by the base of east Squak mountain, encountering some small bedrock outcrops just downstream of the road crossing. Several small tributaries originating from Tiger Mountain enter the stream in this reach. Among them are 0203 and 0203A, both of which support coho populations and may provide spawning habitat for Lake Sammamish kokanee, a diminishing stock of non-migratory sockeye. These tributaries are not accessible for their whole length; upon reaching the valley wall, most of them rise too steeply for anadromous fish to ascend. Other impediments to migration exist also. Tributary 0203 and 0206 have manmade barriers to migration in the form of impassable ponds (0203) and impassable culverts (0206). Tributary 0203 also flows in a ditch for about 200 yards along Issaquah-Hobart Road, the result of diversion for construction of the roadway. The ditch is periodically cleaned, especially after storms, with the consequent destruction of eggs and fish. Prior to the January 1990 storm, 35 coho were observed in this roadside channel.

8.5.2 Middle Issaquah Creek Sub-basin

Above SE May Valley Road, the channel flows through a broad alluvial valley, constrained only by Tiger Mountain to the east (Figure 8-3). Fifteenmile Creek enters on the right bank at RM 6.9 and upstream at RM 7.45, McDonald Creek enters on the left bank. Both tributaries are utilized by anadromous and resident fish. The gradient throughout this long reach (RM 3.5 to RM 11.4) of mainstem Issaquah Creek is less than 1 percent, and the meandering channel is less sinuous than below the city. Gravels are free of fines and unconsolidated, providing excellent spawning conditions. An uneven pool:riffle character predominates; riffles appear to be slightly more frequent, a not entirely unexpected phenomenon, given that LWD is rare and unevenly dispersed in this reach. LWD that does exist invariably produces foci of hydraulic and habitat diversity, and the rare debris jam fairly abounds with fish. Data collected from an October 1990 habitat survey bear this out quite clearly. Braiding is apparent in many sections, particularly near RM 5.9, RM 7.0, RM 9.6, and RM 10.5.

These multiple channels often provide excellent summer rearing habitat and act as refuge for juveniles escaping high winter flows. Bank protection is far less common through this reach than through the city, but can be found at outbends where the roadway encroaches on the creek, at bridge abutments, and more frequently, protecting residences from undesireable erosion and shifts in the stream course. Several recent projects have been placed that have resulted in long sections of relatively sterile bank (confluence of tributaries 0207/0178; tributary 0178 at RM 7.5; tributary 0203A at RM 0.3). Of note are several very recent projects on the mainstem of Issaquah Creek between RM 7.4 and 7.7, through the Four Creeks development; at the mouth



MIDDLE ISSAQUAH AQUATIC HABITAT FEATURES

Issaquah Creek Basin Planning Area

Figure 8-3

of McDonald Creek; and extensive bank protection on an unnamed tributary (0178E) to Issaquah Creek (enters on the right bank at RM 10.8, locally called Pheasant Creek). All were done in response to bank erosion caused by the series of storms in 1990 and have resulted in the rocking of several hundred feet of channel bank.

Large gravel bars and copious amounts of floodplain sediments are in evidence downstream of Fifteenmile Creek and below the Holder-Carey confluence. The lateral tributaries that drain to the mainstem from Tiger and Squak Mountains have been (and continue to be) important sources of sediment to the creek. Tributaries 0203, 0203A, 0206, Fifteenmile (0207), McDonald (0212), and Holder (0178) historically delivered gravels to the mainstem at somewhat irregular and infrequent intervals. This material became stored behind woody debris and in gravel bars where it was mobilized and redistributed during large storm events to become the spawning gravels of the creek (see the section "In-Channel Deposition" in Chapter 7). Some evidence now suggests that the delivery of sediment from these tributaries has become a more frequent and more regular event, even delivering more sediment per event than under historic forested conditions. We may speculate (and not entirely without foundation) that the cause of this phenomenon lies with an induced channel and landscape instability that is a result of early logging practices on the steep slopes of Tiger and Squak mountains.

As slopes are logged and material is hauled away and slopes burned, huge volumes of downed wood are lost. This material formed a matrix that served to anchor slopes and diffuse energy that would otherwise be available for erosion. A similar process occurs in the channels. The large woody debris, whether it occurs in larger streams like Issaquah Creek or in small, steep mountain channels, serves to dissipate energy, reduce velocities, store sediment, and create hydraulic and habitat diversity. Without the large wood, slopes and channels become susceptible to a number of instabilities, one of which is the delivery of sediment. This instability may have been induced decades ago, during the first phases of logging in these areas, and has been exacerbated by recent activity. The instability can be even more pronounced downstream of urbanizing areas because stormflows are greatly increased and recovery of riparian vegetation is not possible, thus, the source of LWD is lost.

The riparian corridor through this reach of mainstem Issaquah Creek is extensive and dominated by deciduous species. The corridor varies from a width of 30-50 feet per bank to over 200 feet per bank, interrupted by pastures, highways, and residences. Alder, cottonwood, Oregon ash, and willow dominate the canopy; salmonberry, snowberry, elderberry, and Indian plum dominate the shrub layer; and evergreen violet, swordfern, youth-on-age, and nettle are represented in the ground layer. Cedar, hemlock, and fir are rare and discontinuous, but evidence of their historic presence is provided by the many large stumps, now sprouting saplings or huckleberry.

Throughout this long reach (7.9 miles, from SE May Valley Road to the Carey/Holder forks), contained within the riparian corridor, are found large riparian forested wetlands, unmapped during the King County inventory. These wetlands serve as floodwater and sediment storage areas during the winter and may act as stream recharge areas during other seasons. Often,

riparian wetlands act as organic storage areas also, entraining woody debris and other organic material that is then swept back into the stream during a subsequent flood, becoming a food supply for aquatic insects. Preliminary mapping, but no inventory or evaluation, of these wetlands is shown on Figure 8-3 (and in the other sub-basins on Figures 8-2 through 8-9). Chapter 10 includes a further discussion of wetlands in the basin.

8.5.3 North Fork Issaquah Creek

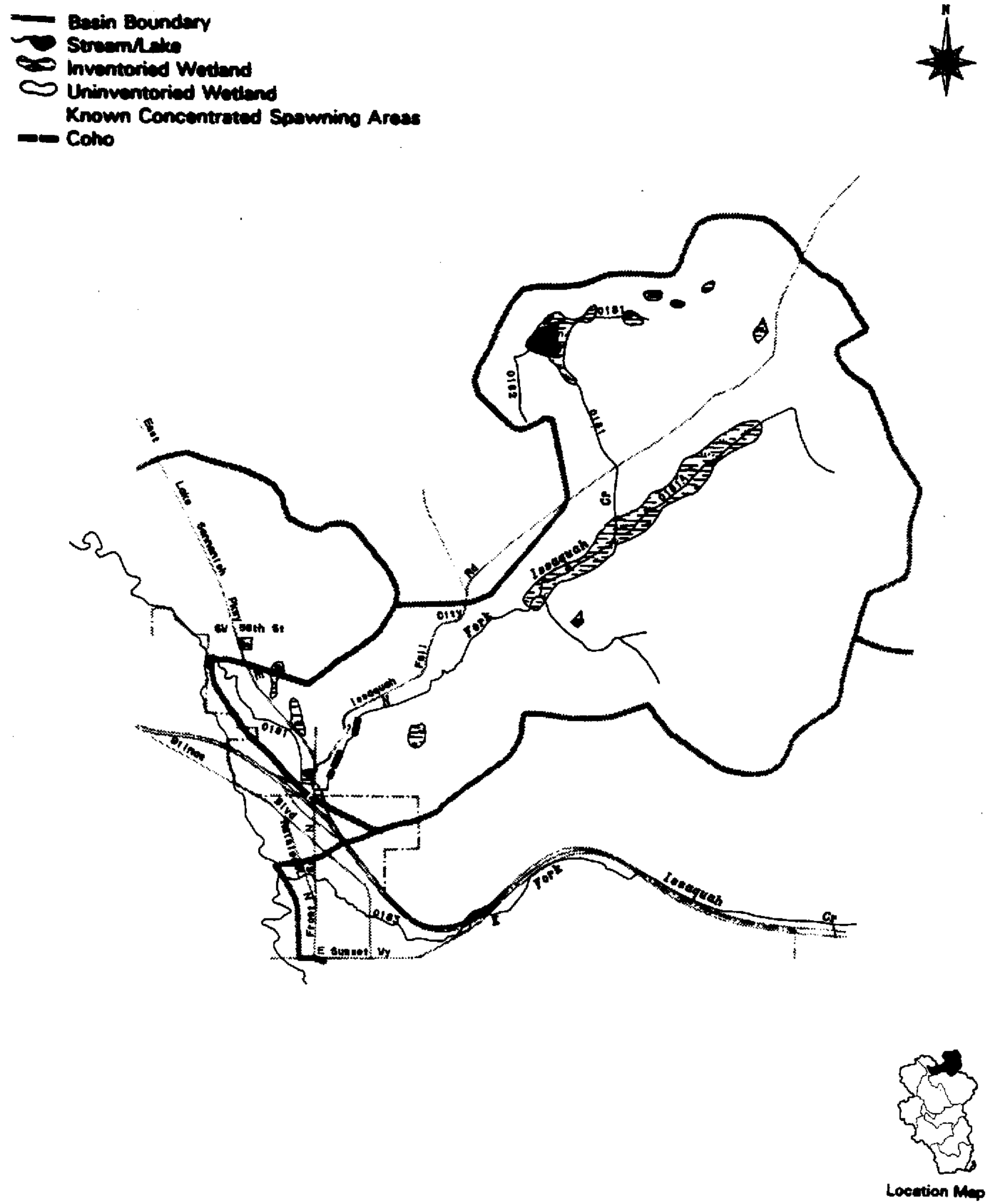
The North Fork consists of one main channel with only limited anadromous fish access, an extentsive wetland system, and several small tributaries. The headwaters of the North Fork are found in the Yellow Lake wetland system on the Sammamish plateau and flows some 3.7 miles to its confluence with the mainstem at RM 1.9 (Figure 8-4). Of the North Fork's four tributaries, three flow steeply from the north slopes of Grand Ridge. The headwater catchment of North Fork is rapidly being developed into a dense residential area, a portion of which is Klahanie, a planned development that virtually surrounds Yellow Lake and its satellite wetlands.

The stream flows from Yellow Lake through a gently-sloping, well-vegetated corridor into Wetland 7, an extensive, linear wetland system. The stream through the corridor is small and bedded with sand and silt, with only an occasional gravel patch. It is an easily eroded bed and is beginning to show some signs of erosion. As it passes into the wetland, the channel lacks definition and often flows sluggishly through the thick vegetation. Tributaries 0181A and 0181B flow into this wetland as well, through rather steep channels cut into the slopes of Grand Ridge. These streams are gravel-bedded as they pass over the valley floor toward the wetland. During the November 1990 storms, these channels unloaded large volumes of gravel into the wooded floodplains bordering the channels; the streams braided and shifted as they deposited their bedload.

Tributary 0181C exhibited the same behavior during the storm. This channel, however, flows from an upslope road network and has been altered as part of a development. Stormflows severely damaged the channel structures, creating large drops in the bed and scouring around and under weirs. The new channel is built partly in sandstone bedrock, and structures placed on this substrate fared poorly during the storm; most are in need of repair. Downstream of these structures, the channel is downcutting through till and gravel, exhibiting the typical signs of instability manifested in urban streams.

The North Fork exits Wetland 7 and enters the canyon at about RM 1.6 over a 15-foot-high falls and a series of bedrock cascades that are the upper limit of anadromous migration. In 1989, coho carcasses were found at the base of this cascade.

Below the falls, the stream flows through the canyon for about eight-tenths of a mile over a bed of cobble to boulder-sized substrate. The upper stream channel is steep and assumes a staircase-like profile the steps of which are separated by about a stream width. The upper slopes of the



NORTH FORK ISSAQUAH AQUATIC HABITAT FEATURES

Issaquah Creek Basin Planning Area

0 1/2 1 mile

Figure 8-4

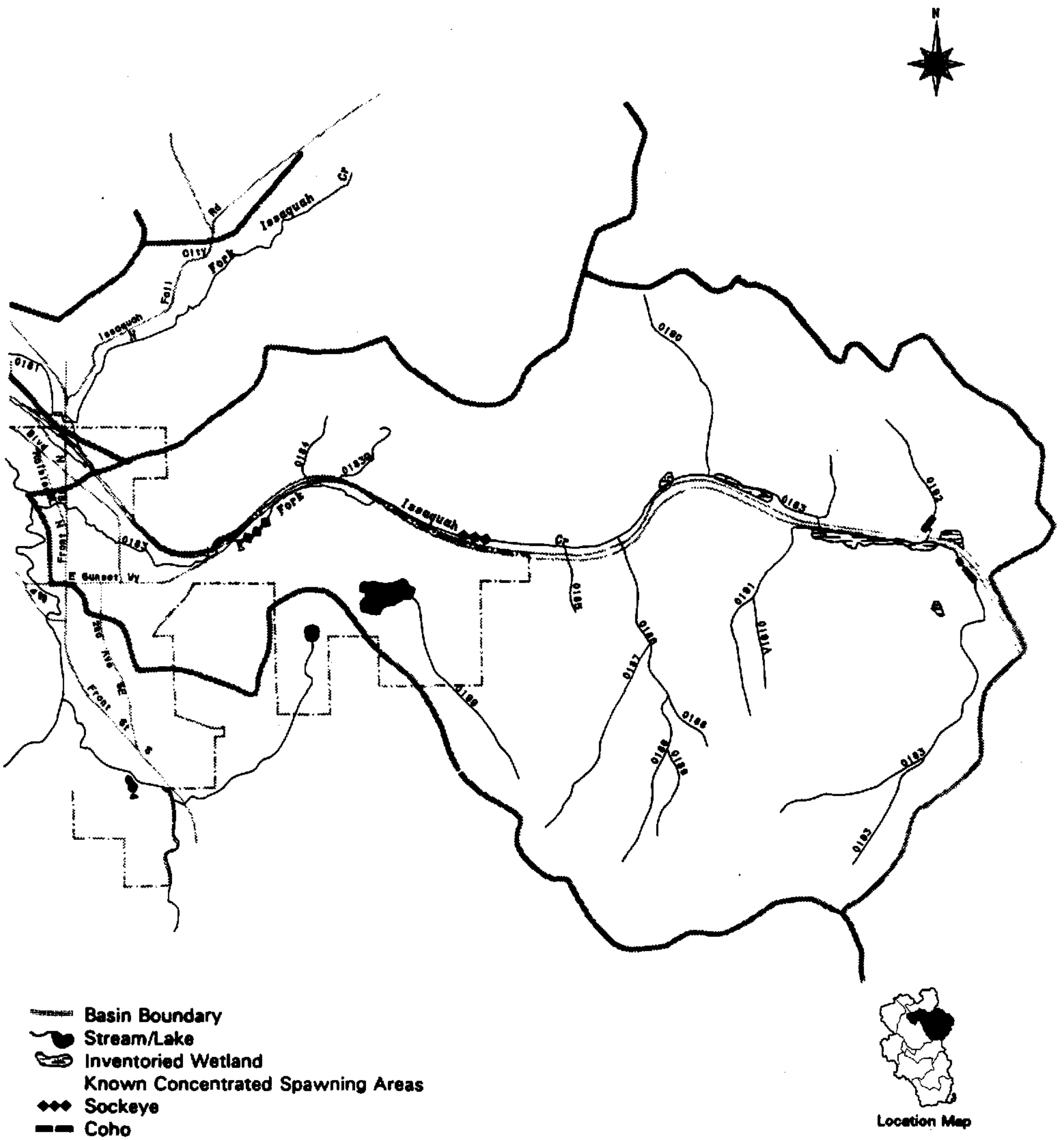
canyon--particularly on the south--are unstable and many small landslides and slumps are evident. Abetting this process, and adding much fine sediment to the stream, is an outflow from setling ponds on the upper plateau. Gravels in this vicinity occur in small patches and pools are small and rare. Large woody debris is common but appears to be too easily moved to provide much stability or to aid in habitat formation. Nevertheless, the material of the channel bed is large enough to resist erosion. The gradient flattens somewhat (to <2 percent) as it exits the canyon near the Lakeside Sand and Gravel Company. The corridor is narrow--often less than 30 feet from side to side and is well armored with rip-rap. A concrete-lined channel leads to culverts under the freeway on-ramp. From here to the confluence with the mainstem, the channel is relatively flat and bedded in silt and organic material. It is alternately squeezed by commercial development on one side, and the East Lake Sammamish Parkway on the other. The channel is deep through this area and runs in a roadside ditch. Trash and debris are common elements of the habitat. For the last 200 yards, the channel passes through the yards of several residences. A riparian corridor is essentially absent here, but the stream is well shaded by large trees. Woody debris is absent and is removed quickly by residents when it falls into the stream.

The North Fork provides some limited spawning habitat for coho and sockeye salmon (Figure 8-4), but the gradient in the canyon precludes the formation of spawning riffles of sufficient size for salmon. The lower reaches of the stream provide rearing and feeding habitats for juvenile salmonids and may act as refuge areas during floods.

Some concern exists that water supply wells in the lower North Fork could affect low summer flows in this stream. Water withdrawal during late summer could reduce low flows even further, reducing pool habitat for rearing salmonids. Portions of the stream would then become more sensitive to temperature fluctuations, potentially affecting survival of stream dwellers. This condition would exacerbate any water quality problems that occur in the lower system, such as the 1989 event that resulted in high mortalities of juvenile salmonids (see chapter 9 for details).

8.5.4 East Fork Issaquah Creek

The East Fork of Issaquah Creek (0183) originates on the north slope of Tiger Mountain. The stream flows for approximately 7.2 miles before its confluence with the mainstem of Issaquah Creek in the city of Issaquah (Figure 8-5). Habitat in the system is in generally good condition and supports significant runs of sockeye, coho, and some chinook salmon (in the lower reaches only) in addition to steelhead and resident and anadromous strains of cutthroat trout (Figure 8-5). Predominant impacts to habitat are from unstable slopes in the upper tributaries on Tiger Mountain and stream course constriction associated with construction of a railway in the late 19th century and of Interstate 90 in the 1960s. Recent commercial/industrial development near the Preston interchange has caused erosion and subsequent sedimentation to upper valley wetlands.



EAST FORK ISSAQUAH AQUATIC HABITAT FEATURES

Issaquah Creek Basin Planning Area

0 1/2 1 mile

Figure 8-5

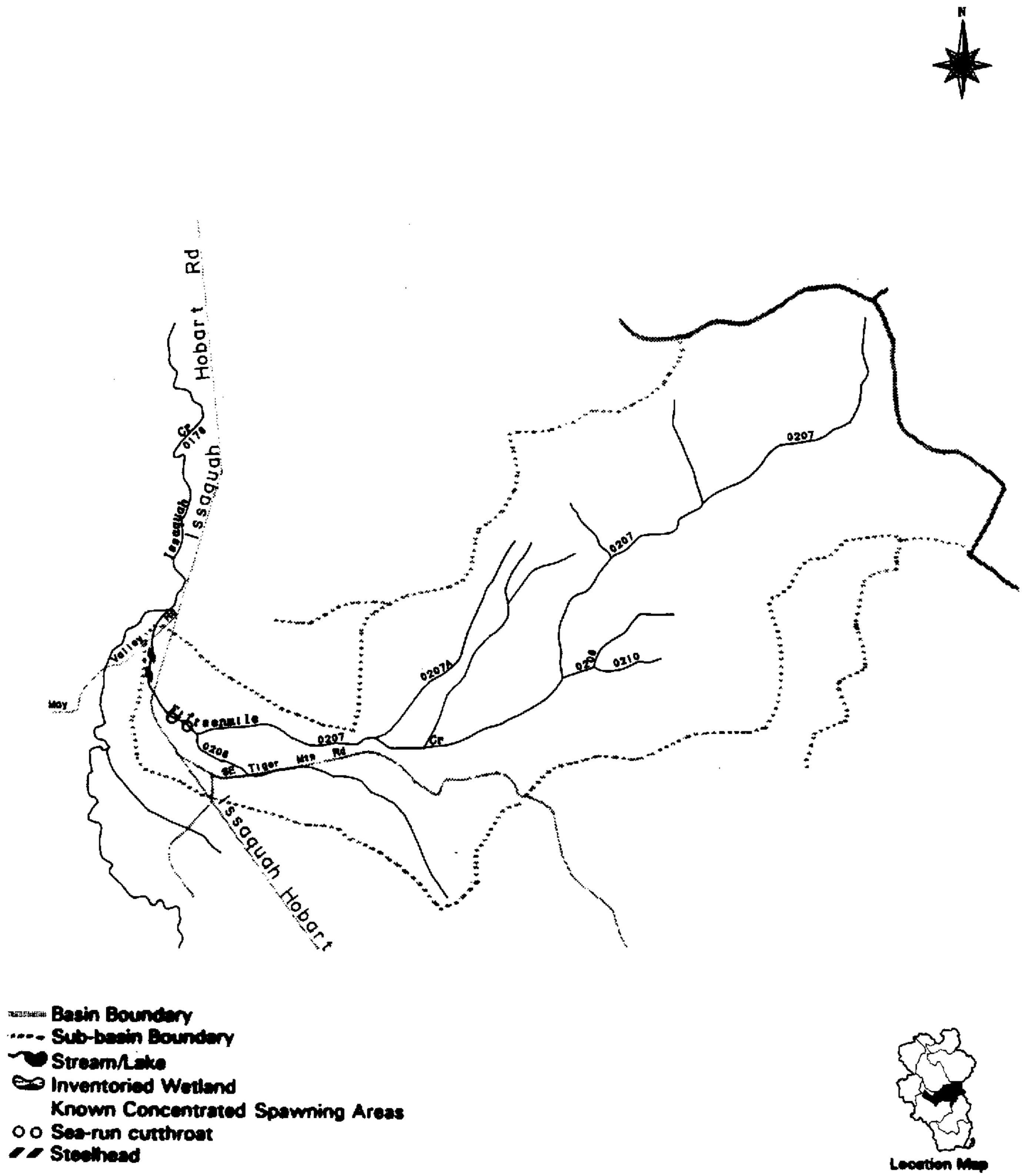
In the early years of this century, the East Fork was splash-dammed to move logs from the Tiger Mountain cuts downstream to the mills near Monohon; the channel still shows some signs of this massive disturbance. The upper limit of anadromous fish use is at RM 5.5, where a water intake dam has been constructed. This dam probably has only limited effect on fish production as stream gradients above the dam are quite steep, ranging up to ten percent, and habitat is more suited to resident trout. Below this barrier, fish habitat is generally quite good except for some channelized reaches of stream near a section of I-90 that was threatened by several past flooding events. From RM 4.4 to RM 5.0, the stream flows through a wetland within which stream flow is subsurface during extreme summer low-flow months. The wetland has been impacted by I-90 during both the original construction and as a result of road surface runoff.

At RM 4.0, the valley becomes confined by Tiger Mountain on the south and Grand Ridge to the north. Interstate 90 dominates the valley configuration through this area. Despite encroachment from the freeway, this reach of stream offers some excellent habitat, particularly from RM 2.3 to RM 3.2, where the stream and road are at their maximum distance apart. In this reach are some outstanding pool and riffle habitats, lacking only in some large organic debris for additional complexity; boulder and cobble substrate are providing good stability throughout most of this reach. Most of the stream corridor in this reach is further protected by a King County park that is planned to eventually be part of a trail system extending to Snoqualmie Pass. Currently, it is providing an excellent forest canopy which, as the conifers mature, should provide even better habitat conditions (park development must be carefully planned to minimize human impact, however). Just downstream, at RM 1.9, an extensive gravel bed provides excellent sockeye spawning among the boulders and logs.

The lower reach of the East Fork Issaquah Creek extends from RM 0.0 to RM 0.4 and has been extensively affected by urban development in the city of Issaquah. The major effect of this development has been to confine the natural channel and reduce streambed stability and habitat complexity. Hardened banks have caused the channel to downcut in places and the various forms of bank protection are being undermined by the stream. So far, the channel has not exhibited the extreme instability that is prevalent in many other streams of the basin. This may be due to limited development and channel problems upstream. Currently the reach is still used by high numbers of salmon for spawning.

8.5.5 Fifteenmile Creek

Fifteenmile Creek has its headwaters on the southeastern slopes of West Tiger Mountain. The mainstem, its three main tributaries and several smaller ones, comprise nine miles of stream channel, most of it of high gradient and dominated by boulder and cobble cascades (Figure 8-6). A barrier to anadromous fish occurs at RM 1.5 in the form of a bedrock cascade topped by an abandoned water supply dam some 20 feet high.



FIFTEENMILE CREEK AQUATIC HABITAT FEATURES

Issaquah Creek Basin Planning Area

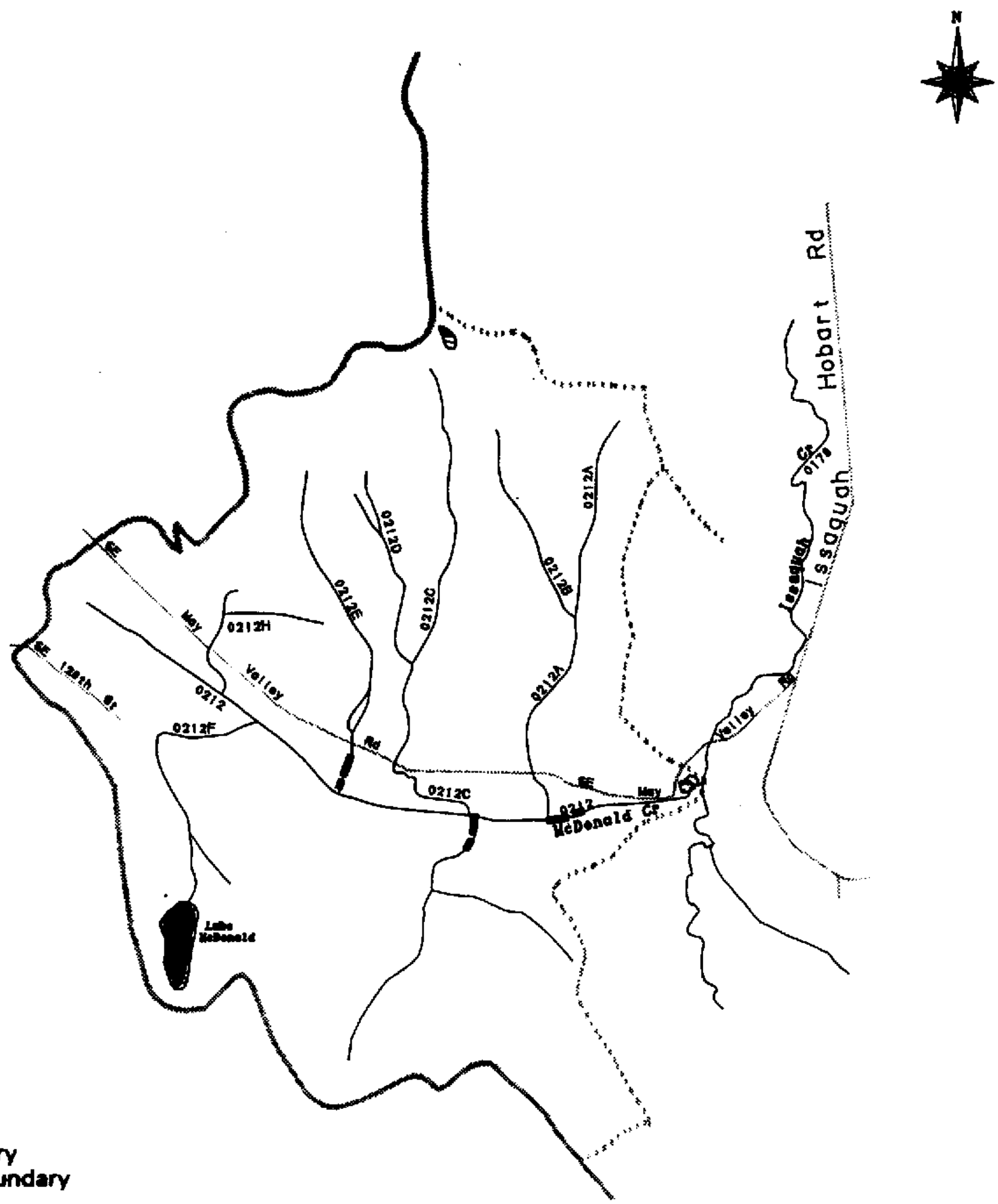
Figure 8-6

The reaches of the stream below the barrier are characterized by gradients of 1 to 1.5 percent and a shallow terrace or staircase profile, essentially a high gradient riffle. The distance between steps is about two to three stream widths and the steps are anchored with large cobble and occasionally boulder. Large gravel fills the spaces between steps forming patches of 0.5 to 1 square yard; small volume pools form behind obstructions and at bends and drops. The habitat units are quite small in size and not at all diverse--two or three habitat types dominate. Despite the continuous presence of a well-vegetated riparian corridor along the stream, large woody debris is rare and unevenly distributed; generally it consists of alder. Few pieces are well anchored; most tend to be parallel with the bank and are often broken. The lack of large wood in the stream probably can be attributed to three factors: the lack of conifers in the riparian zone; the short refractory (resistance to decay) period of alder in the channel (three to five years); and the tendency of property owners and others to remove material that has fallen into the channel. In fact, portions of the riparian zone in this lower reach have been brushed and cleared of all downed wood. The result in the channel is to produce the essentially unbroken riffle character described above. Little hydraulic diversity can occur when large roughness elements are missing or are homogeneous in size and distribution. Furthermore, little sediment can be stored in such a channel. The patches that occur in lower Fifteenmile favor steelhead and cutthroat trout, rather than any of the salmons (Figure 8-6). In fact, the Washington State Department of Wildlife redd tags from 1988 and 1989 show 18 steelhead redds and 14 searun cutthroat redds in the lower one mile of the stream. Observations taken in late November, 1988 show only 13 adult coho in the stream in a three-week period.

Above the water supply dam, the channel flattens for about 150 yards due to the accumulation of sediment behind the structure. Beyond that, however, the channel resumes its high gradient riffle character, and comes to be dominated by rubble and boulder cascades at about RM 3.5. The recent storms have moved large amounts of sediment in Fifteenmile Creek. This material appears to be generated from much higher in the watershed, possibly from slope failures or channel failures that accompany logging activities. One recent source was the result of a culvert washout and major fill failure during the January 1990 storm. Deposition on adjacent flood-plains is rare and little sediment can be stored in the channel. Most appears to pass into Issaquah Creek to be distributed downstream with subsequent floods.

8.5.6 McDonald Creek

McDonald Creek and its five tributaries comprise approximately seven miles of channel that drain the broad valley lying between the Cedar River plateau and Squak Mountain (Figure 8-7). The creek has its headwaters in McDonald Lake, located on the plateau that divides the Cedar River from May Creek and Issaquah Creek. One of its headwater streams flows from the same wetland complex that feeds May Creek. McDonald Creek (also called Mason Creek) has been channelized for about 1.7 miles as it passes through the flat upper valley that parallels SE May Valley Road. The channel in this area is uniformly straight and deep, historically dredged to drain the valley floor for agricultural use. Prior to draining, the valley floor probably contained



Basin Boundary
Sub-basin Boundary
Stream/Lake
Inventoried Wetland
Known Concentrated Spawning Areas
Coho

Location Map

MCDONALD CREEK AQUATIC HABITAT FEATURES

Issaquah Creek Basin Planning Area

0 1/2 1 mile

Figure 8-7

an extensive wetland complex, suggesting that any residential development would be prone to innundation even without additional runoff.

The lateral tributaries that feed this channel are steep and short, draining the plateau on the south and Squak Mountain on the north. The northern tributaries (0212A, B, C, D, and E) are mostly intermittent streams that carry large sediment loads from the slopes to the valley floor. This material was historically deposited in alluvial fans at the base of the hillslope; construction of homes on these fans has led to recent channelization of these drainages by hardening the banks with large rock and installing culverts. This seems to have resulted in much of the sediment passing across the fans to the valley floor and McDonald Creek. Much of the valley floor is now occupied by residences which may be threatened by the deposition.

As tributaries 0212E and C pass across the valley floor, the gradient lessens and conditions are produced that favor use of the lower reaches for salmon spawning (Figure 8-7). Coho use these streams during December through April for spawning and rearing, exiting the channels as they dry up in early summer. During the January 1990 storm and the last series of storms in November 1990, much sediment was delivered to the valley by these tributaries, scouring the channels, causing them to widen, and burying the lower reach of 0212E which contains a habitat restoration project. Much of this sediment will probably be carried through the main channel by succeeding storms and into McDonald Creek. The main channel of McDonald Creek, however, is quite flat and the stream lacks the power to transport sediment of this size. A large plug of sediment is evident at the confluence of the two streams. On the south, two tributaries drain the plateau: 0212F, from McDonald Lake, and 0212I, which flows from the area of the Cedar Hills landfill. Tributary 0212I has coho use in its lowermost reach that flows across the valley floor, and cutthroat in its mid-reaches. It is a perennial stream and marks the upper limit of summer flow in McDonald Creek at RM 1.0. Tributary 0212I regularly receives drainage from settling ponds at Cedar Hills landfill and in a matter of minutes turns from clear to kahki color. This material is not leachate, but a fine suspended sediment from erosion on the landfill site. Its apparent release from the ponds only weakly coincides with rainfall. At about RM 0.75, the gradient of McDonald Creek increases as it begins to fall through its canyon into Issaquah Creek. The bed changes quite abruptly to gravel at the confluence with 0212A (which is a major gravel source). The stream assumes a low gradient riffle character with pools at outbends and at obstructions. The gravels are relatively sandy (perhaps from local bank slumps in the vicinity) but easily dislodged. The corridor becomes densely wooded and the stream through this reach is used extensively by coho salmon. The channel steepens slightly as it joins Issaquah Creek at mainstem RM 7.45.

8.5.7 Carey Creek

In the Issaquah system, Carey Creek is the quintessential salmon stream. For most of its length, large, deep pools, anchored with abundant LWD, provide excellent rearing habitat; gravels, trapped by the very same material, form extensive spawning beds. The riparian corridor is

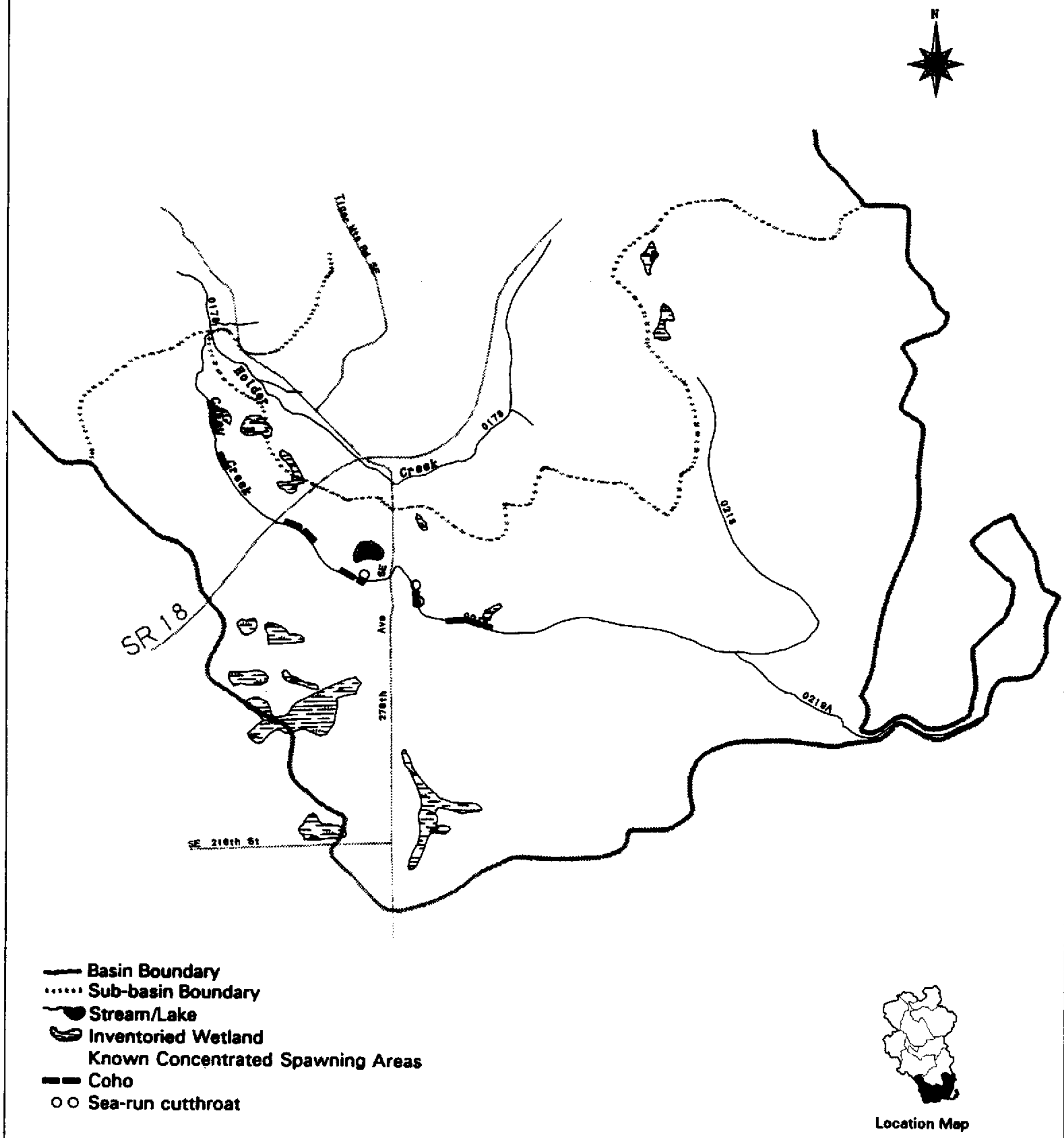
broad and well vegetated, though mainly with deciduous species, and often forms large riparian wetlands and floodplains. The stream headwaters on the south west side of South Taylor Mountain and flows some 5.6 miles to the confluence with Holder Creek, forming the mainstem Issaquah (Figure 8-8). It has only two major tributaries--0218A and 0219A--one of which (0219A) is a diversion out of the Cedar River watershed. The stream gradient is low for most of its length as it travels across the broad upper valley near Hobart, increasing slightly as the stream flows through the heavily wooded areas on the southwest flanks of Taylor Mountain. At about RM 4.2, the Carey Creek Canyon is encountered and an abrupt series of cascades and falls marks the upper limit of anadromous migration. Through the canyon, the channel is steep and assumes a staircaselike profile, anchored by boulders and rubble, with large trees and regular debris jams. Above the canyon, the stream flattens and lies in a rather broad swale that forms the headwaters.

For discussion purposes, it is convenient to divide the stream into three reaches: a lower reach, from RM 2.4 to the confluence with Holder Creek; a middle reach, from RM 2.4 to the cascades at RM 4.2; and an upper reach, from RM 4.2 to the headwaters.

Most salmon production seems to occur in the lower reach of Carey Creek (Figure 8-8). This reach is characterized by low gradients (<0.5 percent), forested riparian zones, and a diversity of habitat types, favoring large, deep pools anchored by abundant LWD. Compared to other tributaries--and the mainstem itself--lower Carey Creek exhibits an almost classic ratio of pool to riffle, often suggested as 60:40, for salmon streams. A habitat survey accomplished in November 1990 clearly shows the dominance of pool-type habitats in this reach. Gravel beds are extensive, and gravels are relatively free of fines and unconsolidated. During a stream survey in 1989, few adult salmon were observed in this reach, however. Unfortunately, most coho and all chinook salmon are diverted at the hatchery and the stream appears to be under-utilized by anadromous salmonids, given the quality and abundance of habitat. Steelhead use the area, as do searrun cutthroat and resident rainbow. Dolly Varden, a char of the genus Salvelinus, have also been observed in this reach.

Compared to other streams in the Issaquah system, the lower reach of Carey Creek has an abundance of LWD. The riparian corridor is quite extensive through this reach and though dominated by deciduous species, conifers are common and are well represented in the stream.

Large riparian wetlands line the channel in places and provide extensive overbank areas for flood waters. Immediately above and below the Issaquah-Hobart Road are two of the more extensive wetland systems in the basin. Because of the soil conditions of these wetland areas, they may be primary sources of LWD. Trees often fall more easily in these wet soils and so are more frequent additions to the stream. Many of the LWD pieces are quite large, often exceeding 36 inches in diameter, and many appear to be quite old. The channel appears to be stabilized by historic LWD that forms a sort of base matrix, accumulating recent inputs as debris jams. If the riparian zone remains intact, conifers will become an increasing portion of the LWD as they mature.



CAREY CREEK AQUATIC HABITAT FEATURES

Issaquah Creek Basin Planning Area

0 1/2 1 mile

Figure 8-8

Any problems in the lower reach appear to be related to the few pastures and consequent livestock access to the stream. Below the Issaquah-Hobart Road, for example, livestock have access to the channel and have caused some locally severe bank erosion. Only a few areas of artificial bank protection exist in this reach at outbends where the stream approaches the roadway.

The middle reach of Carey Creek, from RM 2.4 to RM 4.2, is somewhat steeper and has a much different character from the lower reach. During the recent stream survey in November 1990, the channel was observed to possess an unexpectedly high width to depth ratio, a possible indication of unusually high sediment transport. The stream was observed to contain few pools of any depth, and had assumed a long, relatively unbroken low gradient riffle character with little LWD. Channel banks were eroded and some washouts of crossings were observed in the lower portion of the reach. Gravels in the channel were bright (uncoated with diatoms or silt) and somewhat unsorted, adding to the evidence for very recent heavy sediment inputs. LWD in this portion was concentrated in a few small debris jams, mostly at outcurves, and much material appeared to have been buried, only becoming exposed slowly by scouring flows. The corridor was well vegetated with deciduous trees and the occasional conifer. The valley in this area is only about 300 feet wide and narrows as it enters the canyon. No salmon were observed through this reach during field work for this report, perhaps as a result of an eight-foot-diameter, long (>100 feet) culvert at about RM 3.2 that lacks baffles to pass fish into the upper watershed.

At about RM 3.9, tributary 0219A enters Carey Creek, a diversion from Rock Creek in the Cedar River watershed. As of early 1991, this channel showed clear evidence of recent severe scour for most of its length through the watershed. The bed was eroded to a depth of about one foot for a length of several hundred yards, and large accumulations of gravel occurred at the culvert where the stream enters Carey Creek. The cause of this erosion appears to be related to the confluence of Webster Creek and the siphon which carries the diversion under Webster Creek. During the November, 1990 storm, the culvert under SE 216th Street (the county access road into the watershed) plugged with debris and sediment, causing the stream to overflow into the diversion channel below the siphon outlet. Flow in this diversion channel was substantially increased and caused the observed bed scour. A portion of the diversion ditch bank immediately upstream of the scour point failed as well, resulting in deposition of sediment into the woods as the stream flowed through the breach.

Upstream of this confluence, Carey Creek assumes a brief pool:riffle character before it steepens to boulder cascades and a staircase profile. A possible chinook redd was observed in this small flat reach during November, 1990. LWD is common throughout this upper reach and forms numerous debris jams, trapping sediment and providing some velocity attenuation. At RM 4.2, a series of cascades marks the upper Carey Creek Canyon and the limit of anadromous migration.

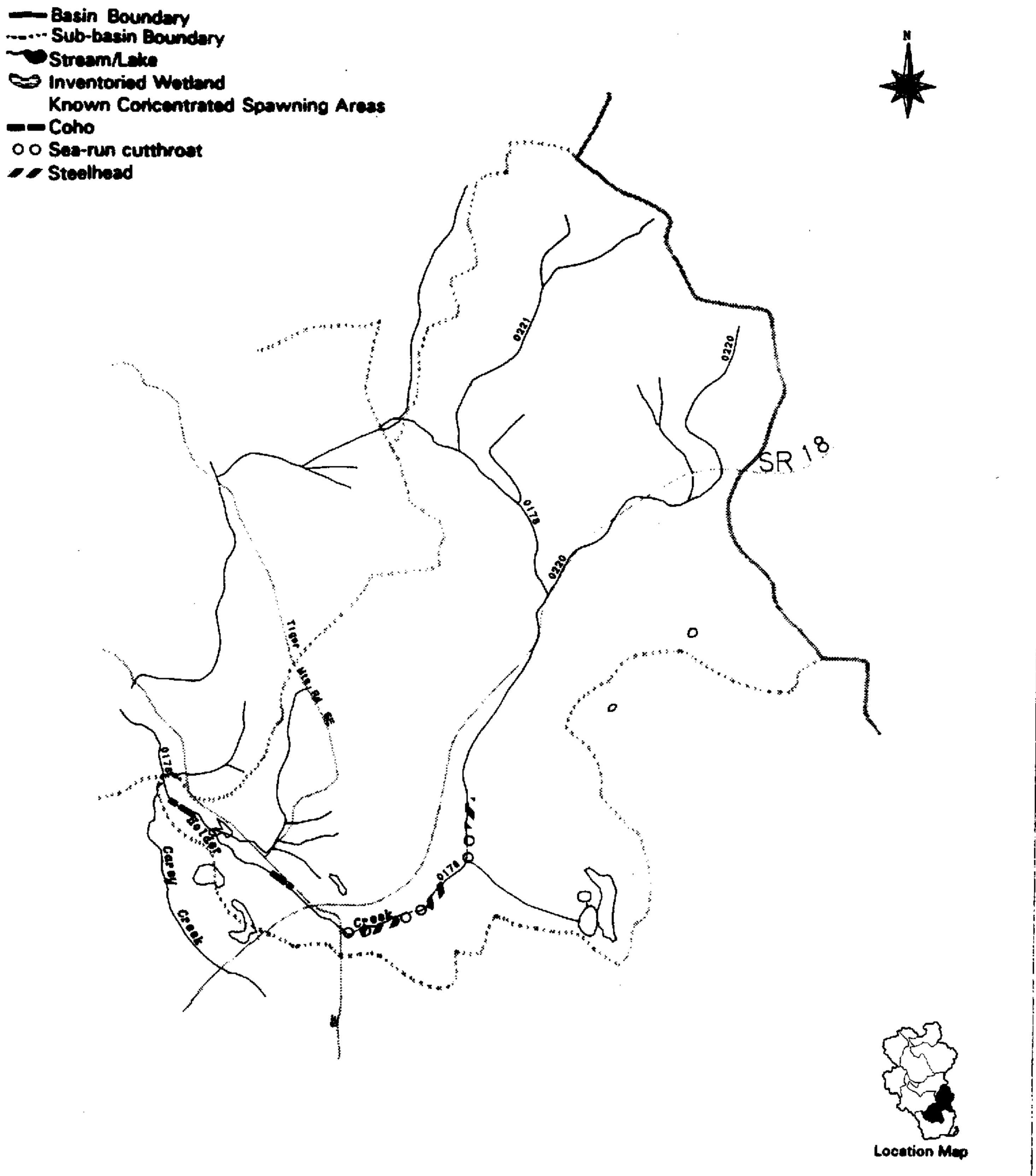
The uppermost reach above the 30- to 40-foot-high cascades begins as a steep, boulder cascade stream as it passes through the canyon. There are some bedrock exposures here and LWD anchors some few but regular benches of smaller gravel and sand. Canyon walls are steep, up to 150 feet high, and well-vegetated with conifers dominating the canopy. Pools are mostly small and shallow and are formed behind obstructions or at drops. No anadromous fish can reach this area and no resident trout were observed during field work for this report. Other forms of animal life abound, however, and elk sign was clear and abundant on the slopes above the canyon.

At the upper end of the canyon, the stream flattens abruptly and the valley broadens from less than 200 feet wide to over 600 feet wide. This broad swale continues for another half mile or so, and collects several small streams that form the headwaters of Carey Creek. The stream here is well suited to trout, having small gravels in small patches and occasional deep pools. No fish were observed during this survey, however. The corridor is well vegetated with deciduous trees, mostly alder and big leaf maple, but some cedar and hemlock remain. Many large cedar stumps are found in the riparian zone, indicating a harvest much earlier in this century. The upper swale appears to be a continuous riparian wetland and will be surveyed prior to completion of the basin plan.

8.5.8 Holder Creek

Holder Creek has its headwaters on the eastern slopes of Tiger Mountain and flows some 5.9 miles to a confluence with Carey Creek, forming the mainstem Issaquah Creek. Holder Creek is considered the extension of Issaquah Creek beyond this confluence (Figure 8-9).

Stream habitat in Holder Creek is being affected by an apparent delayed stream response to past logging practices exacerbated by current logging activity in the upper reaches (upstream of the Issaquah-Hobart Road) and loss of riparian habitat in the lower reaches. The upper reaches of the system are generally very steep with gradients typically greater than three percent and substrate dominated by large cobbles and boulders. These larger substrates assist in stabilizing the overall stream bed and creating small pocket water suitable for limited rearing of salmonids. Larger channel stabilizing elements, such as large woody debris (LWD) are lacking, however. Loss of these elements increases the overall erosive energy of storm runoff by reducing the amount of energy dissipation in the system. This in turn creates downstream channel changes responding to the changing energy dynamics. This is particularly true in lower Holder Creek, where stabilizing elements such as large conifer trees have been almost completely removed from the riparian zone. Current woody vegetation in upper Holder is dominated by alder, which has only short-term benefits as a stabilizing element on the landscape and in the channel. An understory of conifers, dominated by hemlock and cedar, is present but is at least 50 years from being large enough to provide effective stabilization for the stream. Valley and stream channel constriction caused by construction of State Route 18 may also be causing some localized bank



HOLDER CREEK AQUATIC HABITAT FEATURES

Issaquah Creek Basin Planning Area

Figure 8-9

stability problems, particularly where a left bank slide is obvious from the road (at RM 15.8). Runoff from SR 18 is exacerbating these storm-generated problems downstream of roadway outfalls.

The lower reach of Holder Creek is being affected by both upstream changes and local channel and riparian modifications by landowners. For approximately 100 yards below the Issaquah-Hobart Road, the stream channel has been severely downcut with erosion forming a major knickpoint for the stream system. The development of this erosion has been exacerbated by channel constriction caused by the Issaquah-Hobart stream crossing and efforts by the down-stream landowner to protect his banks with rock and a layer of cement; the erosive energy of the stream has caused the channel to deepen locally. The stream channel from the Issaquah-Hobart Road downstream is typified by long reaches of shallow riffle punctuated by small, hydraulically formed pools, the result of deposition and a lack of wood of adequate size to stabilize the channel and aid in pool formation. Approximately 25 percent of the riparian area is vegetated only with grass or shrubs. The remaining riparian habitat is dominated by small deciduous trees. The habitat throughout this reach has low complexity and is much reduced in suitability for salmonids. There are also numerous erosional problems caused by lateral channel cutting in pasture areas throughout the reach; some of these cuts are almost ten feet deep and exhibit much recent activity. Although the habitat is substantially degraded from historical conditions, some coho, steelhead, and sea-run cutthroat find areas suitable for spawning throughout this reach (Figure 8-9).

Of particular interest in the upper Holder Creek system is the apparent diversion of about one square mile of headwater basin area from the Holder Creek system into the Pheasant Creek (0178E) watershed. The date of this diversion is unknown but it appears to be quite recent judging from the lack of a well-formed streambed. The diversion may have been somewhat inadvertant: two culverts lie in a shallow saddle within about 150 feet of each other at milepost 2.4 of the East Tiger Mountain Road. Flow may divert to either culvert depending on the sediment deposition from the upstream channel. At this writing, flow is entering the westernmost culvert, once probably something of a relief valve for the main channel farther to the east.

8.5.9 Tibbetts Creek

Tibbetts Creek (0169) originates high in a valley formed between Squak and Cougar Mountains and flows for approximately five miles before entering Lake Sammamish, approximately 1.8 shore miles to the south of the much larger Issaquah Creek system. The basin is approximately six square miles in area with some 4.3 miles of mainstem channel and approximately 7 miles of tributary. Historically, Tibbetts Creek was a highly productive stream for coho and chinook salmon, and steelhead and cutthroat trout.

Current habitat throughout the drainage ranges from only fair to very poor, the result of reduced stream channel stability. The headwaters of the creek are located in a large mining operation (Sunset Quarry) on the eastern slopes of Squak Mountain. From these headwaters, the stream drops steeply for 2.0 miles through a narrow valley. The Renton-Issaquah Road follows this valley and in several places confines the stream channel. The channel in this reach is exhibiting a high level of instability and increased substrate mobilization. Much of this may be due to sediment inputs and channel erosion problems in several lateral tributaries and in the headwater areas (see EROSION AND DEPOSITION OF STREAM-CHANNEL SEDIMENT, Chapter 7). These problems have been precipitated by activities associated with the gravel mining and logging operations. Likely mechanisms for such changes include increased rill erosion, landslides and road failures, and a loss of large channel-stabilizing woody material.

The valley opens up at RM 2.5 and stream gradient lessens considerably. The land use changes from forestry and mining to hobby farms, all of which are having severe impacts to fish habitat due to eroding banks, lack of streamside vegetation, and loss of instream habitat complexity. Many of these problems were recently worsened by impacts of the January 1990 storm and subsequent landowner efforts to fix perceived channel problems. This is particularly evident at RM 1.15, RM 1.22, and RM 1.5.

At RM 1.4 the creek crosses Newport Road and flows onto the historic alluvial plain formed by Tibbetts and Issaquah Creeks. The stream has been extensively impacted by urbanization and light industry associated with development along the corridor of Interstate 90. Most of the channel between Newport Road and the mouth has been straightened and confined by local development. The result is a much-reduced habitat complexity and that, in turn, results in lowered productivity for salmonids.

8.6.0 LAKE HABITAT

Four named lakes are found in the basin (see Figures 8-2, 8-4, and 8-7). Two have been inventoried as wetlands in the King County Wetland Inventory and will be discussed in more detail in the wetlands section of this report. The largest of the lakes, Tradition Lake lies on the northwestern slope of Tiger Mountain and is approximately 19.2 acres in size. This lake can be reached by one of the many hiking trails that are part of the Tiger Mountain trail network and is a popular destination. Tradition Lake is the headwater for stream 0199, an unnamed tributary to Issaquah Creek. About one-quarter mile to the southwest, and also accessible by trail, is Round Lake, a shallow lake only 2.6 acres in size and also a part of the drainage network of stream 0199.

McDonald Lake (Issaquah Creek Wetland No. 10) has a surface area of 18 acres and an extensively developed shoreline. It lies on the plateau that divides the Cedar River from May Valley and is the headwater of McDonald (Mason) Creek, a tributary to mainstem Issaquah Creek. Yellow Lake (North Fork Issaquah Wetland No. 5) lies on the southern edge of the East

Lake Sammamish plateau and is the headwaters of North Fork Issaquah Creek. It has an open water surface area of approximately 10.5 acres and is surrounded by lush wetland vegetation. Historically, this system has provided excellent waterfowl breeding, feeding, and resting habitat. Extensive urban development on its western and southern boundaries has caused significant damage to this once-isolated system. Due to their small size and relative isolation, the lakes of the Issaquah basin are relatively unimportant hydrographic features.

Except for Yellow Lake, none provides significant breeding or feeding habitat for waterfowl in the basin (Table 8-3, at the end of the chapter, includes waterfowl sightings on these lakes). All are above the limit of migration for salmon so can provide no rearing habitat for juveniles. Recreational uses are limited by inaccessibility and small size, although McDonald Lake does provide some fishing opportunities for lakeshore residents and Lake Tradition has a population of bass that are eagerly sought by local residents. Yellow Lake and McDonald Lake are positioned high in their respective sub-basins and so provide only local attenuation of stormflows. Of the lakes, McDonald is the only one with a developed shoreline, and is surrounded by some sixteen to twenty residences. Table 8-2 gives some morphometric detail of the lakes.

Table 8-2

Lake Morphometry

LAKE	ELEV. MSL (feet)	AREA (acres)	MAX. DEPTH (feet)
Tradition	490	19.2	?
Round	470	2.6	shallow
McDonald	560	18.0	30
Yellow	400	10.5	?

Although not properly within the basin, Lake Sammamish is an important element of the Issaquah Creek drainage. With nearly 4,900 acres of surface area, the lake provides extensive habitat for many species of waterfowl and is the migratory pathway for salmon and steelhead returning to Issaquah Creek. It also provides considerable rearing habitat for juvenile coho and chinook salmon released from the Issaquah Salmon Hatchery and for all salmonids arising from natural spawning in the many streams of the Issaquah drainage. Gravelly areas of the lake's undeveloped shoreline in the vicinity of the creek are used by a select race of shore-spawning sockeye salmon. The lake also is home to bass, yellow perch, catfish, black crappie, rainbow, cutthroat, dolly varden, and a resident kokanee population. This race of land-locked sockeye

are thought to be the remnants of a once much larger population that occupied the lake as much as 3,000 years ago.

The delta built from the sediment of Issaquah Creek is an important feeding area for juvenile salmon, trout, and other fish species. Waterfowl feed here and hawks--even an occasional bald eagle--hunt over the shallow water.

8.7.0 Key Findings

- Salmonid habitats in the Issaquah and Tibbetts creek systems are significantly modified from the historic condition by the loss of channel-stabilizing large woody debris (LWD). Areas of concern are:

  --mainstem Issaquah Creek from RM 1.2 to 4.0
  --mainstem Issaquah Creek from RM 7.3 to 11.4
  --Fifteenmile Creek from RM 0.0 to RM 1.5
  --Holder Creek (numbered as Issaquah) RM 11.4 to 15.0.

  Nevertheless, many habitat areas throughout both basins provide an environment that is still well-suited for a diversity of salmonids.

- Excellent habitat conditions exist in the lower mainstem of Issaquah from RM 0.0 to 1.2 and throughout Carey Creek from RM 0.0 to 2.4.

- Present land uses in Tibbetts Creek are exacerbating erosion and sedimentation problems set in motion by historic logging and quarrying activity. Agricultural pasture use of reaches in the lower mainstem is a major contributor to bank erosion, sedimentation and streambed instability of the channel. Given the level of access by livestock, the intensity of use, and degree of saturation of the soils in winter, severe water quality problems are to be expected as well. Gravel beds are densely infiltrated with fine silts and sands, pools are filling with material, and the stream becomes turbid during virtually every rainfall event, creating conditions intolerant to salmonid survival.

- The WDF Issaquah Salmon Hatchery at RM 3.1 intercepts the majority of anadromous fish that enter the Issaquah Creek system. As a result, the habitat upstream of this point is under-utilized by spawning and rearing salmon.

- Populations of Kokanee that once spawned in Issaquah Creek have declined precipitously. If habitat degradation continues unabated, populations and diversity of other anadromous and resident salmonids are expected to follow suit.

- Certain lateral tributaries appear to be exhibiting a delayed erosional response to logging practices carried out early in the century and to inadequate protections from current practices. These include East Fork Issaquah Creek, Nudist Camp Creek, Holder Creek, Pheasant Creek, and triburtaries 0212A and 0212E to McDonald Creek.

- Flows diverted from the Cedar River watershed coupled with overflow from Webster Creek have caused substantial sediment delivery to upper Carey Creek, which in turn has caused significantly degraded habitat in the downstream reach.

- Large, uninventoried riparian wetlands exist along reaches of mainstem Issaquah Creek and Carey Creek.

- Fragmentation of wetland and stream habitats will become a significant problem as the basin urbanizes. An example of this occurs in the North Fork subbasin at Yellow Lake (NF 5).

- Buffer areas along the streams have been, and continue to be lost to development and other land use activities. Particularly in the city of Issaquah, long reaches of mainstem Issaquah Creek and East Fork Issaquah Creek are without vegetated buffers of even moderate width. Agricultural activities earlier in the century reduced or eliminated tree and shrub vegetation along the channel in the upper and lower Issaquah valley.

Table 8-1

Anadromous Fish Use of Issaquah Creek and Tributaries

STREAM #	LENGTH (mile)	ACCESSIBLE LENGTH	SPECIES	SPAWNING/REARING
0178	17.3	All species to RM 3.1. No CK above hatchery		
0181	4.25	1.6/RES	SE/CO/CT	S/RS/RS
0181A	0.75	RES	CT	RS
0183	7.20	5.5/RES	SE/CO/CK/CT/RB	R/RS/RS/RS/RS
0186	1.75	0.35/RES	CO/SE/CT	RS/S/RS
0191	1.10	0.20/RES	CO/CT	RS/RS
0192	0.75	0.15/N	CO/CT	RS/RS
0194	0.80	O/N	—	—
0195	1.20	0.15/N	CO/CT	S/RS
0198	1.00	0.20/RES	CO/CT	R/RS
0199	2.75	0.75/RES	CO/CT	RS/RS
0200	1.50	0.50/N	CO/CT	RS/RS
0201	0.60	0.1/N	CO/CT	S/S
0203	2.30	0.4/RES	CO/CT	S/SR
0203A	1.10	0.45/N	CO/KO/CT	SR/S/SR
0206	1.00	0.0/RES	CT	SR
0207	5.40	1.5/RES	SH/CO/CK/CT	SR/SR/SR/SR
0208	1.30	1.0/N	CO/CT	SR/SR
0212	3.10	1.8/N	CO/CT/RB	SR/SR/SR
0212C	1.80	0.25/N	CO/CT	R/SR
0212E	1.10	0.25/N	CO	S
UNNMBRD (Enters mainstem on RB* at RM 7.6)	1.60	0.4/RES	CO/CT	SR/SR
0213	1.00	0.35/N	CO/CT	S/SR
0214	0.70	0.50/N	—	—
0215	1.50	0.30/U	CO/CT	SR/SR
0216	0.40	0.1/U	U	—
0217	0.80	0.0/N	—	—
UNNMBRD (Enters mainstem on RB* at RM 10.8)	1.20	0.40	CO/CT/SE	S/S/S
0218	5.60	2.6/RES	CO/SE/CK/RB SRCT/SH/DV	RS/S/RS/RS/ RS/RS/RS
0178 continued as Holder Ck.			CO/SH/DV/CT	RS/RS/RS/RS
0219	1.20	0.7/N	CO/CT	S/RS
0219A	1.10	0.0/N	—	—
0221	1.60	0.0/N	—	—
0169	4.30	3.0/RES	CO/SE/CT	RS/S/RS

TOTAL ACCESSIBLE LENGTH=37.2 MILES
TOTAL STREAM LENGTH = 122 MILES

KEY: ACCESSIBLE LENGTH: X.XX=accessible by anadromous fish to here.

CK=CHINOOK 0=inaccessible to anadromous fish
CO=COHO /RES=Resident fish above this mile
SE=SOCKEYE RES=Resident fish only this stream
CT=CUTTHROAT N=No fish observed
SH=STEELHEAD U=Unknown
SR=SEA RUN RB=RAINBOW RB*=RIGHT BANK
DV=DOLLY VARDEN KO=KOKANEE S=SPAWNING R=REARING

Table 8-3

FAUNAL LIST FOR ISSAQUAH CREEK BASIN

The following species were observed during field investigation, or have been reported to occur in the Issaquah Creek basin planning area.

Mammals:

Deer Mouse
Voles
Douglas Squirrel
Townsend Chipmunk - Introduced
Northern Flying Squirrel
Varying Hare
Eastern Cottontail - Introduced
Shrews
Mole
Shrewmole
Little Brown Bat
Big Brown Bat
Bobcat
Black Bear
Mountain Beaver
Black Tailed Deer
Elk
Striped Skunk
Spotted Skunk
Raccoon
Beaver
Longtailed Weasel
Mink
River Otter
Muskrat
Coyote
Red Fox

Birds:

473 species are reported from Washington. The more commonly observed species in the state, similarly observed in the Issquah basin, are listed below.

Common Loon
Western Grebe
Eared Grebe
Piedbilled Greve
Doublecrested Cormorant
American Bittern
Dipper
Belted Kingfisher
Virginia Rail
American Coot
Killdeer
Greater Yellowlegs
Spotted Sandpiper
Common Snipe
Ringbilled Gull
Herring Gull
Western Gull
Bald Eagle
Northern Harrier
Sharpshinned Hawk
Cooper's Hawk
Redtailed Hawk
Barred Owl
Northern Saw-whet Owl
Northern Spotted Owl (Occasional)
Blackcrowned Night Heron
Canada Goose
Brant

Table 8-3 (cont.)

Mallard	Canvasback
Gadwall Greenwinged Teal	Greater Scaup
Amercian Widgeon	Lesser Scaup
Northern Shoveler	Common Goldeneye
Ruddy Duck	Bufflehead
Wood Duck	Common Merganser

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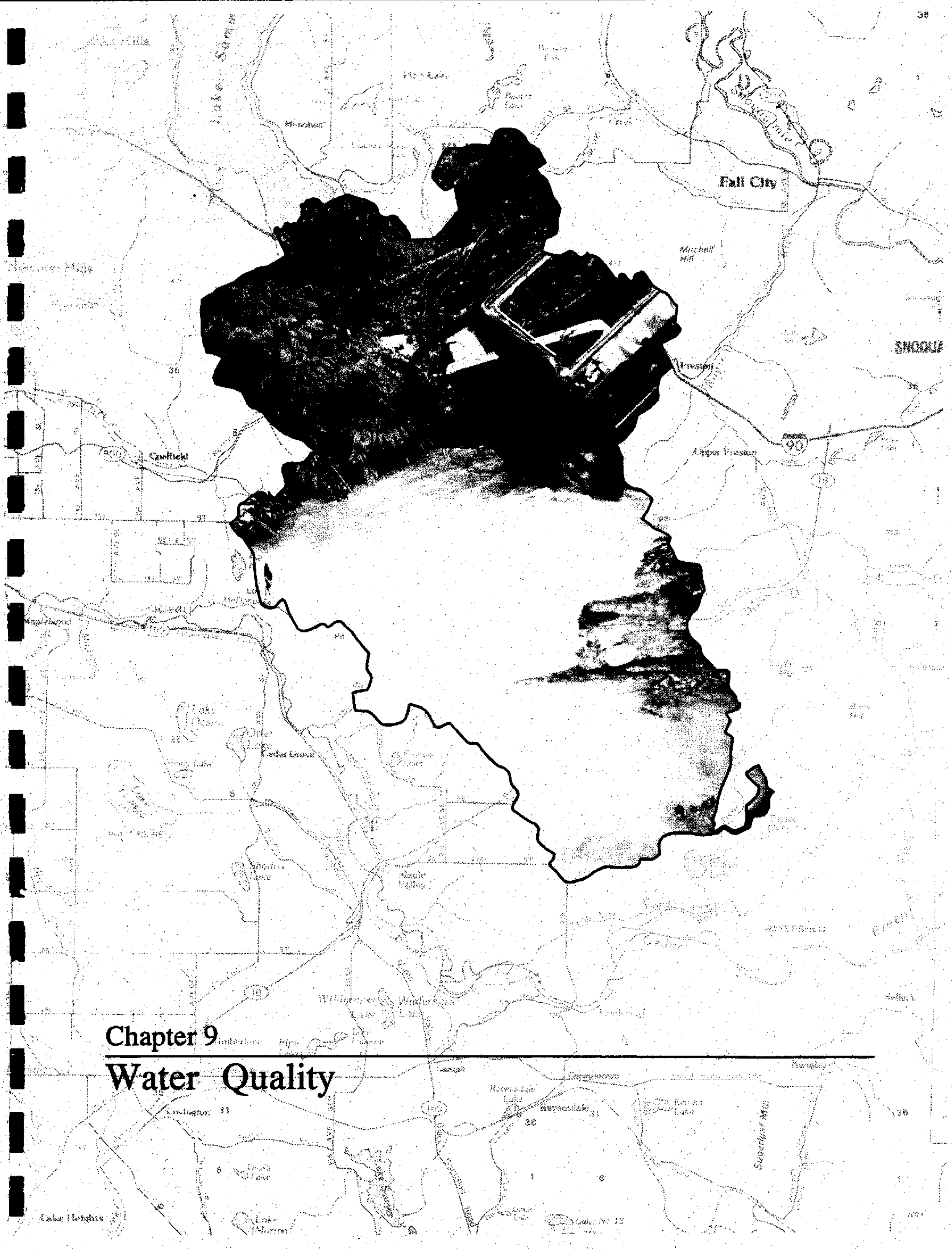


Chapter 9

Water Quality

CHAPTER 9: WATER QUALITY

9.1.0 INTRODUCTION

This chapter assesses the nonpoint water quality impacts in the Issaquah and Tibbetts Creek basins. Nonpoint source pollution is defined as pollution not originating from a specific point such as a pipe. Instead, nonpoint pollution originates from diverse sources that enter surface waters and, in combination, can degrade water quality. The difficulty in identifying and isolating nonpoint pollution sources adds to the complexity of controlling such sources. Non-structural solutions become very important for addressing nonpoint source control problems.

Potential sources of nonpoint pollution in the Issaquah and Tibbetts Creek basin include agriculture (commercial and hobby farms), urbanization (i.e., construction and stormwater runoff), boating, failing onsite septic systems, improper pesticide/ fertilizer applications, hazardous wastes, underground storage tanks, landfills, resource extraction, forestry operations, and gravel mining. Each nonpoint source will be discussed in the problem definition and source identification section.

Point source pollution, on the other hand, originates from a definite source such as a pipe, is readily identifiable, and can be traced to a particular individual residence, business, or activity. Point source pollution can therefore be treated or controlled directly at the source and structural solutions are typically used to control pollutants. There are several businesses in the Issaquah basin that are known point source dischargers. Lakeside Sand and Gravel, Consolidated Dairy Products, Washington State Department of Fisheries, and Sunset Quarry all have National Pollutant Discharge Elimination System (NPDES) permits on file with the DOE (Devitt, oral communication, 1990).

The remainder of this chapter includes a water quality assessment based on existing data. This assessment includes a discussion of beneficial use impairment and threat and future water quality conditions, and has been prepared in accordance with Chapter 400-12 WAC (Washington Administration Code).

9.2.0 BENEFICIAL USES

9.2.1 Introduction

One of the main objectives of the basin plan and nonpoint action plan is to protect resources or "beneficial uses" of the Issaquah basin. The two criteria primarily used to identify water quality problems are beneficial use impairment and exceedence of water quality standards. The former

is the topic of the present section, the latter will be discussed in the water quality assessment section.

In order to assess and solve water quality problems, the various beneficial uses must first be defined. The Water Resources Act of 1971 (Water Quality Laws and Regulations, Chapter 90.54 RCW), originally defined the "fundamentals for utilization and management of waters of the state," to include domestic water supply; agricultural water supply; stock watering; industrial water supply; commercial water supply; mineral extraction; commerce and navigation; hydroelectric power production; thermal power production; salmonid migration, rearing, spawning, and harvesting; recreation; wildlife maintenance and enhancement; aesthetic values; and all other uses compatible with the enjoyment of the public waters of the state.

For the Issaquah and Tibbetts Creek basins, beneficial uses fall into five main categories: water supply, fisheries and wildlife, recreation, wetlands, and aesthetics.

Fisheries and wildlife beneficial uses in the basin are described in detail in the previous chapter of this report and will not be discussed here. A discussion of the beneficial uses of wetlands and their role in water quality can be found in Chapter 10. The remaining beneficial uses found in the basin are discussed as below.

9.2.2 Water Supply

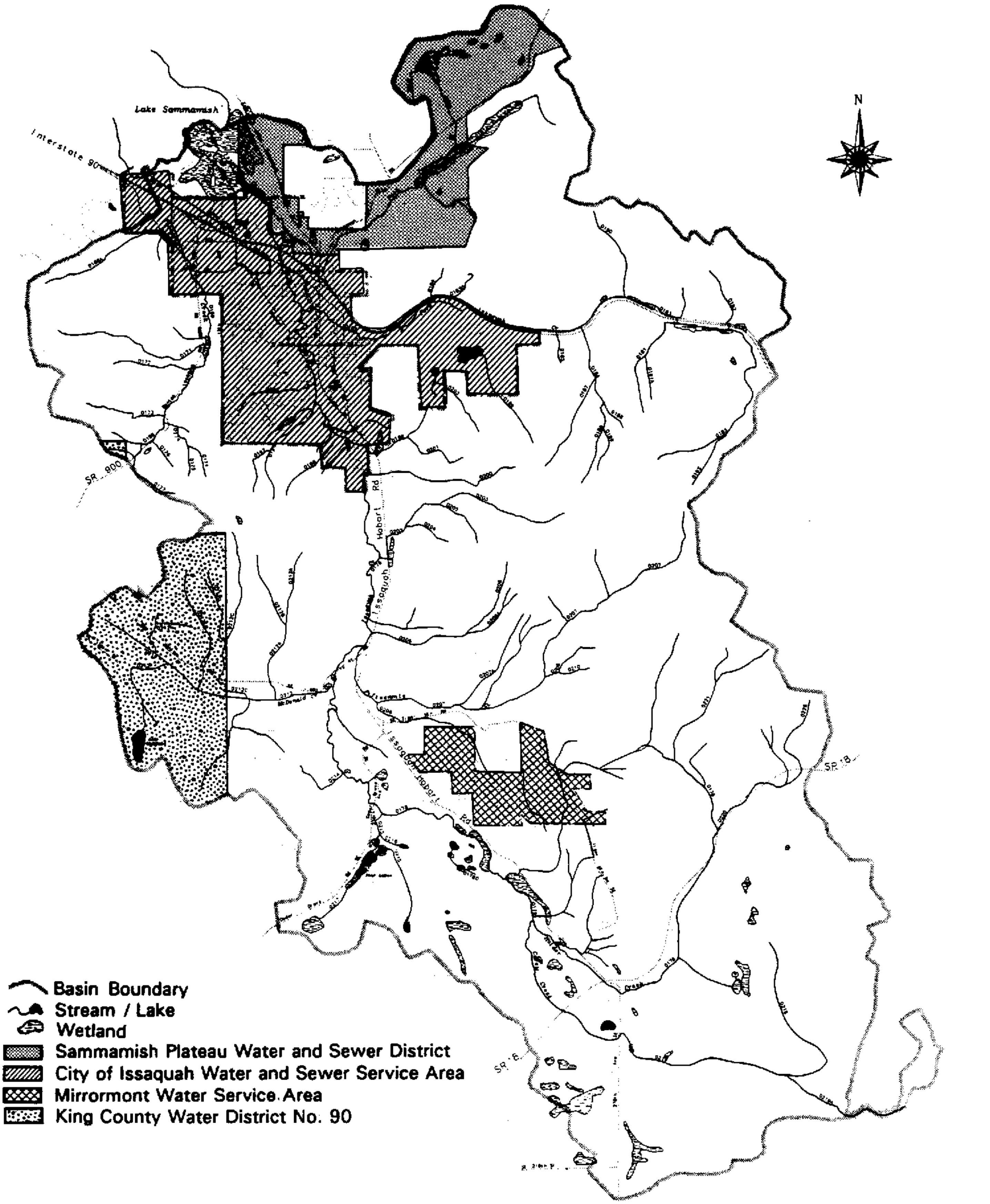
Two water districts (Sammamish Plateau Sewer and Water District, King County Water District 90) and the City of Issaquah serve parts of the Issaquah basin (Figure 9-1). Other small supply groups such as Mirrormont Service serve consolidated residential areas in the southern end of the basin. The remaining water supply for basin residents is obtained through private residential wells. The water source for all of these users originates exclusively from groundwater wells in the basin (see GROUNDWATER, Chapter 4).

9.2.3 Recreation

The streams and lakes in or along the Issaquah and Tibbetts Creek basins provide for many recreational uses. These uses include swimming, wading, water skiing, and skin or scuba diving (primary contact) and hiking, fishing, and boating (secondary contact).

Hiking trails cross or border many of the streams in the basins. Stream fishing is also popular throughout the stream network.

The mouths of both Tibbetts and Issaquah Creek are located in an extensive state park system at the south end of the Lake Sammamish. The lake, which is the receiving water body for both



WATER AND SEWER DISTRICT BOUNDARIES

Issaquah Creek Basin Planning Area

Figure 9-1

basins, is used almost exclusively for recreation. The only commercial boats using the lake are those associated with Indian fishing (Metro, 1983) and pile driving.

Several other small lakes can be found in the Issaquah Creek basin including McDonald, Tradition, Round, and Yellow Lakes. McDonald Lake does not have public access, thereby restricting its primary recreational uses to lakeside residents. Tradition Lake, on the other hand, has public access via hiking trails connected with Tiger Mountain State Forest. The third small lake in the basin, Yellow Lake, is a number-one-rated wetland which has well-developed public recreational access with trails and viewing platform. It continues to provide habitat for many species of wildlife although, as discussed in Chapter 8, much of the surrounding upland habitat has been lost to development.

9.2.4 Aesthetics

The Issaquah and Tibbetts Creek basins have more than 40 wetlands (38 inventoried), several small lakes, and a major state park located on the shores of Lake Sammamish. The wetlands provide particular enjoyment for nature watching as these aquatic systems supply a wide range of habitat for a variety of mammals, birds, insects, amphibians and other wildlife. The visual amenities and options for public utilization of the lakes in the basin are confirmed by the high number of residences surrounding each and the number of people who enjoy the surface waters throughout the year.

9.3.0 PROBLEM DEFINITION AND SOURCE IDENTIFICATION

9.3.1 Agricultural Nonpoint Sources

Agricultural activities associated with nonpoint pollution in the Puget Sound region can be divided into two main groups: animal keeping and crop production. These range from large, commercial ventures to small-acreage hobby farms. Commercial agriculture is defined by the State Department of Agriculture as those farms selling, or are capable of selling, $1000 (or more) of agricultural products per year (Puget Sound Water Quality Authority [PSWQA], 1986). Agricultural activities in the Issaquah basin vary from commercial equestrian farms, livestock or dairy farms, to the smaller non-commercial hobby farms. The last of these, hobby farms, include horse boarding and training, small beef herds, small orchards, llama farms, goat farms, poultry farms, and back yard gardens. Depending on land use practices, both types of agricultural activities can be a significant source of nonpoint pollution.

Sediment, nutrients, pathogens, organic material, and pesticides are the typical pollutants associated with farming activities in Western Washington. Improper pasture management (too many animals and overgrazing), lack of sacrifice areas (confinement), unlimited animal access to streams, and excessive numbers of waterfowl on ponds, are particular sources of nonpoint

pollutants originating from (but not limited to) farms. Other agricultural practices or sources from which nonpoint pollutants originate are improperly managed row cropping, inadequate waste storage facilities, improper soil tillage, and improper timing and application of animal manure, fertilizers, and pesticides.

Nonpoint pollution from farm fields becomes a problem when sacrifice areas and overgrazed pastures receive large amounts of precipitation during a relatively short period of time during the winter months. During these wet periods, the ground is saturated and infiltration rates are low. Improper spreading and timing of animal manure applications, excess runoff generated from over grazed pastures, trampling of streamside vegetation, and direct access to streams by animals are poor practices that can result in water quality degradation.

In a recent King County Conservation District survey of the agricultural activity in the Lake Sammamish basin (which included East Lake Sammamish, East Fork Issaquah Creek, Issaquah Creek, and Tibbetts Creek [survey did not include North Fork Issaquah]) nearly 100 percent of the farming practices were characterized as consisting of small commercial operators and the "hobby farmer". Furthermore, the land adequately protected was estimated as 10-20 percent for these basins (Minton and Fitch, 1988). In this survey, animal numbers were estimated for the four drainage basins (East Lake Sammamish, East Fork Issaquah Creek, Issaquah Creek, and Tibbetts Creek). However, animal number estimates were not broken down by drainage basin in this survey. Estimates for Issaquah and Tibbetts Creek drainage basins were combined with field surveys conducted by SWM division staff and are approximated as follows: 750 horses, 500 cattle, 300-400 goats, and 25-50 llamas.

The DOE, in its statewide assessment of nonpoint pollution, stated, "the primary water quality threat created by hobby farms was due to poor animal-keeping practices." (DOE, 1988b) The agricultural trend has been towards smaller land ownership which in turn can result in higher animal densities. Streams provide a convenient and inexpensive source of water for livestock and other farm animals. Unrestricted animal access to streams is often provided by the farmer who is usually unaware of the impact that this land use practice has on downstream water quality.

Specific sites in the basin where nonpoint pollutants are associated with agricultural activities are listed in the conditions summary (Appendix A). Listed below are two of the most significant problem sites. Both were visited between April 16 and May 15, 1990.

> Kelly's Stables, located on Tibbetts Creek (RM 3.0) has been cited as a major contributor of nonpoint pollutants (King County, 1987; Minton and Fitch, 1988). Site visits confirmed that the pastures continue to be overutilized with as many as forty horses divided among two 1-2 acre pastures. Animal access to the stream is restricted but water quality continues to be degraded by high inputs of nutrients, sediment, and bacterial concentrations.

Animal access occurs to Issaquah Creek on several farms located between SE 156th Street and the south end of Tiger Mountain Road along Issaquah-Hobart Road. The streamside vegetation has been cleared or destroyed by animal access on several of these farms.

9.3.2 Development, Urbanization, and Stormwater Runoff

Development and associated construction activities are two of the major contributors of nonpoint pollution in the Puget Sound area. Natural erosion rates from forested or well-sodded prairies vary from 0.01 to 1.0 tons per acre per year while construction sites lacking effective erosion and sedimentation control measures erode soil at the rate of 50-500 tons per acre per year (DOE, 1988b). Chapter 7 details the erosion and sediment deposition process for the Issaquah and Tibbetts Creek basins.

Stormwater runoff represents both a quantity and quality problem in urban areas where land use has been converted from primarily forested and open-space land use to impervious surfaces in residential, commercial and industrial areas. High stream flows associated with urbanization and large impervious surfaces result in stream bed scouring, erosion, and degradation of spawning and rearing habitat for fish.

Typical pollutants found in surface water runoff in urbanized watersheds include solids, nutrients, pathogens, heavy metals, petroleum products, organics, and toxic contaminants. During the development phase of a watershed, construction activity typically results in increased sedimentation and nutrient release from bare soil. In heavily urbanized areas, pets usually replace farm animals as a source of fecal pathogens.

One interstate (I-90), two state roads (SR 900 and SR 18), and one major county road (Issaquah-Hobart Road) are located in the basin. In many places where streams and roads cross, untreated road runoff is discharged directly to the streams. Petroleum products and by-products, heavy metals, and soot are the common pollutants contained in this runoff.

Currently, the State Department of Ecology, under the direction of the 1989 Puget Sound Water Quality Management Plan, is developing stormwater management guidelines to be implemented by local jurisdictions and the State Department of Transportation. Highway runoff will be the primary focus of the program. These guidelines will be particularly relevant to the management of stormwater runoff from I-90, SR 18, and SR 900.

Urban watersheds are also characterized by many types of impervious surfaces, including rooftops, driveways, buildings, sidewalks, parking lots, and highways. Sediment and a variety of accumulated chemicals tend to build up on these surfaces. These elements are washed off into storm drains and/or directly into streams during heavy rainfall. Surface runoff, then, becomes the principal method by which pollutants are transported to lakes and streams.

Urban nonpoint pollutants enter the waste stream typically from runoff; however, atmospheric deposition of dust, volatilized hydrocarbons, and a variety of other airborne pollutants also contribute to degraded water quality. Galvin and Moore (1982) characterized the sources of toxicants from urban runoff to include both street dust and atmospheric suspended particles. In their study, the average concentration (in undiluted stormwater) for five metals (cadmium, copper, lead, nickel, and zinc) exceeded both chronic and acute federal water quality criteria. This is typical of many urbanized basins in the Puget Sound area.

The conversion of forest land to residential developments and the conversion of non-forested lowland into commercial land use appear to be the most common land use changes presently occurring in the basin. A survey of the basin showed many new developments (1-10 years old), including Sunset Valley Farms, Cascade Condominiums, Hunter's Ridge, and many more sites currently under construction. Sediment and nutrients are typical pollutants associated with forested land use. As urbanization occurs, the pollutant types become more complex and variable as described above.

The conditions summary (Appendix A) lists basin sites that are potential sources of nonpoint pollutants associated with development, urbanization, and storm water runoff. A subset of these sites is listed below to highlight specific problem areas.

> At the end of Black Nugget Road, construction on a small 40 acre site development has been initiated. Sites have been graded, roads have been paved and the drainage network installed. A tributary to the North Fork Issaquah Creek runs through the development site and has been disturbed. Siltation fences around the tributary have not been maintained and are currently failing resulting in sediment entering the stream (Field visit April 23, 1990).
>
> Untreated roadway runoff continues to be discharged into the North Fork Issaquah Creek at RM 0.2 and 1.2. Pollutants associated with this runoff include oil, fuel, sediment, and heavy metals. Discharges from storm drains along Front Street and Gilman Boulevard into the North Fork Issaquah Creek also occur at RM 0.2. The site of annual juvenile fish kills is downstream of this location.

9.3.3 Onsite Septic Systems

A typical onsite sewage disposal system consists of a septic tank and drainfield. The system provides initial treatment of liquid-borne wastes and settling of solids before purification occurs in native soils. The average life expectancy of an onsite sewage disposal system is from 20-40 years if adequately maintained.

The identification of onsite sewage disposal systems as a nonpoint source of pollution to groundwater and surface waters can generally be attributed to failing systems. By traditional

definition, a system failure occurs when the volume of effluent exceeds the absorbent capacity of the soils and results in a backup in the building plumbing or the release of partially-treated effluent onto the ground's surface. This definition of failure represents the most obvious sewage system malfunction, however, the potential contamination of groundwater through inadequate treatment of effluent by surrounding soils is not addressed by the above definition.

Pre-failing onsite systems are identified as those displaying one or more of the following characteristics: 1) heavy lush growth over the drainfield area which indicates sewage may be rising near the surface of the ground; 2) wet or swampy areas adjacent to or in the drainfield area; and/or 3) profuse growth of wetland plants over the drainfield area.

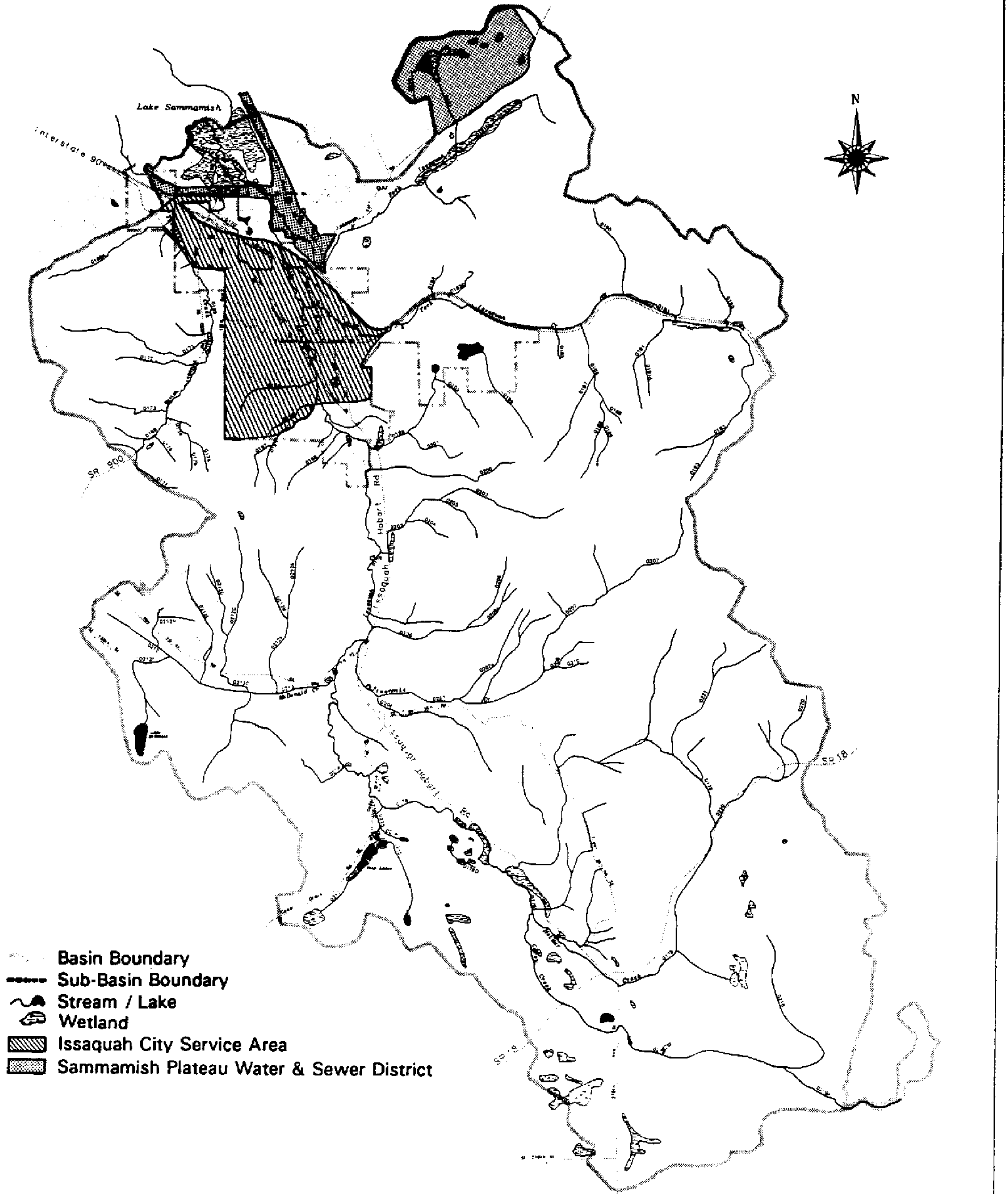
The ability to treat and absorb sewage effluent is dependent on the receiving depth, structure, and texture of the soil. Soils such as clays, or clay loams (i.e., Kitsap series) are efficient in filtering and attenuating contaminates but are limited in their ability to absorb effluent. Coarse soils (i.e., Everett series) have a substantial capacity to accept effluent, but the high permeability of the soil is ineffective in removing contaminates. Septic systems installed on these highly infiltrative soils (rocky or sandy) or on steep slopes may fail due to the inadequate ability of the soil to absorb the effluent. System failures are usually due to poor soil conditions, inadequate design, inadequate construction, lack of maintenance, and/or abuse of the system.

The Washington State Department of Health has determined that a minimum of 3 feet of unsaturated soil is needed to assure adequate treatment of effluent and to protect potable groundwater aquifers (WAC 248-96-100). This depth of soil required to effectively treat effluent is most often limited by high seasonal water tables. Most soils in the basin are characterized as moderately drained (Alderwood series) underlain by shallow, slowly permeable glacial till with seasonal water-table depths of 24-40 inches. This minimum depth, in certain instances, may be reduced by the health officer.

Prior to July 1987, the Seattle-King County Department of Public Health allowed conventional gravity-type onsite disposal systems to be placed on sites with 30 inches of suitable soil. A minimum of 18 inches of native permeable soil between the drainfield and any evidence of groundwater or other restrictive layer was required. In July 1987, the minimum separation between drainfield and restrictive layers was increased to 36 inches for gravity systems and 24 inches for pressure distribution systems.

The limitations of soil types and depth on sites within the basin are identified by the Seattle-King County Department of Public Health during the initial design phase of newly proposed projects. The use of a mound system or other alternative type of system may be required at that time to assure both treatment and disposal concerns are met.

The Issaquah and Tibbetts Creek basins are currently served by two sewer and water districts. The North Fork sub-basin is served by Sammamish Plateau Sewer and Water District. The East Fork, Issaquah Creek, and Tibbetts Creek sub-basins are served by the Issaquah Sewer District.



EXISTING SEWER SERVICE

Issaquah Creek Basin Planning Area

Figure 9-2

Figure 9-2 shows the extent of existing public sewers. The remainder of the basin has approximately 1965 households using onsite sewage disposal systems (King County, 1986; Anderberg, 1991).

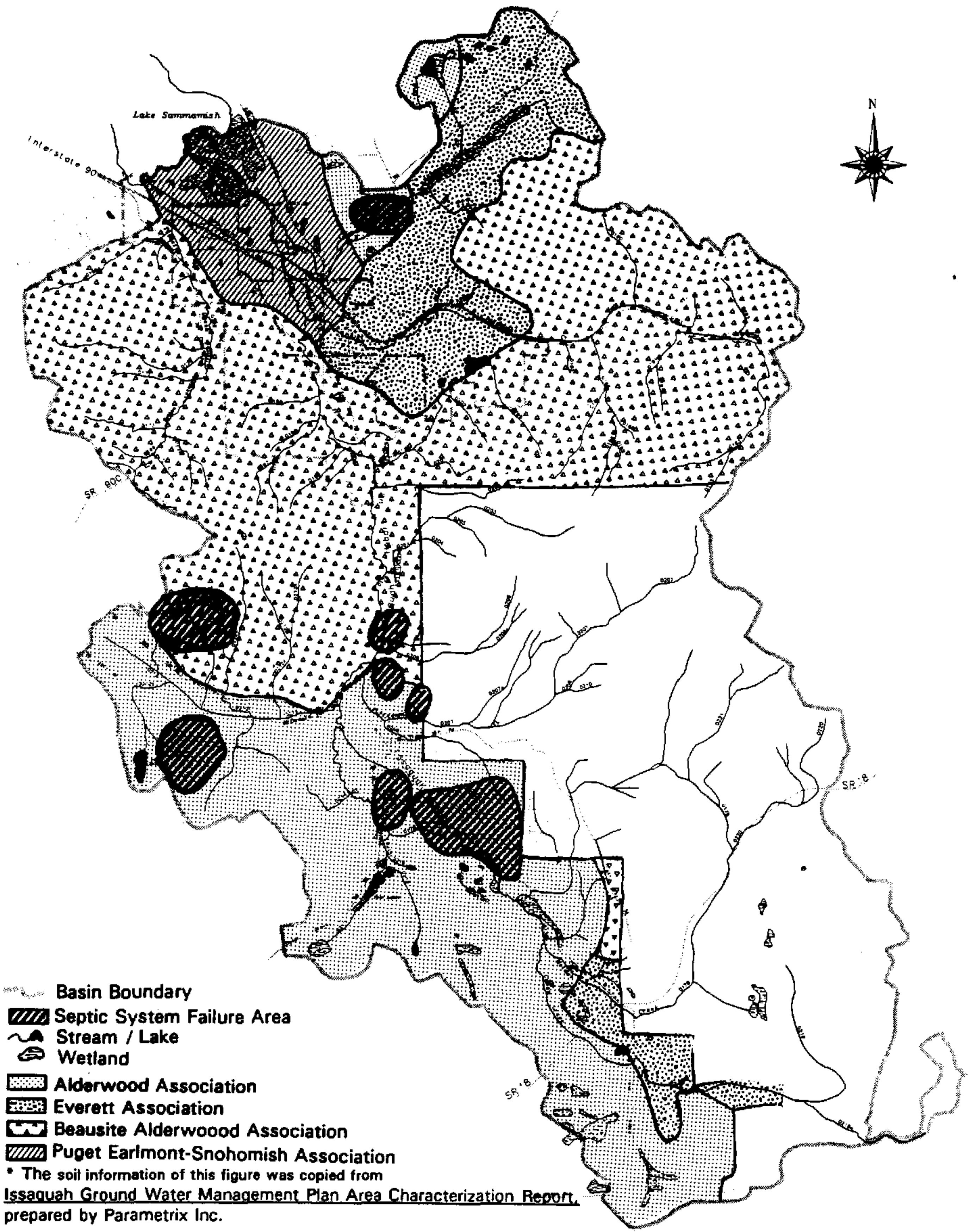
The status of onsite sewage disposal systems was reviewed and analyzed by the Health Department. The review included examination of past surveys, a record review, and a 1990 field survey of 192 septic systems. Based on file reviews of 1432 systems, the Health Department estimated a failure rate for the basin to be 5.5 percent (Anderberg, 1991). This 5.5 percent failure rate identified is slightly higher than the 3-5 percent failure rate for the entire Puget Sound area (PSWQA, 1989a). The field survey revealed a overall 9 percent failure rate and a 5 percent prefailure rate. The combined failure rate for file and field failures is 5.7 percent. However, current failures comprised only 1.6 percent of the field survey results. The limited sample size (192 systems) may account for the difference in failure rates seen for the file and field survey. Or, more importantly, the fact that failures are less likely to be reported than seen in field visits may account for the overall higher failure rate seen in the field survey results.

Perhaps the more accurate picture is given by field results because not all failures are reported or documented. A current failure rate of 1.5 percent is not excessive. Also, failure rates of 5.5 percent and 5.7 percent are consistent with the average failure rates. There is no indication that the septic systems within the Issaquah and Tibbetts Creek basins present a significant threat to groundwater and surface water quality when adequately maintained and repaired when needed.

There are, however, several significant points which should be considered when evaluating these results. Onsite sewage disposal systems installed prior to 1970 were generally designed for disposal, not treatment of wastewater. These systems make up approximately 32 percent of the systems reviewed and may be a source of nonpoint pollution of groundwater if located in excessively permeable soils (Type 1) or within high recharge areas above groundwater. The Issaquah Creek basin has limited areas of excessively permeable soils (Everett) and large areas of shallow soils (Alderwood). Soil association and areas where concentrations of failure are located are shown in Figure 9-3. The shallow Alderwood soils may have an impact on surface water quality. Failure areas were identified by plotting all known current failures, prefailures and past repairs to systems on a map of the basin area (Anderberg, 1991). Lack of septic system maintenance (pumping) may contribute to an increase in the number of failures in the future as only 10 percent of all systems have records of being pumped in the last 20 years.

9.3.4 Pesticides

The use of pesticides in agricultural, roadside maintenance, forestry, and household products presents a potential nonpoint pollution source in the Issaquah and Tibbetts Creek basins. The usage of pesticides in the basin, however, is not well documented. Nevertheless, the potential for groundwater contamination from chemical residuals and surface water contamination from over-sprays is a concern relative to the long-term protection of these resources.



MAP OF SEPTIC SYSTEM FAILURE CONCENTRATION

Issaquah Creek Basin Planning Area

Figure 9-3

The application of pesticides within the basin is governed by WAC 16-288 (DOE, 1989). These laws and regulations apply to labeling, ingredients, distribution, transportation, application, use restrictions, and disposal. The Washington State Department of Agriculture is responsible for the issuance and monitoring of statewide pesticide use permits. All commercial applicators are required to obtain permits and keep records on types, amounts, and locations of pesticides. Records are currently not available from the Department of Agriculture concerning location or amounts of pesticides used within the state.

King County Department of Public Works operates a roadside herbicide spraying program within the basin boundary. Herbicides applied in 1989 included Simazine, Atrazine, and Diuron. These chemicals have been declared "restricted use" pesticides for the protection of ground water in the state and may only be distributed to, and applied by, certified pesticide applicators.

In 1990, herbicide applied in the area included approximately 450 pounds of Diuron and Atrazine, and less than five gallons each of Glyphosate and Dicamba (Anderberg, 1991). These herbicides were sprayed over approximately 240 miles of roadside within the study area. The amount of applied herbicide residual has been steadily decreased in the last several years as a result of better application methods (dilution and decreased application volumes, SKCDPH, 1989).

The Health Department has an ongoing soils and water monitoring program to determine the residual levels of pesticide within the areas sprayed and to monitor their degradation over time. The conclusions of the 1989 report states "the spray operation appeared to be well-managed." No herbicide residuals were identified in any surface water samples obtained. Low concentrations of herbicides, as expected, were detected at soil test depth of 4 inches. There is an increased concern at both the state (Department of Agriculture) and federal (EPA) levels about the continued use of Atrazine, Simazine, and Diuron, and further restricted use may be forthcoming.

The Washington State Department of Agriculture reports that although accurate use figures are not available, the majority of pesticide and herbicide use within the Issaquah basin is through household applications. When properly applied, this type of application should not pose a threat to water quality (Wick, 1990). The apparent limited application through agricultural and roadside spraying does not appear to pose a significant threat to water quality at this time (Anderberg, 1991).

Washington State Department of Transportation (WSDOT) is responsible for chemicals applied to those sections of I-90, SR 900, and SR 18 that are within the basin. The use of herbicides and pesticides along those state highways for pest control purposes can result in runoff of contaminants. Highway runoff from I-90 and other heavily traveled roads, flows into storm water channels which may reach surface waters. In 1990 DOT applied a variety of chemicals including Fosamine Ammonium, Glysphosate, Dicambia, Triclopyr, Diuron, and Diquat over

12 miles of highway within the Issaquah and Tibbetts Creek basin areas. No follow up testing has been done to determine residuals from any of the DOT projects.

9.3.5 Forestry

Forest Practices are defined as activities "conducted on or directly pertaining to forest land and relating to growing, harvesting, or producing timber" (RCW 76.09.010 [19]). These activities can trigger nonpoint pollution by affecting surface water movement, runoff/absorption, surface water quality and quantity, erosion, and groundwater recharge characteristics. Water quality is most directly affected by changes in water temperature, suspended sediment, and dissolved nutrients (which are considered the most significant pollutant) in forest streams (Geppert, 1984).

Road construction, maintenance, and accompanying vehicular traffic are commonly the dominant sources of accelerated erosion and sediment caused by forest practices (Swanson, 1988). The activities alter the timing and volume of runoff and expose large areas of soil to varying degrees of erosion as a function of rainfall, soil type, and topography (Geppert, 1984).

Timber harvest results in increasing annual water yield by as much as 36 percent in a completely clearcut watershed. Increased water yields may not be easily measured when small portions of a watershed are harvested (Geppert, 1984). Where increased flows are created, low summer stream flows will increase immediately following harvest and then decrease slowly over time. Continued harvesting of small watersheds within a large basin will result in a persistent increase in the flow peaks of the mainstem during average autumn and winter storms (Geppert, 1984). Forest practices can change stream channel morphology by disrupting the balance of sediment input and removal when storm events deliver elevated quantities of sediment and water (Sullivan, 1988). All of these trends can be magnified if the conversion of forested land through development (which involves clearcutting or removal of understory and stumps) occurs.

The 61 square miles of the Issaquah and Tibbetts Creek basins are forested primarily with native tree species. The dominant species are Douglas fir (Pseudotsuga menziesii), western hemlock (Tsuga heterophylla), red alder (Alnus rubra), western red cedar (Thuja plicata), and big leaf maple (Acer macrophyllum). At the present time, 22.5 square miles (35 percent of the basin) are used for commercial forestry. Washington State Department of Natural Resources (DNR) manages Tiger Mountain State Forest, a 15-square mile tract within the watershed. Weyerhaeuser operates a tree farm on 2 square miles within the watershed. Both of these areas are south of the East Fork and east of mainstem Issaquah Creek.

The Weyerhaeuser property within Holder Creek (all located within Section 20, 28 and 29 of Range 7, Township 23) is nominally on a rotation length of 50 years. However, three quarters

of the 1,200 acres were harvested in the 1982-86 period and will be unavailable for any commercial harvest until after the year 2020 (Ryon, 1990).

In 1984, the State of Washington adopted a sustainable harvest base which uses a 60-year rotation which will limit clearcuts (0- to 10-year age class) to 16 percent or less in each of the four forest drainages (WSDNR, 1986). At present, 100 acres are scheduled to be harvested yearly forest-wide, amounting to 975 acres per decade for all mainstem creeks (Table 9-1).

Table 9-1

Projected DNR Harvest for the Issaquah Basin

Sub-basin	Acres/Decade
E. Fork Iss. Cr. Sub-basin	205
Fifteenmile Cr. Sub-basin	165
Holder Cr. Sub-basin	430
Issaquah Cr. Sub-basins	175

An additional 5.5 square miles (3500 acres) are registered under the Forest Land Taxation Act and are considered part of the total commercial forestry base. These holdings consist of land development company ownership of 500 acres in the North Fork and of 1,070 acres in the East Fork as well as almost 2000 acres dispersed throughout the watershed in individually owned tracts as small as 20 acres.

One hundred forty acres of the mainstem drainages were registered under Open Space Taxation in 1990. Squak Mountain and a portion of Cougar Mountain State Parks constitute approximately 1.0 and 0.75 square miles, respectively, of non-commercial forest or open space land. The City of Issaquah maintains almost 0.75 square miles of forest, park and protected watershed. Logging presently is not a significant activity on the properties.

One means of estimating the area's long-term commitment to forestry activities is through the numbers of landowners who have sought the tax-relief option available to them for these activities. Both RCW 84.33 - Forest Land Taxation (20-acre minimum) and RCW 84.34 - Open Space Act (5-acre minimum) allow land to be assessed on the basis of its current use, rather than its highest and best use. King County Assessor's Office records were researched to determine

how much of the watershed was classified in this tax deferred category and what trends, if any, were detectable. The Forest Land acreage has remained constant with the exception of the North Fork sub-basin, where 26 percent of the tax deferred land was withdrawn as shown in Table 9-2.

Table 9-2

Change of Forest Land Classification in Acres, 1987-1990
Tibbetts Creek and Issaquah Creek Basins

Sub-basin	1987	1990	% Change
E. Fork Issaquah Creek	1070	1070	0
Issaquah Creek	3140	3140	0
N. Fork Issaquah Creek	672	500	-26
Tibbetts Creek	0	0	0

Source: George Kritsonis, King County Assessor, Forestry Appraiser, Kroll's County Atlas, Declassification Checklists for 1987-1990.

Using the Forest Practice Act (FPA) permit record, the Issaquah basin had four times as many FPA permits as the other sub-basins combined. For the Tibbetts and Issaquah Creeks sub-basins, conversions were only a quarter of all the FPA permits. Most logging did not occur on slopes considered sensitive (over 40 percent steepness). Complete clearcuts were uncommon; most sites were cut between 60 and 80 percent.

The logged volume in the Issaquah Creek basin ranged between 234,000 and 5,440,000 board feet per year. Volume on some of the smaller, private sites, subject to conversion, was as little as 5,000 board feet while commercial forest land produced as much as 38,000 board feet per acre. These private site logging figures indicate a history of frequent harvesting of immature timber and land disturbance occurring on a frequency greater than the minimal standard industry rotation of 40 years.

Incomplete permit application data, especially for the 1987-88 period prevented any statistical evaluation of road building mileage and stream protection as a function of buffer width.

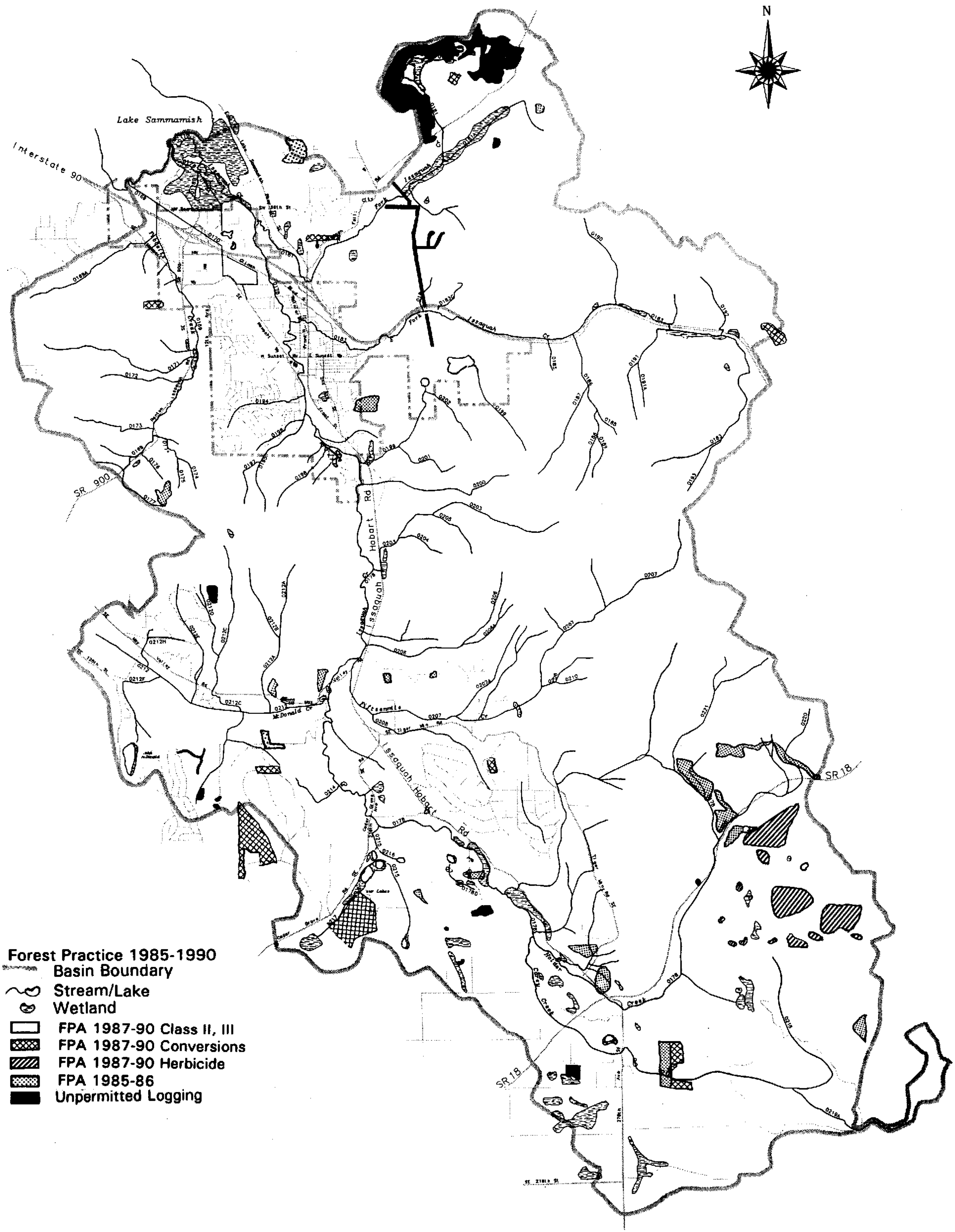
Most FPA applications did not indicate any road building distances in spite of the fact that it is necessary to provide road access to most sites. Four and one-half miles of road building (Issaquah Creek, 1988) was the highest mileage reported for any year. Where stream protection was listed on the FPA application, there was a trend of wider and more consistent stream buffers for harvesting and for herbicide applications in recent years.

A large percentage of the watershed (27 percent) is committed to long-term forest rotations which allow sites to recover from forest practices. These short-term activities generally have less impact than other active land uses, such as mineral extraction, agriculture, and residential development. However, nonpoint water quality problems have been documented for class II and III forest practices, as well as for Class IV conversions. The data analysis and field reviews show that logging into sensitive areas is no more likely to occur for land conversions than for forest practices on land committed to forestry.

The task of prescribing adequate buffer widths to protect the integrity of the aquatic ecosystem is complex. It is clear from the scientific literature that buffer widths must be wide enough and dense enough to preserve the most sensitive structure and function upon which the stream depends. Under existing Sensitive Areas Ordinance regulations, stream buffers range from 25 up to 100 feet in width. However, DNR-prescribed buffer widths may be the only ones applied if no development permit accompanies the logging. Under a variety of conditions those widths may be no more than 25 feet, which is not adequate to perform even the primary function of trapping sediment.

Enforcement functions, permit compliance, and coordination of forest practice review with other local jurisdictions such as the City of Issaquah are not adequately performed by DNR. King County review of Class IV DNR conversions and application of its SEPA and Sensitive Areas ordinances can minimize water quality problems when linked to a series of land uses approvals leading to greater site utilization. Therefore, an increase in enforcement and greater agency coordination are needed to minimize forest practice impacts on water quality.

Logged sites not authorized by a DNR permit are considered to be unpermitted sites and were determined for all sub-basins from 1985 and 1989 aerial photo comparisons. Newly cleared areas were compared to the 1987-90 record FPA permits and the King County Annual Growth Report records of acreages harvested in 1985-86. Figure 9-4 highlights the permitted and unpermitted forest practice areas. Table 9-3 summarizes unpermitted logging in four major sub-basins. The North Fork sub-basin contains the greatest acreage of unpermitted sites. This is explained by the presence of the Klahanie development (275 acres) and of a portion of a gas pipeline right-of-way clearing (14 acres). The pipeline clearing amounted to 12 acres in the East Fork Issaquah Creek sub-basin.



FOREST PRACTICE PERMITTED & UNPERMITTED AREA

Figure 9-4

Issaquah Creek Basin Planning Area

Table 9-3

Unpermitted Logging in Four Sub-Basins

Sub-basin	Acres	Sites
E. Fork Issaquah Creek	14	2
Issaquah Creek	40	5
N. Fork Issaquah Creek	297	4
Tibbetts Creek	13	2
TOTAL	364	13

The conditions summary (Appendix A) lists sites in the Issaquah and Tibbetts Creeks basins that are potential sources of nonpoint pollutants associated with forestry. For each site, logging within prescribed buffers resulted in sediment transport from the site to the stream. Apparent weaknesses in enforcement and permit compliance functions by DNR extended the period of time during which this condition existed.

9.3.6 Landfills

Landfills are potential sources of nonpoint pollution. Major earth-moving activities are a part of the day-to-day operations of a landfill. Inadequate erosion and sedimentation control can result in excessive quantities of sediments being entrained in storm water. Improper management of landfill leachate can also lead to nonpoint pollution. Leachate that is not collected, treated, and disposed of properly can result in surface water contamination.

Landfill leachate is the wastewater that is generated from the decomposition of the wastes that have been disposed of in the landfill. Any water from external sources, such as precipitation or groundwater intrusion, that comes into contact with the wastes is also considered to be leachate. Leachate from municipal landfill typically exhibits high specific conductivity and high concentrations of iron, manganese, zinc, biological oxygen demand (BOD), chemical oxygen demand (COD), ammonia, coliforms, and several volatile and semi-volatile organics such as methylene chloride, acetone, benzene, toluene, and phenols. The nutrient phosphorus is normally detected in very low concentrations in landfill leachate.

The Cedar Hills Landfill operates on a 920-acre site approximately 4 miles south of the City of Issaquah, 3 miles north of Maple Valley, and 6 miles east of Renton. Cedar Hills is the regional municipal solid waste landfill for King County. It is operated and managed by the King County Department of Public Works Solid Waste Division.

At Cedar Hills, an extensive leachate collection and pretreatment system has been constructed. The leachate collection system consists of a network of perforated collection pipes located in and around active and inactive landfilling areas. The leachate is conveyed to two aerated lagoons where it is treated for organic waste strength and solids reduction prior to being discharged into the Metro sewage collection system. Since solids reduction by the aerated lagoons is minimal, there are currently no solids handling or testing procedures. The treated leachate is routinely monitored to ensure that it is meeting all the requirements of the Metro administered industrial wastewater discharge permit.

Cedar Hills is divided into two separate surface water drainage basins. The northern half of the site is located in the Issaquah Creek basin and the southern half is included in the Cedar River basin. The primary objectives for the surface water control system at Cedar Hills are 1) to collect stormwater runoff from nonwaste and nonactive (closed) waste areas, 2) to prevent leachate from entering the stormwater collection system, 3) to convey runoff to stormwater detention basins for peak flow attenuation and sediment removal, 4) to release flows from detention basins at rates that are less than predevelopment rates, and 5) to minimize onsite erosion as well as erosion and sedimentation in downstream areas.

The Cedar Hills site originally consisted mostly of forest land use. As the landfill has developed, the forested areas have been cleared, and waste disposal areas have been constructed and brought into active operation. There are five waste disposal areas at Cedar Hills that are located in the Issaquah Creek basin. These include the North Main Hill, Central Pit and Refuse Disposal Areas 2, 3, and 4 (Figure 9-5).

As areas of the landfill are completed, an impermeable clay and high density polyethylene (HDPE) cover is constructed which prevents surface water from infiltrating the buried refuse and generating excess quantities of leachate. Recent studies at Cedar Hills have shown that the quantity of surface water generated by rain fall increases because of the cover, while the quantity of ground water decreases.

Surface water that is not impacted by landfill operations is directed to onsite stormwater detention lagoons for sediment and silt removal and control of the peak release rates. There are several lagoons onsite, two of which are in the Issaquah Creek Basin. The lagoons are designed and constructed for peak rate control. Although the lagoons at Cedar Hills have been constructed prior to 1990, their design was based upon the anticipated 1990 design standards. Currently, these facilities are being evaluated to confirm that they are meeting all of the new standards.

* This map is copied from Cedar Hills Regional Landfill Draft Site Development Plan, prepared by CH2MHILL, Dec.1987

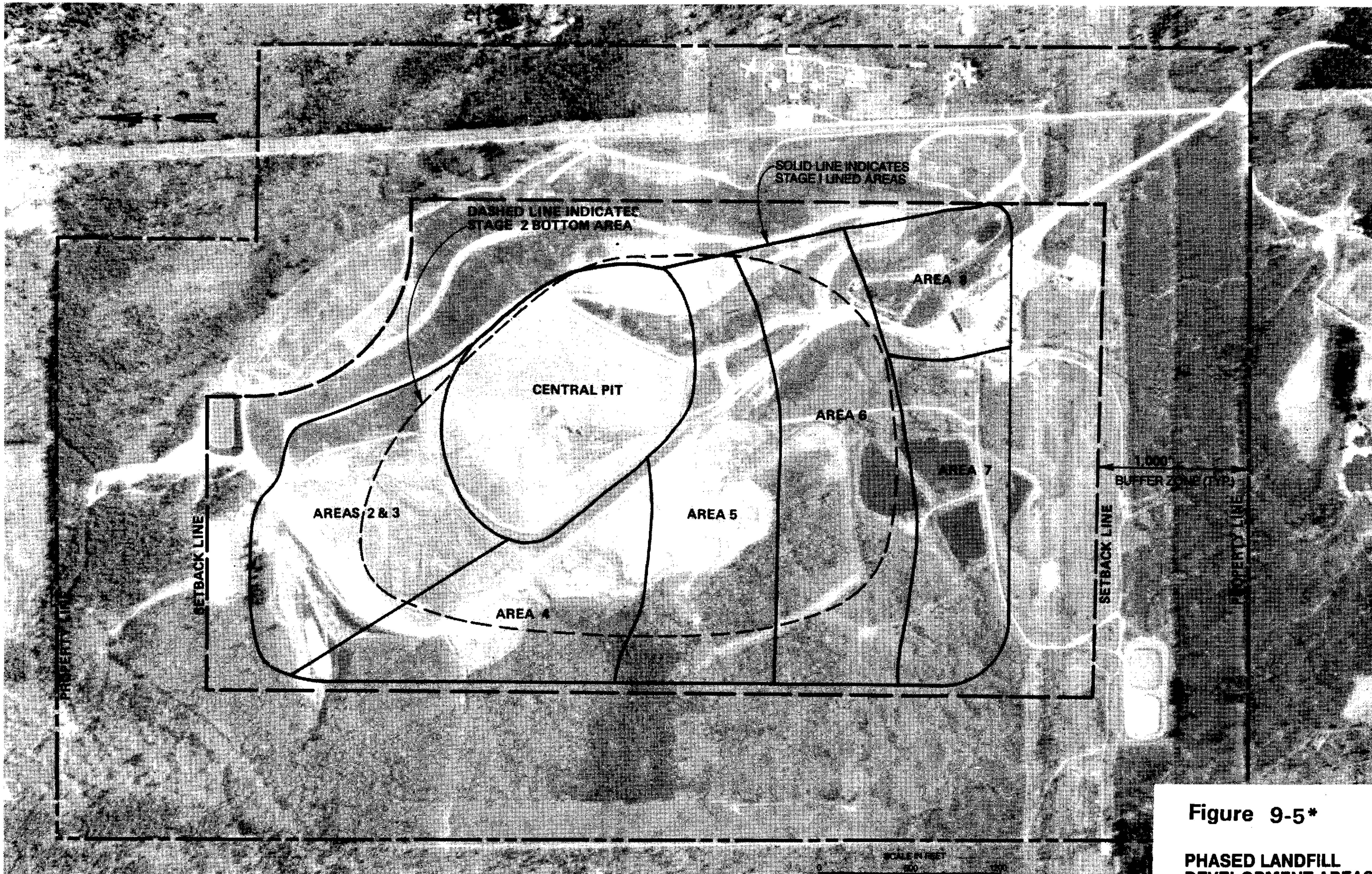
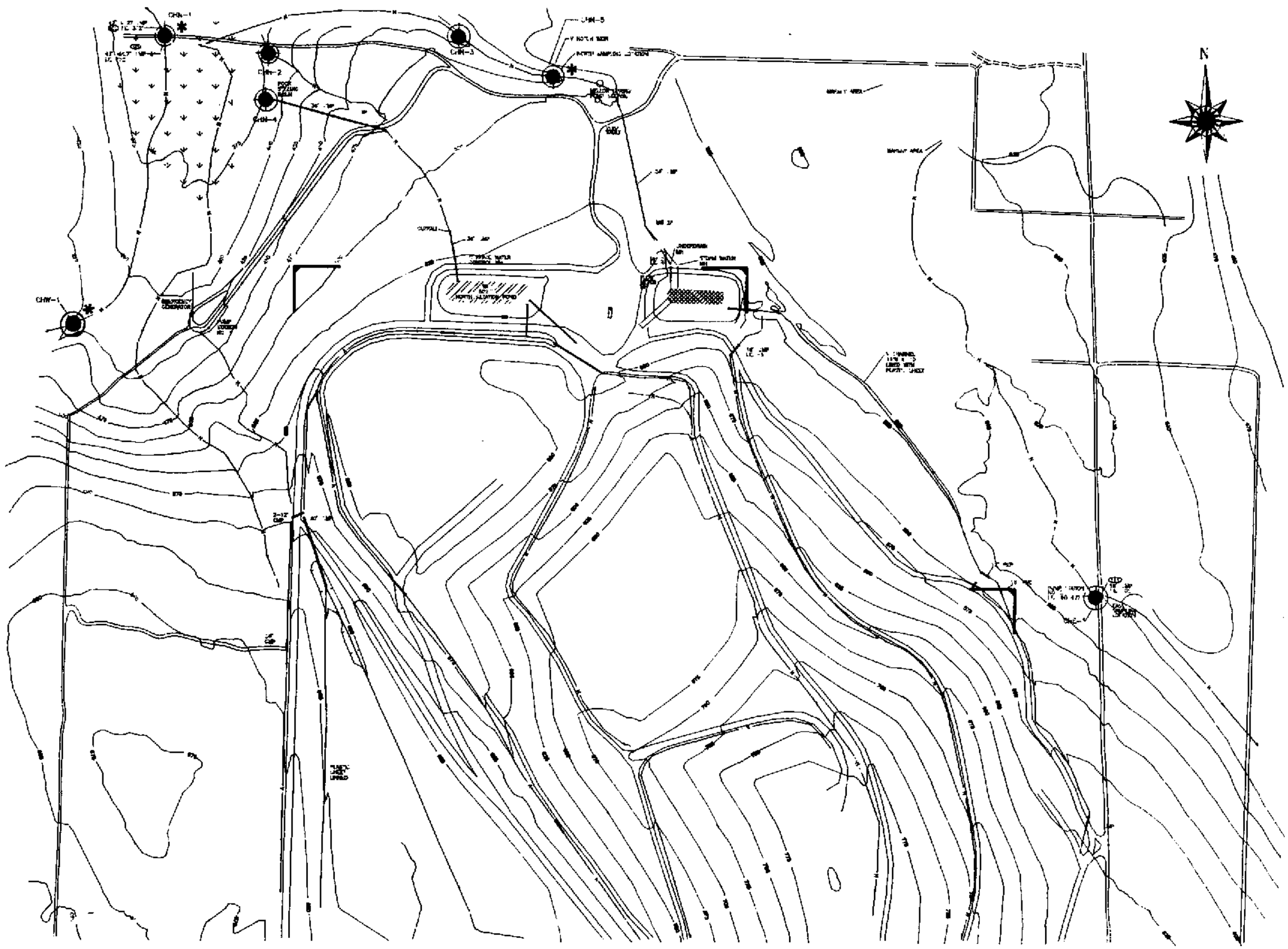


Figure 9-5*

PHASED LANDFILL DEVELOPMENT AREAS

* The soil information of this figure was copied from Issaquah Ground Water Management Plan Area Characterization Report, prepared by Parametrix Inc.



CEDAR HILLS LANDFILL WATER QUALITY MONITORING SITES

Issaquah Creek Basin Planning

◉ Surface Water Monitoring Station

* Site Referenced in Text

Figure 9-6

Water quality has been monitored at sites throughout the landfill drainage area, as well as at specific lagoon outflows (Figure 9-6). For this analysis, however, water quality data were evaluated at locations where water entered natural drainages only (see Water Quality Analysis section in this chapter). Three of the four stations where water quality data were analyzed (CHN-1, CHN-4, and CHN-5, Figure 9-6) receive storm water pond outflow. Water samples collected at these locations would be expected to reflect water quality impacts originating from the detention ponds.

Several key components are currently missing to completely evaluate landfill impacts on water quality. First, the absence of a completed storm water quality sampling program makes full evaluation of nonpoint impacts qualitative at best. Second, without the collection of hardness data during sampling events, potential metal toxicity cannot be evaluated. In 1992, Cedar Hills will have to comply with NPDES stormwater discharge program and obtain a surface water discharge permit for the landfill. In meeting the requirements of the permitting process, current storm water quality will be evaluated and the question of whether or not nonpoint impacts exist can be answered. However, King County Solid Waste Division to date has already made extensive efforts to control, treat, and evaluate point and nonpoint pollution at the Cedar Hills site.

9.3.7 Resource Extraction

Gravel mining is the leading mineral extraction in Washington state and occurs primarily west of the Cascades (DOE, 1988). Sediment is the most common pollutant associated with gravel mining. During the extraction process, large areas of rock and soil are mined and sorted according to size. Fine silts and sands that result from this separation process are then washed into streams or into the drainage system during storm events producing significant amounts of surface water runoff. Downstream, these silts and sands are deposited into the large pores found in gravel beds; these can, in essence, result in the "cementing" of salmon spawning beds and other aquatic habitat.

In the Tibbetts and Issaquah Creek basins there are two active mining operations, Sunset Quarry and Lakeside Sand and Gravel. Sunset Quarry, located on Squak Mountain along tributary 0169, is a major source of silt, sand, and sediment to Tibbetts Creek. This spring (1991), King County Building and Land Development (BALD) issued an enforcement action against the owner of the quarry. This action requires the owner to prepare drainage, erosion, and sediment control plans and to provide enhancement and stream restoration to Tibbetts Creek (as well as to May Creek, south of the quarry).

Lakeside Sand and Gravel Company, located on tributary 0181 at river mile 1.30, also has been an ongoing source of silt, sand, and sediment. In the past, the location of the company's settling ponds near the high-water mark of North Fork Issaquah Creek had allowed large quantities of

silt and sediment to enter the creek during runoff events. The drainage system has been redesigned and most of the site runoff is now infiltrated. Sediment release to the North Fork is currently limited to runoff from roadways and adjacent areas near to the Creek.

Both gravel extraction operations represent sources of sediment to Tibbetts and Issaquah Creek basins. The ongoing problems with runoff discharges from Sunset Quarry to Tibbetts Creek (and May Creek) have resulted in substantial water quality and habitat degradation. The enforcement action by BALD is the most recent attempt to resolve an ongoing problem. The impacts to Issaquah Creek from Lakeside Sand and Gravel runoff discharges have been reduced and are much more difficult to detect because of other upstream activities that also result in sediment release.

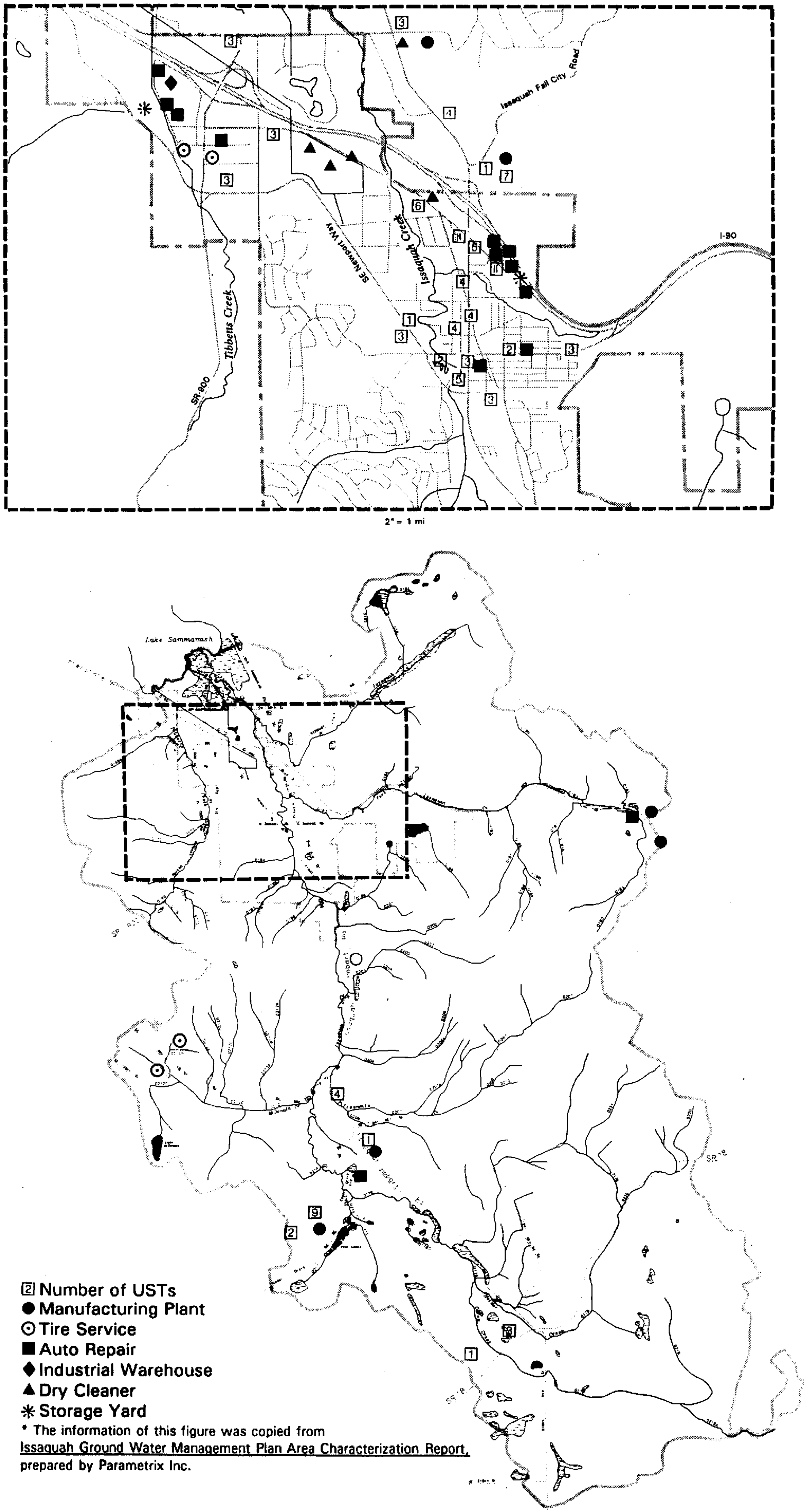
9.3.8 Small Quantity Hazardous Waste Generators

Small quantity hazardous waste generators (SQHWG) were investigated by the Health Department as a potential source of nonpoint pollution in the basin. The increased use of chemicals in the home and in small businesses has resulted in growing amounts of leftover wastes. Auto service and repair shops, print shops, dry cleaners, beauty salons, medical facilities, and school shops, are some of the businesses that are potential SQHWG in the basin. Since this emerging problem may have a serious impact on ground water and surface water supplies, it must be considered as a potential threat within the basin (Anderberg, 1991).

Currently, there is no accurate estimate of the amount of hazardous waste disposal in the Issaquah and Tibbetts Creek basins. Some of the existing SQHWG, primarily concentrated in the downtown Issaquah area, are shown in Figure 9-7. These concentrated locations of SQHWG in the basin may pose a significant threat to water quality. The Health Department, in conjunction with Metro, is developing a list of small hazardous waste generators in the county. Within King County, though, it is assumed that there are 20,000 businesses which may be small quantity generators. An unknown but probably small percentage of these generators are located in the Issaquah Basin planning area. The disposal of household hazardous wastes poses a current threat to water quality and will increase with population growth in the basin (Anderberg, 1991).

9.3.9 Underground Storage Tanks

Underground storage tanks (USTs) were investigated by the Health Department as a potential source of nonpoint pollution in the basin. USTs are used for the storage of petroleum and other regulated substances and pose a threat to public health through potential pollution of groundwater aquifers. Since the majority of the population in the Issaquah basin is dependent on groundwater as a drinking water source, serious consideration should be given to the condition of USTs in the basin. The EPA has estimated that as many as 25 percent of all USTs may be leaking



POTENTIAL POINT CONTAMINANT* & UNDERGROUND STORAGE TANK(UST) LOCATION

Issaquah Creek Basin Planning Area

Figure 9-7

nationwide (USEPA, 1988). Tank leakage may be caused by deterioration of the tank, improper installation, pipe failures, and/or spills and overfills.

The DOE has identified and registered 123 USTs in the basin (Figure 9-7). This list is not all-inclusive, but does include the majority of underground tanks in the area. Exempt from DOE registration are the thousands of underground heating oil storage tanks not covered by DOE USTs regulations. There is some discrepancy between the number of the USTs shown on the map and the number positively identified, due to the recent removal of USTs to comply with DOE's upgrading of construction and monitoring standards. Many of the USTs are in the 6-to-20 year age bracket, with 43 percent of those 11 to 20 years old. Eleven percent of the tanks are more than 30 years old. Based on size classification, 25 percent of the tanks fall within the range of 10,000 to 20,000 gallons. Additionally, leaded, unleaded, and diesel fuel account for 77 percent of the compounds stored in USTs in the Issaquah basin.

Single-walled, bare steel tanks without corrosion protection, particularly those that have been in the ground over 15 years, are the most vulnerable to leakage. A recent Department of Ecology survey of USTs in the Issaquah area indicates that of the 75 USTs older than 15 years and of known tank material, 57 (76 percent) are steel tanks. Twenty-two (39 %) of those steel tanks are further documented as single-wall tanks. USTs without special leak containment or leak detection systems represent a potential for surface water and groundwater contamination. The Department of Ecology has found that 37 percent of the listed USTs in the Issaquah basin do not have leak detection systems. Deterioration of the tank, improper installation, pipe failures, spills or overfills may all contribute to tank leakage.

The DOE is currently implementing a program of identification and registration of unregistered USTs and enforcement of construction upgrades and monitoring system on all systems on tanks covered under Resource Conservation and Recovery Act Subtitle I. This program is mandated to be completed by December 1993.

Although it is clear that USTs may represent a severe threat to groundwater in the region, it is less clear that they represent a significant threat to surface water quality. The extent of the problem depends on the types of contaminants that are leaked, the migration patterns of the groundwater, and the sensitivity of the resources. USTs found in close proximity to surface water features could pose a significant threat to water quality. Within the Issaquah basin, the USTs are concentrated in the business center of Issaquah. Tibbetts Creek, and the North and East Forks of Issaquah Creek flow through the City of Issaquah and are therefore the surface waters most susceptible to contamination.

In April 1991, DOE notified SPWSD that a shallow aquifer near I-90 and Front Street was being contaminated by a leaking UST at the ARCO service station. The extent of contamination is still being determined through test-well sampling. Since then, SPWSD has stopped pumping wells that could potentially be affected by the aquifer contamination.

Contaminated soils were originally detected in April 1990 but little concern was raised at that time. In November 1990, the tanks were replaced and 1500 yards of contaminated soil removed. During routine testing in February 1991, detectable levels of hydrocarbons were found.

This particular contamination of groundwater by a leaking UST in downtown Issaquah points to how easily such contamination may occur and go undetected or unannounced for extended periods. Groundwater quality contamination has occurred and will remain a threat given the number of older tanks in the basin.

9.3.10 Boating and Marinas

Recreational boating and associated facilities, (i.e., marinas and launching/access sites) can contribute pollutants to lake systems. The most common concern associated with boating activities is the discharge of untreated or partially treated human waste (PSWQA, 1989b). Other nonpoint contaminants from marinas and recreational boating activities include: oils and greases, including petroleum hydrocarbons; detergents; solvents; paints; antifouling agents (i.e., tributyltin [TBT], which is highly toxic to aquatic life); and litter (particularly plastics and styrofoam).

There are presently no marinas in the Issaquah basin. Lake Sammamish State Park, near the south end of the basin, is the only boating facility in the vicinity listed in the publication "Public Boating Facilities in Washington State" (1988). The Lake Sammamish State Park has nine boat launching lanes and parking space available for 250 vehicles. Boat launch attendance for 1989 was 606,777 people and 173,363 vehicles. Between the months of April through September, 85 percent of the park's boat launch activities occur. During peak use in the month of July, boat launch parking capacity is exceeded by a factor of four (Benson, 1990). Small pleasure craft owners are the dominant users of the launching facility (Bjorkland, 1990). Public restrooms are available at the site, but there is no pumpout facility available to boaters with holding tanks.

Currently, nonpoint pollution originating from boating activities is probably minimal as compared to other land use practices and activities in the basins. However, marina and boating related nonpoint pollution may pose a future problem in the basins as usage of the area lakes for recreation increases. A 100-unit condominium project that includes a marina and restaurant has been proposed near the state park in the Tibbetts Creek basin. If completed, boating and marina nonpoint pollutants will increase in Lake Sammamish.

9.4.0 WATER QUALITY ASSESSMENT

9.4.1 Introduction

In addition to identifying the potential range of nonpoint problems in the basins, significant water quality problems were also identified in the Issaquah and Tibbetts basins using historical data, base flow data (non-storm), storm water quality sampling results (1989-1990), and field surveys. Comparison of water quality results were made using Washington State water quality standards for Class AA (Extraordinary) and A (Excellent) waterbodies, EPA water quality criteria, and State Board of Health Drinking Water Regulations. A brief discussion of these standards is presented here.

Base and storm flow water quality data are available for both Issaquah and Tibbetts Creeks and are summarized separately below. Because Lake Sammamish is the receiving water body for both Issaquah and Tibbetts creeks, activities in the basins influence the water quality of Lake Sammamish. A brief summary of Lake Sammamish historical water quality is therefore included. A more detailed analysis of Lake Sammamish water quality, future conditions, and management alternatives is presented in another study conducted by Metro (1989). Bioavailable phosphorus loading estimates from this report for the Issaquah basin are summarized below. Additional water quality data relevant to the basin from the DOE, and King County Solid Waste, are also presented below.

9.4.2 Standards

The water quality standards for the State of Washington are defined in Chapter 173-201 of the Washington Administrative Code (WAC). This chapter establishes the water quality standards for the surface waters of the State that are consistent with public health and enjoyment and the protection and propagation of fish, shellfish, and wildlife.

All waters in the Issaquah Creek and Tibbetts Creek basins are classified as Class AA (Extraordinary) or Class A (Excellent). Waters under AA classification are characterized as "markedly and uniformly exceeding the requirements for all or substantially all uses" (i.e., beneficial uses). Class A waters are characterized as meeting or exceeding the requirements for all or substantially all uses. State water quality criteria (DOE, 1988a) are defined for fecal coliforms, dissolved oxygen, temperature, Ph, and turbidity. Other water quality variables, such as phosphorus and nitrogen, do not have State water quality criteria established.

EPA's water quality criteria (1986) establish acute and chronic concentrations for both freshwater and marine systems for a variety of constituents including most heavy metals, and some pesticides and a few organics. These include cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc, and suggested guidelines for phosphorus.

For two constituents (nitrate+nitrite-nitrogen, and total suspended solids), no State or Federal criteria exist. For the purpose of this report, a basin plan "threshold value" was set to allow comparisons of sampling sites and to identify problem areas. These threshold values were

determined by King County SWM water quality staff following review of other studies (Gammon, 1970) and monitoring results.

9.4.3 Metro

The Municipality of Metropolitan Seattle (Metro), as part of its annual quality of local lakes and streams program, monitors several sites within the watershed on a monthly basis during base flow conditions. Monitoring sites include three sites on Issaquah Creek and one site on Tibbetts Creek. Since 1987, grab samples have been taken during high flow or storm events by Metro including one site located on Issaquah Creek. During the 1989-1990 water year (October 1 through September 30), a storm water quality sampling program was conducted by Metro, at five sites located throughout the basin. Samples were collected during five storm events.

As part of Metro's major and minor lakes surveys, monthly or bimonthly water quality sampling is currently being performed for Lake Sammamish. This monitoring work is part of a long-term monitoring program for lakes that have public access. Lake Sammamish has been the subject of many water quality monitoring programs conducted by Metro and the University of Washington. The most recent study completed (Metro, 1989) has proposed specific management alternatives to reduce phosphorus concentrations in urban runoff and subsequent degradation of lake water quality.

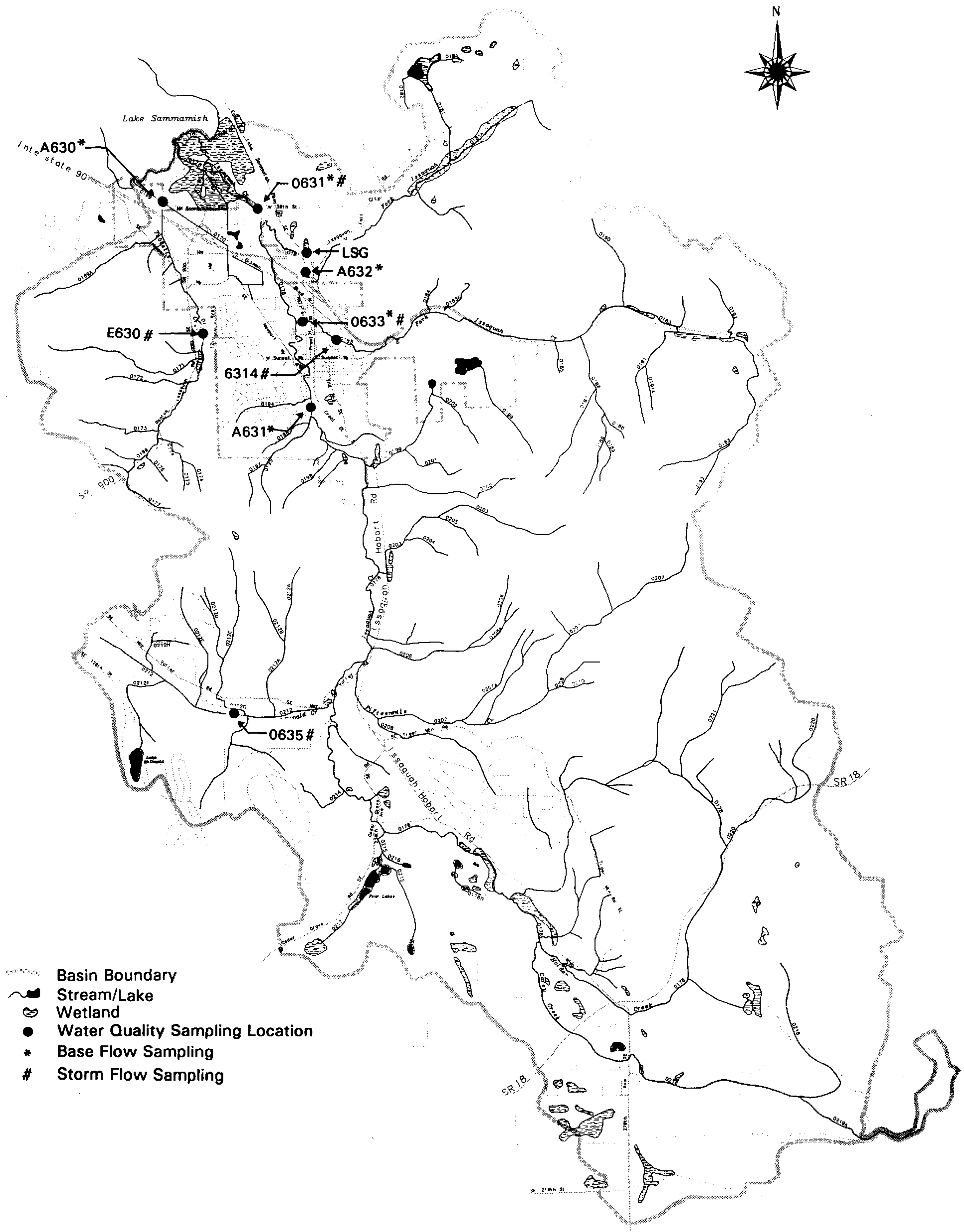
9.4.4 Water Quality Analysis

<u>Metro 1989-1990 Base Flow</u>

As part of their 1989-1990 Freshwater Assessment Program, water quality conditions during base flow was monitored at two sites on the mainstem of Issaquah Creek, one site on the North Fork Issaquah Creek, one site on Tibbetts Creek, and three sites in Lake Sammamish (Metro, unpublished data, 1990). Since 1987, Metro has conducted a limited wet weather sampling program which includes ten river and stream sites throughout the County. Issaquah Creek is one of the streams sampled in this program. Discussion of wet weather monitoring contained in this Metro status report will be included in the supplemental storm monitoring section below.

Water quality variables routinely monitored in Metro's program (streams) include temperature, pH, conductivity, turbidity, total suspended solids, alkalinity, ammonia, dissolved oxygen, nitrate+nitrite-nitrogen, ortho-phosphate, total phosphorus, cadmium, chromium, copper, iron, mercury, nickel, lead, zinc, fecal coliform, and <u>enterococcus</u> bacteria. Chlorophyll <u>a</u> and transparency, as well as some of the above parameters, are routinely monitored in lakes.

Both fecal coliform and <u>enterococcus</u> bacteria were sampled at five sites (Figure 9-8) in the study area during Metro's ongoing base flow monitoring program. Fecal coliforms, while



WATER QUALITY SAMPLING LOCATIONS

Issaquah Creek Basin Planning Area

Figure 9-8

generally not harmful themselves, are an indicator organism used to identify potential animal waste contamination in waterbodies, while enterococcus bacteria are a better indicator of contamination by human waste.

Dry season (April-September), wet season (October-March) and yearly fecal coliform geometric means were calculated for five stream locations. Dry season geometric means exceeded state water quality standards at all sites except the East Fork Issaquah Creek site. Dry season geometric means exceeded state standards by a factor of seven at the Tibbetts Creek site. At the remaining sites, the criterion was only slightly exceeded or exceeded by a factor of two. Yearly geometric means exceeded the standard at three of the five sites while wet season geometric means exceeded the standard at the Tibbetts Creek site. Generally, it appears that fecal coliform standards are exceeded in the basin during base flow conditions. However, during base flow conditions, it does not appear that fecal coliform concentrations result in water quality degradation.

Yearly dry season (April-September) and wet season (October-March) enterococcus geometric means were also calculated for the five stream sites and compared to EPA criteria for enterococcus. The steady state geometric mean criteria require a statistically sufficient number of samples (generally not less than five) equally spaced over a 30-day period. Geometric mean comparisons to the federal criteria were made even though samples were collected on a monthly basis (i.e., it was not possible to meet the suggested criteria assumptions). All geometric means, except the wet season means for Tibbetts Creek and Issaquah Creek above the fish hatchery, exceeded the steady state geometric mean indicator density of 33 organism per 100 Ml. Based on EPA's "Single Sample Maximum Allowable Density for Moderate Full Body Contact Recreation" of 89 organisms per 100 ml, Tibbetts Creek, North Fork Issaquah Creek, Issaquah Creek at SE 56th Street, and Issaquah Creek above the fish hatchery, exceeded the federal criteria five times, twice, twice, and once, respectively. The frequency of enterococcus standard exceedence is typical of slightly urbanized basins but does not necessarily indicate nonpoint pollutants due to sources such as failing septic systems.

The conditions study included the evaluation of base flow total metal concentrations were evaluated. Lead and cadmium would tend to be of concern, given the residential land use in the basin. Copper, chromium, iron, nickel and zinc concentrations were all below their respective toxic criteria (using a hardness value of 100 mg $CaCO3/L$). Cadmium, mercury, and lead concentrations where all less than their respective detection limits of 0.002, 0.0002 and 0.03 mg/L (using the Inductively Coupled Plasma method). Base flow metal concentrations do not appear to represent a current threat to water quality.

Nutrients such as nitrogen and phosphorus do not have specific state or federal standards but are used as indicators of water quality problems. To reduce algal growth and maintain water clarity, total phosphates (TP) as phosphorus (P) should not exceed 50 ug/L in any stream at the point where it enters any lake reservoir (EPA, 1986). Base flow yearly mean total phosphorus concentration exceeded this guideline at Tibbetts Creek only.

A basin plan threshold value of 1,250 ug/L as nitrate+nitrite-nitrogen has been set by KCSWM staff. Annual base flow concentrations exceeded this value at two sites, Tibbetts Creek, and East Fork Issaquah Creek (Figure 9-8).

Metro 1988-1989 Status Report

A) Issaquah Creek: Four indicator parameters (fecal coliform, temperature, dissolved oxygen, and turbidity) were chosen by Metro to evaluate water quality for contact recreation, salmonid rearing, and general instream disturbances or impacts (Metro, 1990). During the 1988-1989 monitoring season, fecal coliform counts exceeded water quality standards four and six times out of 12 samples for sites 0631 (mainstem at SE 56th Street) and A632 (North Fork), respectively.

B) Tibbetts Creek: Exceedance of water quality standards for dissolved oxygen, temperature and fecal coliforms has occurred on Tibbetts Creek. General base flow water quality is characterized by variable turbidity with high levels in the late winter and summer periods, high fecal coliform counts, wide temperature range, and a lower dissolved oxygen content than characterized by Class AA waters. Specifically, during the 1988-1989 monitoring season, fecal coliform counts were exceptionally high during November, May, and June and exceeded water quality criteria seven of 12 times. Dissolved oxygen similarly failed to meet State water quality criteria five of 12 times.

Tibbetts Creek water quality continually fails to meet Class AA standards and has failed to meet such standards throughout the Metro freshwater monitoring program. Metro in their 1988-1989 Status Report (Metro, 1990) characterized Tibbetts Creek water quality as "fair". Under WAC 173-201-070, Tibbetts Creek is classified as Class AA because all feeder streams to lakes are classified as Class AA unless specifically identified in WAC 173-201-080. Issaquah Creek is one such stream which is specifically classified as Class A. However, it usually has better overall water quality and rating (consider "very good" in the Metro, 1990) than Tibbetts Creek. Classification of both Tibbetts and Issaquah Creeks should be reviewed by DOE. If enforcement of standards cannot be performed to meet water quality goals (for Tibbetts Creek especially), then the current classification process should be reevaluated.

C) Lake Sammamish: Lake Sammamish is rated as mesotrophic (medium productivity) based on water quality data collected from three lake sites. The annual mean volume-weighted total phosphorus (TP) concentration was 21 ug/L in 1989. This concentration is approximately 3 ug/L higher than that of its historical mean (1979-1988) but remains substantially lower than presewage diversion (1964-1966) concentration of 33 ug/L. Generally, winter TP concentrations of 20-30 ug/L and summer TP concentrations of 6-10 ug/L characterize eutrophic (high productivity) waters (Welch, 1980).

Annual mean transparencies in Lake Sammamish in 1988-1989 ranged from 3.4 to 4.1 meters which are slightly less than the historical range of 3.6-4.5 meters. Generally a summer secchi

disk transparency of 3 to 5 meters characterizes oligotrophic (low productivity) waters (Welch, 1980). Although TP concentrations alone place Lake Sammamish water quality in the eutrophic category, relatively good water clarity remains giving the lake its current mesotrophic rating.

Lake Sammamish Water Quality Management Project, 1989

Bioavailable phosphorus (BAP) was calculated for the basin for present and future land use using loading estimates from the Lake Sammamish Water Quality Management Project (Metro, 1989). Present BAP from the Issaquah basin was computed as 4,164 kg BAP per year or 67 percent of the total (6,175 kg BAP per year) external lake BAP loadings. Future (build-out conditions) loadings are expected to increase to 7,335 kg BAP per year for the basin or 70 percent of the total (10,431 kg BAP per year) external lake loadings. Based on current and future BAP estimates, a 57 percent future increase in BAP loadings will occur. This increase represents 70 percent of the total increase in BAP loadings to Lake Sammamish.

Algal growth in the lake is phosphorus limited. Increases in phosphorus concentrations can then result in increases in algal growth, which in turn, can lead to decreases in water clarity and dissolved oxygen, surface scums, foul odors, foul tastes in fish, and ultimately, a shift in lake trophic structure. It is probable then, under future build-out conditions with no water quality controls, water quality degradation of Lake Sammamish will occur as a result of increased phosphorus loadings from the Issaquah basin. Localized beneficial use impacts (e.g., increased macrophyte densities and algal blooms) to the lake in the vicinity of the State Park and along the lake shore where the basin's drainages enter are likely to appear first. Impacts to regional beneficial use to the lake will likely be noticed as decreases in water clarity and increases in whole lake algal blooms occur.

Supplemental Storm Monitoring Data 1989-1990

Previous storm data collected by Metro beginning in 1987 for Issaquah Creek (one site) were of limited value for basinwide water quality assessment. Subsequently, storm water quality samples were collected by Metro from five locations in the study area (Figure 9-8) during five storm events during 1989-1990. Average suspended solids, fecal coliform, nitrate+nitrite-nitrogen, and total phosphorus values were measured at the five sampling sites. "Pollution Points" were assigned to average storm concentrations for each parameter and the water quality at each site ranked from high to low. Total points were added for each variable and the sites were than ranked accordingly. McDonald Creek (0635) and Tibbetts Creek (E630) were the highest scoring sites and exhibited the worst water quality of all sites measured. Issaquah Creek (0631) also exhibited poor water quality and ranked third among the five sites. East Fork Issaquah Creek (0633 and 6314) water quality had the lowest storm concentrations for three of the four variables used for storm water quality evaluation suggesting a limited number of pollutant sources in the sub-basin.

Storm-event water quality was also compared with base flow water quality where sampling sites were the same (Figure 9-8). Total suspended solids concentration were 12 and 17 times higher during storm events at stations 0631 and 0633, respectively. Generally, where data were available for comparing storm and base flows, storm pollutant concentrations were higher than base-flow concentrations.

Fecal coliform concentrations during storm events exceeded water quality standards at all five sites. At McDonald Creek, average storm fecal coliform concentration (as a geometric mean) was 1535 organism/100 Ml, which exceeds water quality criteria by a factor of 15. Average nitrate+nitrite-nitrogen concentrations at Tibbetts Creek (E630) and at Issaquah Creek (0631) were 1425 and 1224 ug/L, respectively, and were close to exceeding or exceeded recommend criteria during storm events. Total phosphorus concentrations exceeded recommended criteria (50 mg/L) at all five sites during storm events.

Cadmium, chromium, copper, mercury, nickel, lead, zinc, and iron concentrations were measured during five storm events. Using a representative hardness value of 20 mg $CaCO_3$/L, metal toxicity was evaluated. Most sites did not show any acute or chronic standard violations except during the December 4, 1989 samples. Site 0635 (Figure 9-8), however, showed chronic standards violation during most sampling events for cadmium, chromium, copper, nickel, and zinc. The high concentrations of metals are particularly interesting given the land use of this site. The site is located on McDonald Creek which drains primarily residential land use. Road runoff may be one source of these concentrations. Higher flows at the remaining sites may dilute and subsequently mask metal concentrations at other sites. The timing of sample collection is another factor which may affect the concentrations recorded.

Fish Kill Data 1990

The DOE and City of Issaquah Public Works Department conducted an investigation into the fish kills on the North Fork Issaquah Creek, which occurred during storm events in late March and early April of 1990. Water and tissue samples of fish were collected after the second event. Pollutants including metals, ammonia, sulfides, 1,2 Benzenedicarboxylic Acid, and Diisonyl Ester are believed to have acted in combination with low hardness to result in the death of juvenile salmonids (Devitt, unpublished data, 1990). Source identification focused on the storm drainage system that enters the North Fork Issaquah Creek at RM 0.2. Sediment samples that were collected in that storm drains several weeks after the event failed to identify the source of the above mentioned pollutants.

Issaquah Salmon Hatchery management believe that toxic conditions exist year round downstream of RM 0.2. These conditions, however, are only noticed after fish release (and death) from the hatchery occur. An in situ fish bioassay using juvenile coho was used to evaluate the year round potential toxicity. In the autumn of 1990, two bioassays were conducted. In both cases, fish in cages located downstream of the outfall (RM 0.2) died shortly

after placement in the stream, while fish in upstream cages remained healthy (S. Lynne, oral communication, 1991). A source identification sampling program to pinpoint the toxicity is currently being developed by the DOE and the City of Issaquah Public Works Department.

Lakeside Sand and Gravel, 1990

During supplemental storm water quality sampling in the East Lake Sammamish basin (April 24, 1990), one water quality sample was obtained from a drainage ditch (Figure 9-8, site LSG) in front of the Lakeside Sand and Gravel property along East Lake Sammamish Parkway. Concentrations of 374 ug/L total phosphorus, 278 mg/L total suspended solids, 320 NTU turbidity, 24.8 ug/L copper, 7.4 ug/L lead, and 19 ug/L zinc were recorded. The gravel mining operation has been a historical source of sediment to the North Fork Issaquah Creek. Phosphorus, suspended solid, turbidity, and copper (based on 20 mg $CaCO_3$/L hardness) concentrations exceeded standards or recommended guidelines.

Cedar Hills Landfill, King County Solid Waste, 1990

Surface water quality is monitored predominately during base flow conditions at Cedar Hills. There are approximately 20 monitoring stations surrounding the site, 11 of which are in locations that discharge to the north (towards McDonald Creek). A majority of these stations are sampled as frequently as once per month. Constituents analyzed include pH, conductance, ammonia, nitrite, nitrate, chloride, cyanide, fluoride, sulfate, chemical oxygen demand (COD), solids, turbidity, alkalinity, heavy metals, volatile and semi-volatile organics, pesticides and herbicides.

Water quality monitoring data collected during 1989 for four stations (CHN-1, CHN-4, CHN-5, and CHW-1) located in the Issaquah Creek basin at Cedar Hills were evaluated (Figure 9-6). No specific effort was made by King County Solid Waste Division to collect stormwater runoff samples. Consequently, much of the water quality data consists of base flow sampling. Additionally, water quality for cadmium, mercury, and lead were not evaluated because criteria concentrations were below the laboratory detection limits used. Metal toxicity evaluation was further limited since the water quality criteria are dependent on water hardness data which are currently not collected at Cedar Hills. Chromium, copper, iron, nickel, and zinc concentrations were therefore evaluated using an assumed base flow hardness value of 100 mg/L as CaCO3. The 1989 monitoring data for the four stations evaluated were compared with the chronic water quality criteria for this hardness value. One of the four monitoring stations is located in a drainage channel leading onto the Cedar Hills site and was therefore used as a background comparison (CHW-1). Although concentrations in excess of the water quality criteria were noted for iron and copper, these compounds were also found in the background samples but at

lower concentrations (See Appendix). Cadmium, mercury and lead were usually undetectable at all sites (See Appendix).

The 1989 monitoring data for the four sites evaluated were also compared with Class A State water quality standards for pH, turbidity, and dissolved oxygen. Single samples from CHN-1 and CHN-4, and two samples from CHW-1 (the background station), violated pH standards. The background station also had a single sample that exceeded the upper pH standard.

Monitoring station CHN-5 exhibited dissolved oxygen concentrations below the standards; however, dissolved oxygen concentrations at CHN-1 (downstream of CHN-5), which is the ultimate discharge point for surface waters leaving the Cedar Hills site, were above the recommended standard.

Surface water leaving the Cedar Hills site during base flow usually does not show leachate impacts. However, increased sedimentation, presumably produced by earth-moving operations during landfilling, has been observed. Fine silt and clay particles become suspended in the storm water and are very difficult to remove. Past experience has indicated that siltation and sedimentation facilities are only marginally effective in removing silt and clay site particles. Turbidity readings from the north monitoring stations have been as high 120 NTU between 1987-1989. The state turbidity standard is written such that "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 when the background turbidity is more than 50 NTU."

Examination of Issaquah Creek base flow turbidity values over 11 years for several sites in the basin show turbidity values less than 10 NTU. Based on a basin wide background turbidity reading of 10 NTU, then it seems that Cedar Hills Landfill discharge would violate the state turbidity standard for Class A waters. To address this ongoing turbidity problem, King County Solid Waste Division adopted an erosion and sedimentation control plan that places primary emphasis on source control. Additionally, the Disivion is conducting an extensive surface water quality study to evaluate additional measures for removing suspended particles.

9.4.5 Beneficial Use Impairment and Threat

Areas of natural erosion, together with construction, urbanization, gravel mining, and agricultural practices are the major source of nutrients, sediments, and fecal coliforms in the Issaquah and Tibbetts Creek basins. Construction practices, combined with subsequent urbanization, represent major nonpoint sources in the basins, particularly in the lower portion of each basin.

As forested lands are logged or pasture lands are converted to residential and commercial developments, increasing amounts of sediments, nutrients, heavy metals (primarily from the downtown area), and other toxins are transported to the surrounding streams. Reduction of fish

spawning and rearing habitat along with an overall loss in biological usage occurs (see Chapter 8). Degraded microhabitat (e.g., localized conditions such as depth, velocity, substrate, and cover) and macrohabitat (e.g., those characteristics of the environment that affect the distribution and abundance of species such as water quality, temperature, particle size and discharge) for both anadromous and resident fish and other aquatic species are the cumulative impacts of increased urbanization and nonpoint pollution. The absence of large woody debris and riparian shading, particularly on the lower stream reaches, limits fish usage. Additional components of beneficial use impairment of aquatic habitat are detailed in Chapter 8.

The increase in impervious surfaces associated with urbanization is also associated with degradation of water quality. Pollutants, including sediment (primarily during construction), metals, oil, grease, nutrients and fecal coliforms are concentrated in urban watersheds and are washed into the storm drains and streams during storm events. Accumulation of pollutants in storm drains in the downtown area has resulted in significant beneficial use impairment including fish kills on the North Fork Issaquah Creek.

Based on state standards for Class AA and A waters, water quality associated with these classifications is degraded in the basins. Fecal coliform counts, temperature, and dissolved oxygen concentrations fail to meet standards during portions of the year.

High nutrient levels in Lake Sammamish, McDonald Lake, Yellow Lake, and all tributary waters, are also a threat to water quality and beneficial uses. Increased nutrient concentrations, particularly phosphorus, can result in increased algal growth, increased aquatic macrophyte densities, decreased dissolved oxygen content, and subsequent water quality degradation. Beneficial uses, including swimming, boating, fishing, scuba diving, water skiing, wildlife, and fisheries, can be severely impacted in basin streams, Lake Sammamish, and other basin lakes.

9.4.6 Future Water Quality Conditions

In the Issaquah basin, land use is changing from largely agricultural and forested land to residential, non-commercial farming, and light commercial development. New developments in the downtown area and along the I-90 corridor, such as the I-90 Corporate Center, Sammamish Park Place, and Brown Bear Car Wash, are currently impacting surface water quality and will continue to do so as the sites are graded, paved, and landscaped. This change in land use has resulted in, and will continue to result in, increased stormwater flows and concentration and transport of nonpoint pollutants to the basin's streams, lakes, and groundwater. The increase in quantity as well as quality of the water is of concern now, and will continue to be of concern in the future.

Several studies have characterized pollutants associated with stormwater. Richey (1982) examined the effects of urbanization in Kelsey Creek, Bellevue, Washington, and found the concentrations of nutrients and suspended solids to increase with urbanization. The EPA has

characterized pollutants found in stormwater that are associated with several urban land uses. The concentrations as a function of land use are shown in Table 9-4.

Table 9-4

Stormwater Pollutant Concentrations (mg/L) Versus Land Use

Urban Land Use	TSS+	BOD*
Residential	240	12
Commercial	140	20
Industrial	215	9
Other developed areas	17	1

+ Total Suspended Solids, standard 50 mg/L
* Biochemical Oxygen Demand

Source: Sullivan et al., 1977.

Tibbetts Creek and McDonald Creek already exhibit average TSS concentrations of 236 mg/L and 241 mg/L, respectively, during storm events. These concentrations are comparable to those found by EPA in residential land use (240 mg/L). As residential development increases along other stream systems in the basin (i.e., North Fork Issaquah Creek and Issaquah Creek), increases in TSS concentrations could be expected as well.

Recent fish kills on the North Fork Issaquah suggests the relevance of metal toxicity as a current and future water quality problem. Beneficial uses are already being impacted. It could be expected that even with the implementation of BMPs, changes in land use described above will result in increased concentrations of these pollutants as well as others.

Mean pollutant concentration for the five Issaquah and Tibbetts Creek basin sites were compared to ten Metro high flow sampling sites (Table 9-5). Metro (1989) collected six high flow events between April 1987 and March 1989 from ten sites (Bear-Evans Creek, Cedar River, Coal Creek, McAleer Creek, Middle Green River, Soos Creek, and Springbrook Creek).

Table 9-5

Mean stormwater concentrations for ten Metro sites and five Issaquah Basin sites (including Tibbetts Sub-basin)

Variable	Unit	Metro 10 Station Mean*	Issaquah Basin 5 Station Mean**	Standard***
TSS	mg/L	39	132	50
Turbidity	mg/L	14	55	15
Fecal Coliforms	organ-isms/ 100 mL	474	442	100
Ammonia	mg/L	64	295	--
Nitrate	mg/L	894	1018	1250
Phosphorus	mg/L	104	193	50

* Based on six storms
** Based on five storms
*** See text

Issaquah and Tibbetts Creek basins pollutant concentrations were typically higher by several orders of magnitude than the combined Metro sites except for fecal coliform and nitrate concentrations. Concentrated agricultural activity along two of the Issaquah and Tibbetts Creek basin sites (McDonald Creek and Tibbetts Creek) in part may explain the relatively high combined site averages recorded for the nutrient variables. The threefold increase in TSS concentration seen for the Issaquah and Tibbetts Creek basins might also be explained by agricultural activity (i.e., worn pastures), mining, forest practices, and channel failure, combined with highly erodible soils. As current land use shifts to more impervious surfaces in the future, a decrease in the above pollutants may occur while metal, oil and grease, and other more toxic pollutant concentrations may increase.

Current water quality analysis based on Metro's base flow and storm flow monitoring programs, and DOE North Fork Issaquah Creek water quality analysis, suggest suspended solids, fecal contaminants, nutrients, metals, and sulfides, to be the major nonpoint pollutants in the basin. Suspended solids, fecal contaminants and nutrients will most likely continue to be the most

common nonpoint pollutants in the basin. Heavy metal toxicity, as well as other forms of chemical toxicity, will become an increasing water quality concern in the future as the number of businesses and acreage of impervious surface increases in the downtown area of Issaquah. Other generic water-quality impacts are likely as development continues in the basins, particularly from increases in fine sediment into fish spawning habitat and increased algal blooms from nutrient enrichment.

Although large-scale commercial agricultural land use has significantly decreased in the basin, numerous small hobby farms operate in low density zoned areas. These small farms frequently present the potential for nonpoint pollutant problems due to overstocking of pastures and consequent overgrazing and denuding. Denuded pastures then become a source of sediment and nutrients since there is nothing to hold the soil in place. Based on historical trends, hobby farms will likely increase in areas zoned for low density development and therefore have the potential to increase water quality impacts in the future.

The quality and quantity of water received by downstream systems will be altered as development occurs. Proper implementation of BMPs and other controls can significantly reduce the impacts of nonpoint pollutants. Beneficial use (i.e., water supply fisheries and wildlife, recreation, aesthetics, wetlands) impairment will occur at a substantially reduced level than would occur without any mitigation.

9.5.0 WATER QUALITY KEY FINDINGS

- Water quality during base flow conditions are generally impaired with frequent standards violation of fecal coliform and enterococcus bacteria counts in Tibbetts Creek, Issaquah Creek, and Issaquah Creek tributary waters. Average nutrient concentrations during base flow conditions did not exceed recommended guidelines except in Tibbetts Creek. Dissolved oxygen standards in Tibbetts Creek were frequently violated. These threaten fishery-related beneficial uses.

- During storm flow events, McDonald Creek, Tibbetts Creek, and Issaquah Creek were characterized by high concentrations of suspended solids, fecal contaminants, nitrate+nitrite-nitrogen concentrations, and total phosphorus concentrations. Storm concentrations for most variables at each site exceeded standards or recommended guidelines. Instream, small lake, and Lake Sammamish beneficial uses are being impacted by these pollutants. High nutrient concentration result in nuisance algal growth in streams and lakes. Sediment creates deltas, fills salmon spawning gravels, and reduces fishery and instream beneficial uses. In the future, pollutant concentrations and loadings are expected to increase, escalating beneficial use impairment.

- o Monitoring of base flow surface water discharges from the Cedar Hills Landfill area does not suggest any significant water quality problems stemming from landfilling activities. However, base flow monitoring alone does not provide sufficient water quality information to determine if land filling operations result in water quality degradation during storm events. Therefore, subsequent water quality monitoring should specifically target storm events when potential nonpoint water quality problems are typically detected.

- o Based on combined file reviews and field observations, the Health Department estimates a septic system failure rate for the basin to be 6 percent. This rate is slightly higher than the 3-5 percent failure rate identified for the Puget Sound region but does not suggest failing septic are a current nonpoint source. Other factors including age of septic systems and soil type may in the future result in higher septic failure rates and subsequent nonpoint pollution.

- o Groundwater contamination related to underground storage tanks (USTs) has been detected in the City, confirming the threat USTs pose to groundwater supplies. The threat to surface water quality, however, is less clear. Within the Issaquah basin, the USTs are concentrated in the downtown area of Issaquah. Therefore, the surface waters of Tibbetts and Issaquah Creek that flow through the downtown area are those most susceptible to contamination from leaking USTs.

- o Prescribed forest practices buffer widths of 25 feet, applied by DNR under a variety of conditions where no other permit is involved, are not adequate to perform even the primary function of trapping sediment. Exposed soil even less than 25 feet of streams, and drainage of suspended solids directly into small channels, was the significant water quality problem observed during forestry nonpoint field work. Suspended sediment was ranked as the most impacting forestry related nonpoint pollutant because of its direct effect on the downstream beneficial use of anadromous fish.

- o Although large landowners may harvest the greatest amount of forest in a basin, smaller cuts with inadequate conditions or without permits have the greatest potential per forested acre to create nonpoint pollution. Increased regulatory controls need to address all scales of land-clearing activity and insure, in particular, (1) the recognition and disclosure of environmentally sensitive area features, (2) accurate information pertaining to distances from streams or steepness of slope, (3) necessary equipment to harvest in wet areas or steep slopes, and (4) understanding of how storm-related events acting on logged sites will generate downslope and downstream impacts.

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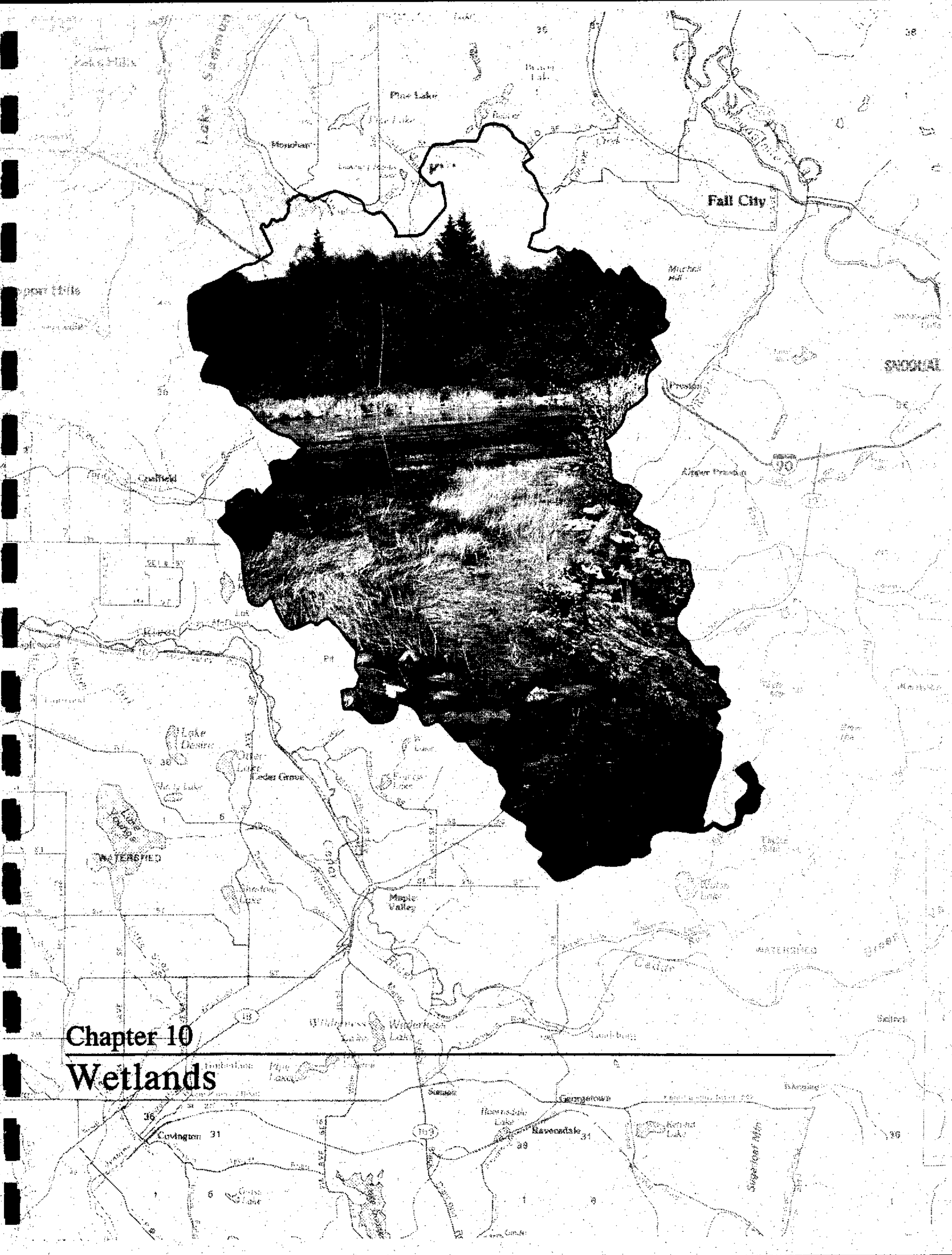


Chapter 10

Wetlands

CHAPTER 10: WETLANDS

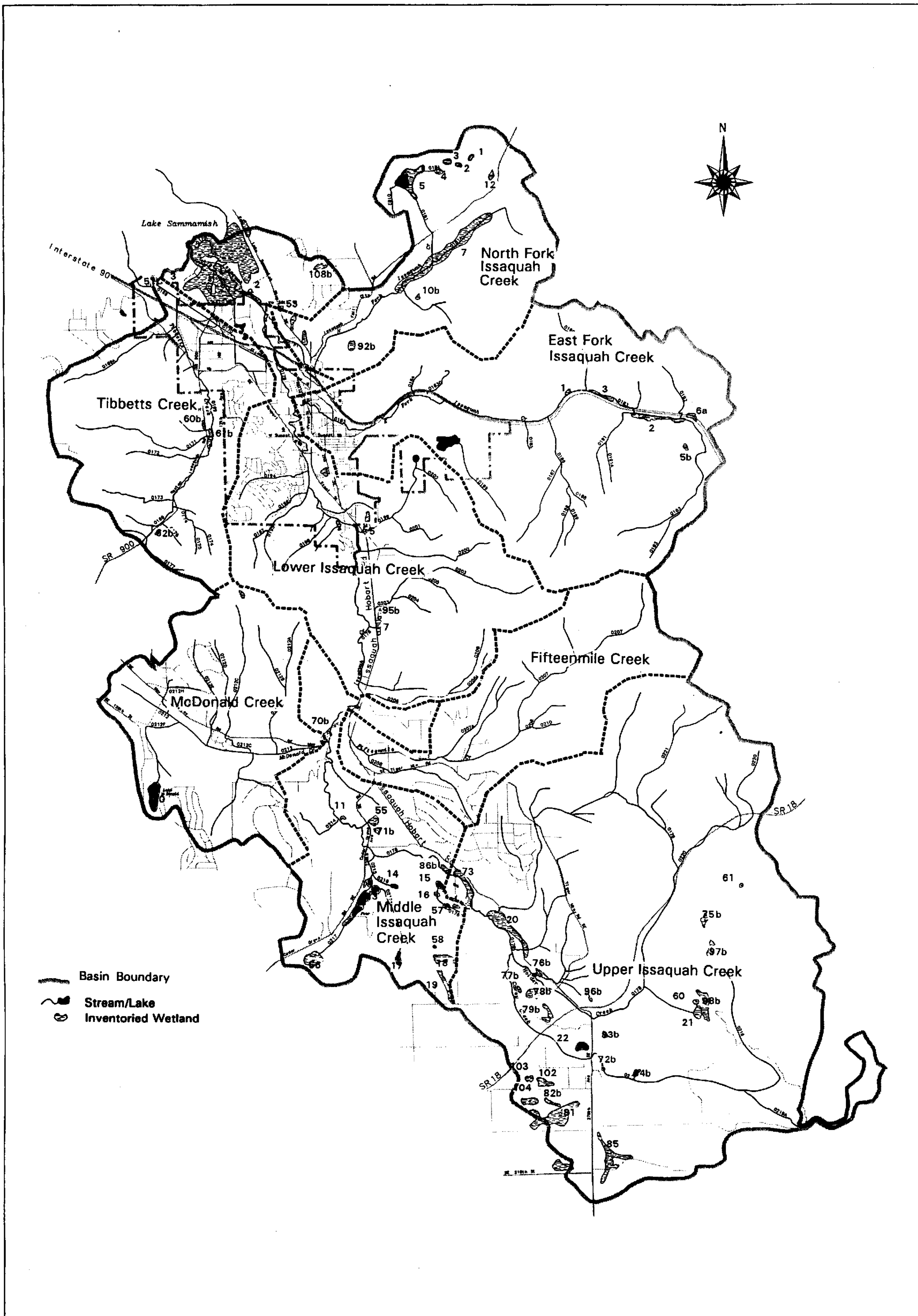
10.1.0 INTRODUCTION

Wetlands are defined to include marshes, bogs, wet meadows, wet forests, and shallow waters of lakes and ponds. They are identified by saturated soils or by the presence of plants that require wet soils for their survival. Wetlands store water in rainy periods and release it slowly during periods of dry weather. By acting as storage areas during rainstorms, wetlands protect streams from excessive peak flows, erosion, and scouring. They also provide a source of summertime low flow. Wetlands help to filter silt and pollutants, thereby protecting water quality in streams and in Puget Sound.

Wetlands serve as critical fish and wildlife habitat by providing food, cover, water, refuge from predation, breeding and rearing areas, and migration paths for many animals. Wildlife diversity in wetlands is high. More than 230 species of wildlife in western Washington depend on wetlands and riparian areas for survival during one or more stage of their life cycle (Brown, 1985). In some surface water ecosystems, as much as 90 percent of the biological energy (food for fish and aquatic invertebrates) is derived from adjacent wetlands and riparian vegetation.

Five general types of freshwater wetland are found in the Issaquah Creek basin. The King County Wetland Inventory recognizes six types countywide. Table 10-1 provides a compilation of wetland classes and lists total acreage by sub-basin; their locations are shown on Figure 10-1. Thirty-eight inventoried wetlands account for 324.8 acres, somewhat less than 1 percent of the land area in a basin of some 40,000 acres. The total acreage is slightly greater if all areas considered to possess hydric soil characteristics are included, and some additional wetlands in the basin probably have not been discovered. Staff experience in other locales suggests that aerial surveys coupled with limited field survey account for only about 75 percent of the total wetland area present. Furthermore, riparian wetlands (those that are developed on floodplains along streams) were largely omitted in the original inventory process (King County, 1981) and have not been evaluated for this basin plan. Preliminary estimates from aerial photography indicate that some 200 to 400 acres of riparian wetland remain to be mapped, much of this along the Issaquah Creek main stem and along Carey Creek. Therefore, a more realistic estimate places the total wetland acreage in the basin at perhaps 600-700 acres, or about 1.5 percent of the basin area.

Many of the wetland habitats in the basin are relatively unimpacted owing to the current light amount of urban development. Wetlands that have been lost or heavily impacted are located in the lower reaches of Tibbetts Creek, and all three forks of Issaquah Creek. This essentially constitutes the southern shore of Lake Sammamish, which historically contained a considerable area of forested and emergent palustrine wetland; some of this area is now in



MAP OF INVENTORIED WETLANDS

Issaquah Creek Basin Planning Area

Figure 10-1

the Lake Sammamish State Park; however, most has been lost to draining and filling activities associated with farming and development of housing, commercial structures, and transportation systems.

Upland buffers next to streams and wetlands also provide significant resource benefit. Such buffers contain cover and nesting habitat for birds and mammals, such as bald eagles, osprey, various duck species, and beavers that depend on wetlands. Upland buffers also protect sensitive wetlands from noise, light, glare, pollutants, and predation of their inhabitants by house pets.

Table 10-1

Wetland Acreage by General Type for Each Sub-Basin

Wetland/Class	Issaquah/27	North Fork/7	East Fork/3	Tibbetts/1
Bog (10.0)	10.0	NI	NI	NI
Forested (149.2)	92.6	2.6	3.0	51.0
Scrub-Shrub (75.8)	22.0	43.9	9.9	NI
Marsh (53.0)	23.1	24.1	5.8	NI
Open Water (36.8)	26.3	10.5	NI	NI
Wet Meadow (0)	NI	NI	NI	NI
TOTAL (324.8)	174.0	81.1	18.7	51.0

NI = None inventoried
Numbers following sub-basins are total inventoried wetlands in that basin.
Numbers in parentheses are acreage totals by class.

10.2.0 PRESENT AND FUTURE CONDITIONS

As a result of the geologic form, the topography, and the past agricultural practices in the basin, the diversity and total acreage of wetlands here are lower than that found in other lowland basins in the county. For example, wetlands in the Soos Creek basin account for 2000 acres in a basin of 44,800 acres, or some 4.5 percent of the land area. One wetland

type, the wet meadow, is missing entirely in the Issaquah basin. This is probably the result of incomplete inventory or historic drainage for crop production or pasturing in these wetlands. This is particularly evident in the McDonald (Mason) Creek valley, a broad, gently sloping area of pastures and, more recently, subdivisions. Similar areas appear in the lower Issaquah Creek valley above and below the city, and in the lower Tibbetts valley. Some of these areas appear to be reverting to vegetation characteristic of wetland environments and may be enumerated in future inventories.

In spite of the relatively small number of wetlands, certain of them exhibit important characteristics of habitat and plant and animal diversity. In North Fork Wetland 5, for example, four subclasses occur in 22 acres, including open water, two deep marsh subclasses, and a scrub-shrub subclass. North Fork Wetland 7 (51 acres) consists of only two subclasses (scrub-shrub and shallow marsh), but hosts a tremendous variety of trees (five), shrubs (eight), herbs (13), and other vegetation. There is also a large stand of quaking aspen (Populus tremuloides), rare in that it is several miles south of its usual range. In addition, numerous species of birds, mammals, and other fauna occur throughout this wetland. Other wetlands in the basin that exhibit similar characteristics of habitat or species diversity are Issaquah Creek 2, a forested system at the mouth of the creek; Issaquah Creek 18, a well-developed bog and shallow marsh; and East Fork 3, a system of shallow marsh, scrub-shrub, and forest subclasses.

Three wetlands with bog-like characteristics have been identified in the Issaquah basin: Issaquah Creek Wetlands 17, 18, and 19. All have vegetative communities characterized by a tolerance for the conditions brought about by the presence of sphagnum mosses. Such communities are rare in the Pacific Northwest and are usually mixed with other, more broadly adapted species to produce a fen rather than a true bog. Species represented in the Issaquah bogs are spirea, bog bean, sphagnum moss, and bog laurel. Wetlands 17 and 19 appear to be older systems that have been overtaken by scrub-shrub vegetation, while Wetland 18 exhibits clearer boglike characteristics. Cranberry, labrador tea, and sundew are some of the more unusual species in this wetland. These species are able to tolerate the acidic conditions produced by the sphagnum.

Wetlands throughout King County are assigned one of three ratings based on their hydrologic, biologic and cultural characteristics. Rating 1 wetlands are considered unique and outstanding; rating 2 wetlands are considered significant; and rating 3 wetlands are important but of low concern.

In order to achieve the unique/outstanding rating (class one), a wetland must exhibit one or more of the following characteristics: a) presence of an endangered, threatened, or sensitive species or outstanding habitat for these species; b) near equal proportions of open water to vegetation in dispersed patches with a high diversity of wetland classes; c) greater than ten acres in size with three or more wetland classes, one of which is open water; and d) the presence of plant class associations of infrequent occurrence. Rating 3 wetlands (low

concern) must meet either of the following criteria: a) one acre or less with two or less wetland classes, a low diversity of wetland subclasses and a high proportion of vegetative cover or open water; and b) those wetlands that fall below the tenth percentile countywide in three or more evaluation categories with both biology and hydrology percentiles less than 75 percent. Rating 2 wetlands (significant) are those wetlands that do not meet either the criteria for unique/outstanding (class 1) or low concern (class 3). Table 10-2 lists the unique/outstanding wetlands in the basin and the evaluation criteria upon which that rating was based. Of the acreage given in Table 10-2, class 1 wetlands (9) account for 154.5 acres, class 2 wetlands (27) for 169.7 acres, and class 3 wetlands (1) for only 0.6 acres; one wetland (Issaquah Creek 11) is inventoried but unranked.

Table 10-2

Unique/Outstanding Wetlands in the Issaquah Basin

Wetland No.	Justification
I1	Presence of endangered, threatened, or sensitive species: Bald Eagle
I2	Presence of Bald Eagle
I10	Wetland is larger than 10 acres, has three wetland classes including open water (McDonald Lake).
I18	Bog. Plant association of infrequent occurrence.
I19	Plant association of infrequent occurrence.
I22, I60	Near equal proportions of open water to dispersed vegetation.
NF5	Near equal proportion of open water to dispersed vegetation. Larger than 10 acres with three wetland classes.
NF7	Near equal proportions of open water to dispersed vegetation.

I = Issaquah
NF = North Fork Issaquah

SOURCE: King County Wetland Inventory

The structural characteristics of wetlands are quite easily identified and can provide clues to wetlands' functional attributes. Wildlife habitat can be assessed from observations of nesting, feeding and wintering use of the wetland and by the number of habitat elements of interest that the wetland contains. Other functional characteristics, such as food web support, nutrient cycling, recharge/discharge, or pollutant capture, are more difficult to evaluate without detailed investigations. It is at once apparent that various wetlands perform functions unequally and that some functions are not performed at all. Table 10-3 shows the results of a preliminary functional assessment of wetlands in the Issaquah basin.

Table 10-3

Preliminary Assessment of Issaquah Creek Wetlands
(Not an inclusive list of wetlands or their functions)

FUNCTION/ATTRIBUTE

Storage	Pollutant	Food Web Support	Recharge*	Fish/Wildlife Habitat
EF2, EF3, I5, I6, I13, I56, NF5, NF7	EF2, EF3, I13, NF5, NF7	NF5, NF7, EF2, EF3, T51, I1, I2	I20, I56, NF5, NF7	NF5, NF7, T51, I1, I2, I3, I13, I22

EF = East Fork
I = Issaquah
NF = North Fork
T = Tibbetts

* Recharge to groundwater has a higher probability in those wetlands that are underlain by outwash and that have large winter storage capacities.

10.3.0 HISTORICAL AND CURRENT PROBLEMS

Wetlands in the basin have been historically affected by agricultural, forestry, and development activities. A comparison among aerial photographs from 1961, 1980, and 1989, together with limited field visits during the summer of 1990, provided information for the following observations.

Historic wetland losses occurred throughout the valley of Issaquah Creek and near the mouth

of the creek. Similar losses occurred in the McDonald Creek valley as the areas were converted to agricultural uses earlier in this century. Evidence of drainage ditches and tile drains can be seen on aerial photographs of the Lake Sammamish State Park, lower Tibbetts Creek, middle and lower Issaquah, and throughout the upper McDonald Creek valley. Conversion to residential and commercial uses followed this agricultural activity in the floodplain of lower Issaquah and Tibbetts. Lost were areas of extensive shallow marsh and scrub-shrub habitats that now remain in small patches elsewhere in the valley. Forestry activity has had largely unknown effects on wetlands in this basin although certain wetlands, for example Issaquah Creek Wetland 61 and Issaquah Creek Wetland 19, have been cut over, destroying buffering vegetation. North Fork Wetland 5 (Yellow Lake) has had most of its catchment cleared within the past ten years.

Current threats to wetlands in this basin are due primarily to development of commercial and residential uses and may conveniently be grouped into three categories: 1) intrusion into the wetland or its buffer, 2) conversion or outright loss of the wetland, 3) isolation of the wetland from its surrounding catchment.

Many wetlands in this basin have suffered some kind of intrusion. Various roadways, pipelines, and power lines are seen to cross these areas, and the occasional dwelling can even be found abutting or built within the wetland. Issaquah Creek Wetlands 7, 18, 19, 20, 22, 51, and 56 all have some level of intrusion that likely has had some deleterious effect on wetland function. North Fork Wetlands 5 and 7 show similar intrusions. Areas historically altered for agricultural activities are now being converted to urban uses and other areas are being cleared at a rapid rate. In the McDonald Creek valley, residential subdivisions now occupy the site of a dairy farm, once an extensive valley bottom wetland. Much of the commercial activity occurring on the lower Issaquah and Tibbetts Creek fans is taking place on historic wetland areas. Issaquah 53 has been completely lost to commercial activity.

An excellent (though disturbing) example of urban encroachment and isolation of wetlands has occurred in the North Fork Wetland 5, Yellow Lake. In 1980, the catchment of Yellow Lake and its satellite wetlands was almost completely forested. By 1985, the western third of the catchment had been cleared to make way for residential development. By 1989, approximately one-half of the catchment had been cleared and the wetland was surrounded on three sides by development. Further clearing has been done since. The effect of such a profound change now can be seen in several ways. First, during construction on the surrounding slopes, sediment delivery to the wetland and its outlet stream increased dramatically. In spite of a filter berm (erected in the wetland), a sediment plume was clearly visible in the lake at the time of the study. The system still receives stormwater runoff from the development. Second, the proximity of the development coupled with a desire for access to the wetland has resulted in the construction of a viewing dock into the wetland and a trail system near its edge. Trash and debris are accumulating in this once pristine wetland. Third, as development proceeds, the wetland is becoming increasingly isolated from the surrounding upland forest and from other wetland and stream habitats in the area. For some

species, such as herons and wood ducks, nesting sites will be lost as the upland area is lost; other species that require corridors for travel from one wetland to another, such as grebes, kingfishers, and otters, will also tend to be lost.

Hydrology of wetlands also can be affected as areas of upland infiltration are lost to impervious surfaces. Interflow is converted to surface flow and may be diverted away from the wetland altogether. Habitat isolation may be most pronounced in those wetlands with high habitat and species diversity or with species not wholly dependent on wetlands for all life requirements. In addition to North Fork Wetland 5, other susceptible wetlands are North Fork 7; Issaquah 13, 18, and 22; and many of the riparian wetlands that have not yet been mapped.

10.4.0 WETLAND WATER QUALITY

10.4.1 Introduction

The information in this section is condensed from a comprehensive report describing water quality in Issaquah and Tibbetts Creek wetlands (Horner, 1991). The primary focus of the report is the relationship between runoff water quality to the ecological integrity of the planning area's wetlands. The possible effects of hydroperiod change on these wetlands is discussed briefly here, with an overview of study methods and emphasis on the qualitative findings (detailed information about the methods can be found in the full study). This section reviews the methods briefly and presents the results and discussion of the analysis in detail.

10.4.2 Pollutant Loading Estimation

Current and future land use data were compiled for 67 subcatchments within eight sub-basins (Tibbetts, Issaquah, East Fork, North Fork, McDonald, Carey, Holder, and Fifteen Mile) in the Issaquah Creek Basin planning area. Estimates were made for the potential loadings of four water pollutants (total suspended solids, TSS; total phosphorus, TP; lead, Pb; and fecal coliform bacteria, FC) in surface runoff received by identified wetlands under current and future conditions, using regional coefficients for pollutant yields. These four contaminants are representative of important classes of pollutants that degrade the water quality of wetlands and other receiving waters. Future conditions were evaluated with no mitigation.

Wetlands that are documented in the King County Wetlands Inventory (1983) were designated with their inventory name. Uninventoried wetlands were identified by sub-basin and a distinguishing number in parentheses. The accuracy of the current land use maps were evaluated by field examinations of some of the wetlands to confirm both their existence and positions in Planning Area drainage patterns. The maps appeared to be quite accurate based on these brief field checks.

In some sub-basins, tabulated wetland areas were not in accord with the land use maps. In most of these cases, the tabulated data indicated greater wetland areas than shown on the maps. Only wetlands that could be identified on the maps were included in the calculation of wetland area, because of the impossibility of determining drainage patterns into unmarked wetlands. As a result, more wetlands may receive surface runoff than are specifically identified in this report.

The sizes of specific wetlands were determined using Wetlands Inventory data and by estimating the areas of uninventoried wetland on the map using a square grid. Probable drainage patterns were determined by map examination, occasionally combined with information gained during the field visits. Where wetlands receive runoff from a portion of a single subcatchment, the areas of each specific land use in the drainage of identified wetlands were calculated using the area squares. Where wetlands receive runoff from the entirety of one or more sub-basins, the tabulated data were used. The loadings of pollutants to each wetland were calculated using the drainage area land use and wetland area estimates and pollutant yield coefficients for each type of land use.

Future pollutant yields to wetlands were projected using techniques similar to those described above. More reliance was placed on the table of future land use produced by KCSWM (1990c), than in the case of current pollutant loading estimates, because the map of future land use (KCSWM 1991) provided only general information on wetland locations and sizes and land use configurations. Where the future land use table indicates a loss of wet soils, it was estimated, if possible, which SCS wet soils (but not King County identified wetlands) were completely or partially lost by referring to the representation of wetlands and land use patterns on the future land use map. Because of the lower precision of the future land use map and the uncertainties of correlating the map with future land use data, errors may be greater than for the current estimates.

Similar to the derivation of current pollutant loadings to wetlands, the projected delivery of pollutants was based on expected drainage and land use patterns within the watersheds of specific wetlands. SCS wet soils that may be lost were excluded from the future pollutant delivery estimates. Although some sub-basins are predicted to have more wetland acreage in the future due to changes in land use and vegetation patterns, calculations of pollutant loadings to new wetlands could not be made, because their positions and sizes are unknown. Therefore, more runoff from some areas may be distributed to wetlands than is represented in the future loadings estimates. Net future median loading increases were divided by current median values to yield a percentage growth of pollutant loadings without mitigation.

10.4.3 Pollutant Yield Coefficients

The pollutant yield coefficients for Issaquah basin land use types were derived from published literature. Since the yield coefficients used as bases for the analysis have

considerable uncertainties, the estimates were expressed as ranges including a minimum, a median value, and a maximum. The median is considered to be the most likely value of pollutant loading, and the minimum and maximum represent an estimate of error. Performing the analysis in this way permits exploration of whether conclusions could change as a consequence of selecting information for the analysis from uncertain data. Derivation of pollutant yield coefficients are detailed in the original report (Horner, 1991) and will not be repeated here.

10.4.4 Estimated Current Pollutant Loadings

Estimated minimum, median, and maximum pollutant loadings normalized to wetland for current land use are available in Horner (1991). A real loadings of the four pollutants to wetlands are generally in the low to medium portion of the overall reported range. Only a few wetlands are thought to experience loadings of the respective pollutants near the upper ends of the ranges. This result is largely due to the relatively small areas of these wetlands compared to the areas of their watersheds, rather than to the land uses in their watersheds. The highest loadings are estimated to be received by Issaquah Creek Wetlands 15, 16, and 57, and by East Fork Wetlands 3 and 2. Specific comparisons among wetland loadings will be made in a later discussion.

Table 10-4 gives an estimate of the percentage increases in pollutant loadings to wetlands in each sub-basin for the future build-out zone without any mitigation and with two levels of mitigation, respectively. From Table 10-5 it may be seen that loadings to approximately half of the wetlands are projected to at least double if expected development occurs without any provisions to protect water quality. The four pollutants follow the same general trends in most cases. Pollutant loadings are predicted to grow most dramatically in Tibbetts Wetlands 1 and 3, and Issaquah Creek Wetlands 51 and 56, due to the potential for conversion of wetland to urban land uses and the drainage of larger quantities of pollutants to wetlands of diminished area. Decreases in loadings of FC to Issaquah Creek 51; TSS and FC to Issaquah Creek 11; and TSS, Pb, and FC to Issaquah Creek 55 are due to the conversion of grasslands, which can export more of these pollutants than some urban lands, to urban land uses.

Loadings of total phosphorus are expected to increase by the largest average percentage among the four pollutants in half of the wetlands, even where other pollutants decline. Most of the wetlands where no increases in pollutant loadings are predicted are in areas already completely urbanized or in Lake Sammamish State Park. It is likely that with loading increases, most of the wetlands would exhibit pollutant accumulations and other signs of disturbance that have been documented in studies that characterize wetlands in heavily urbanized watersheds (Horner et al., 1988; Horner, 1989).

The projections of pollutant loadings to wetlands with mitigation are expressed as a percent-

Table 10-4

Estimated Current Loadings of Four Pollutants to Wetlands in the Issaquah Creek Planning Area

	LOADING[a]											
	TSS[b]			TP			Pb			FC[c]		
Wetland	**Min**	**Med**	**Max**	**Min**	**Med**	**Max**	**Min**	**Med**	**Max**	**Min**	**Med**	**Max**
TIBBETTS												
51	No external input											
ISSAQUAH												
1	0.46	1.98	3.36	0.1	1.8	3.5	0.2	0.4	0.6	2.74	9.14	15.43
2	No external input											
3	0.11	0.49	0.84	0.0	0.5	0.9	0.0	0.1	0.1	0.69	2.29	3.86
51	0.06	0.27	0.46	0.0	0.3	0.5	0.0	0.1	0.1	0.38	1.26	2.13
53	0.48	1.61	2.74	4.4	5.0	5.4	3.2	6.2	9.4	0.34	1.12	1.90
5	2.68	9.06	15.39	21.9	27.6	35.1	1.0	2.1	3.1	12.63	42.12	71.6
7	0.24	0.78	1.32	2.0	2.4	3.1	0.1	0.2	0.3	1.09	3.62	6.15
11	0.42	1.58	2.69	3.4	5.0	6.6	0.2	0.4	0.6	2.20	7.33	12.4
55	1.60	6.24	10.61	12.8	19.7	26.4	0.7	1.4	2.2	8.69	28.91	49.1
13	1.81	6.29	10.68	18.3	23.9	30.1	1.0	1.9	2.9	8.64	28.77	49.1
56	0.16	0.52	0.88	1.3	1.6	2.0	0.1	0.1	0.2	0.72	2.41	4.10
17	0.28	0.92	1.56	2.3	2.9	3.6	0.1	0.2	0.3	1.28	4.27	7.25
14	0.29	0.95	1.62	4.4	5.6	6.8	0.1	0.3	0.4	1.33	4.43	7.60
15	10.26	35.18	59.77	133.4	172.3	213.8	4.6	9.2	13.9	49.13	163.4	279
16	29.66	101.4	172.2	387.9	499.9	619.8	13.3	26.7	40.1	141.6	471.1	805
57	16.78	57.37	97.47	219.7	283.2	351.1	7.5	15.1	22.7	80.13	266.6	456
18	0.37	1.25	2.12	4.2	5.4	6.7	0.2	0.3	0.5	1.74	5.80	9.90
19	0.39	1.33	2.27	4.6	5.9	7.3	0.2	0.3	0.5	1.86	6.20	10.6
58	0.26	0.86	1.46	2.2	2.7	3.4	0.1	0.2	0.3	1.20	4.00	6.80
20	0.54	1.86	3.16	7.1	9.2	11.5	0.2	0.5	0.7	2.60	8.64	14.8
22	0.47	1.81	3.07	3.8	5.7	7.6	0.2	0.4	0.6	2.51	8.37	14.2
21	0.22	0.72	1.22	1.8	2.3	2.8	0.1	0.2	0.3	1.00	3.33	5.67
60	0.33	1.08	1.83	2.8	3.4	4.3	0.1	0.3	0.4	1.50	5.00	8.50
59	0.05	0.17	0.29	0.4	0.5	0.7	0.0	0.0	0.1	0.24	0.80	1.36
6	0.02	0.05	0.09	0.1	0.2	0.2	0.0	0.0	0.0	0.08	0.25	0.43
10	0.22	0.73	1.24	3.7	4.7	5.7	0.1	0.2	0.3	1.02	3.38	5.82
EAST FORK												
1	0.19	0.64	1.08	2.9	3.7	4.5	0.1	0.2	0.3	0.89	2.96	5.07
3	9.81	33.16	56.33	98.9	125.2	156.4	5.9	11.8	17.8	45.04	150.0	256
2	6.87	23.26	39.51	71.2	90.3	112.5	4.5	8.9	13.5	31.39	104.6	178

Table 10-4 (cont.)

Wetland	LOADING[a]											
	TSS[b]			TP			Pb			FC[c]		
	Min	Med	Max	Min	Med	Max	Min	Med	Max	Min	Med	Max
NORTH FORK												
9	0.40	1.34	2.28	3.7	4.2	4.5	2.7	5.2	7.8	0.28	0.93	1.58
5	0.42	1.42	2.42	4.4	5.6	7.0	0.2	0.4	0.7	1.99	6.62	11.3
7	0.87	3.04	5.16	7.4	9.7	12.5	0.5	0.9	1.4	4.18	13.92	23.7
1	2.07	7.39	12.56	20.1	27.5	35.4	0.9	1.8	2.8	10.31	34.33	58.6
2	2.67	9.35	15.88	26.3	35.1	44.8	1.2	2.3	3.5	13.04	43.43	74.2
3	0.09	0.29	0.50	1.1	1.4	1.7	0.0	0.1	0.1	0.41	1.36	2.34
4	2.80	9.68	16.44	28.3	37.4	47.4	1.2	2.5	3.7	13.51	45.00	76.9

[a]kg/ha wetland surface for TSS, TP, and Pb; number/ha wetland surface for FC
[b]Given as TSS x 10^{-3} (multiply values by 10^3)
[c]Given as FC x 10^{-10} (multiply values by 10^{10})

Table 10-5

Estimated Percentage Change in Pollutant Loadings/Unit Wetland Area With Future Land Use Changes but Without Mitigation

Wetland	TSS	TP	Pb	FC
TIBBETTS				
51	No external input			
ISSAQUAH				
1	0	0	0	0
2	No external input			
3	0	0	0	0
51	321	1235	7882	-8
7	0	0	0	0
11	-5	111	24	-5
55	-27	63	-4	-26
13	45	139	57	46
56	418	972	548	418
17	133	419	200	133
14	51	74	63	50
18	75	177	110	75
19	77	174	110	77
58	133	419	200	133
20	39	85	56	39
22	40	212	83	41
21	126	398	190	126
60	133	419	200	133
59	25	25	25	25
6	45	45	45	45
10	74	43	83	75
EAST FORK				
1	0	0	0	0
3	53	103	254	37
2	58	102	282	38
NORTH FORK				
9	0	0	0	0
5	119	169	127	119
7	140	306	159	141
1	83	148	121	83
2	109	182	151	109
3	58	73	67	58

age increase over current loadings. Table 10-4 shows that the median level of treatment, which is regarded as more likely to be achievable in practice than the maximum level, can significantly reduce loadings to wetlands. Nevertheless, loadings would more than double for specific pollutants in some wetlands due to reductions in wetland sizes, major intensification of urban land use in wetland watersheds, or a combination of these influences. With medium treatment, total phosphorus would continue to lead in relative increased loading of the four pollutants to 24 of 28 wetlands where loadings increases are forecast to occur. Because of the lower level of TP removal compared to other pollutants, its loadings would rise by more than 100 percent in 10 of 40 wetlands. The more moderate pollutant loading increases afforded by median treatment would probably save the majority of the wetlands from urban degradation. However this level of treatment would not adequately protect those receiving the largest loadings.

If the maximum treatment level, which is the goal of the Lake Sammamish water quality plan, could be achieved, it would keep most TSS loading increases under 40 percent, most Pb increases under 10 percent, and most FC increases under 5 percent, except in certain wetlands for the reasons noted above (Metro, 1989). Total phosphorus would experience the largest increase of the pollutants in all wetlands where loadings increases are predicted. It would at least double in four wetlands relative to current minimum estimates, reflecting the lower relative efficiency of phosphorus removal afforded by storm runoff treatment practices. Most wetlands that are not already harmed by urban impacts would probably escape with these very high levels of treatment, if they could be maintained over the years.

10.4.5 Assessment of Consequences of Loading Increases

Table 10-5 lists the individual wetlands that lie in each subcatchment, along with rankings of the estimated loadings currently and in the future. In this table, A signifies the highest category of loadings relative to wetland surface area and E the lowest category. Currently, the highest overall loadings are estimated to be received by Issaquah Creek Wetlands 15, 16, and 57, and East Fork Wetlands 3 and 2. For each of these wetlands, the high loadings are due to their interception of runoff from large areas combined with their small sizes.

In the future, Issaquah Creek Wetlands 15, 16, and 17 are predicted to be significantly modified. Even higher overall loadings will be received by East Fork 3 and 2 because of significant urbanization in their watersheds. Issaquah Creek Wetlands 1 and 13 will move into the highest categories for Pb and TP, respectively. Two other wetlands, North Fork 1 and 2, will both receive high loadings of TSS and TP. Of the 40 identified wetlands, the rankings indicate that 26 will receive substantially higher loadings for one or more pollutants. In most of these cases, loadings increase by only one ranking level.

However, these estimates reflect expected long-term releases from finished developments and do not take into account the construction phase, when very high sediment discharges from

erosion of bare ground can occur. In fact, the Puget Sound Wetlands and Stormwater Management Research Program observed such impacts in East Lake Sammamish Wetlands 39 and 61. When these wetlands were first observed and monitored in 1987 or early 1988, before the start of development, signs of impact were much less than those seen later. Mitigation measures (sedimentation ponds and silt fences) were poorly designed and maintained, and buffers were invaded by construction activity. Over the first two years in which King County wetlands were monitored, East Lake Sammamish 61 exhibited the highest mean values of TSS and algal biomass (as measured by chlorophyll a) and the second highest winter mean TP (Reinelt and Horner, 1990). It is clear from these observations that protecting wetlands depends on high quality erosion control programs during building just as much as on mitigation of runoff impacts after building is complete.

10.4.6 Hydrologic Factors

Stream flow volume simulations for the Issaquah Creek Basin planning area were generated for 1989 and future land use conditions (KCSWM 1990d). Because the predictions are expressed as flow rate within stream channels rather than as runoff yield per subcatchment area, hydrologic impacts (Table 10-6) on wetlands can be expressed only for wetlands located on principal channels. Wetlands whose downstream boundaries are coterminous with a subcatchment boundary were determined to receive the flow volumes predicted for that subcatchment. If a wetland was not so positioned, then the flow volumes it received were estimated to be the flows predicted for the next subcatchment upstream plus the runoff contributed by the wetland's subcatchment based on the portion of the sub-basin in the wetlands watershed.

Table 10-6

Current and Future Flow Volumes Received by Main Channel Wetlands

Subcatchment	Wetland	1989 Flow	Future Flow	% Flow Increase
I19	IC13	19.0	35.3	86
I19a	IC7	1.7	3.5	106
EF5	EF3	210.9	260.7	24
	EF2	134.0	178.9	34
NF5 & 6	NF5	22.6	47.3	109
NF3-5	NF7	67.0	118.1	76
NF6	NF4	14.9	31.2	109

SCS wet soil areas projected to be lost in the future are excluded from these estimates. Two-year storm flow predictions are used in estimating hydrologic impacts to these wetlands, because stormwater detention facilities are typically designed to accommodate such volumes in normal operation. The wetlands projected to have the greatest changes in flow volumes received are Issaquah Creek 13 and 17, and North Fork 4, 5, and 7. The watersheds of these wetlands are predicted to become highly residential in the future (KCSWM, 1990c).

10.4.7 Current Status of Inventoried Wetlands

The study included field reconnaissance at most wetlands in the Issaquah Creek Planning Area for the purpose of describing their current status (Walton, 1990). The following reports the conditions found at wetlands examined, including the signs of human intrusion and water quality deterioration observed during these visits.

TC51 -- Some small concentrations of litter from Lake Sammamish State Park in wetland; park-related human intrusion; evidence of attempt to fill wetland; bank-undercutting by channel of Tibbetts Creek;

IC1 -- Light and scattered debris from boat launch; moderate human intrusion from Lake Sammamish State Park that is moderately damaging to wetland vegetation;

IC2 -- Small concentrations of garbage from Lake Sammamish State Park; widespread heavy foot traffic that is very damaging to wetland vegetation; moderate scour by channel of Issaquah Creek;

IC3 -- Some small concentrations of garbage from Lake Sammamish State Park; widespread human foot intrusion that is very damaging to wetland vegetation;

IC5 -- Some small concentrations of yard trimmings, concrete rubble, tree limbs and debris from land clearing; moderate intrusion by foot that is lightly damaging to wetland vegetation;

IC7 -- Some small concentrations of garbage from roadway; widespread intrusion by pasture that was very damaging to vegetation; past channelization near current outlet; some blockage of outlet by sediment;

IC10 -- Surrounded by residential development with yards typically maintained to water's edge that is very damaging to wetland vegetation;

IC13 -- Human intrusion throughout and possible past conversion of wetland to create small lakes;

IC14 -- Widespread intrusion by residential development that is moderately damaging to wetland vegetation;

IC15 -- Some small concentrations of tree trimmings; creation of pond to west of wetland; widespread human intrusion that is moderately damaging to wetland vegetation; evidence of filling of wetland on western edge to create berm; muddy brown water coloration;

IC16 -- Abandoned truck on west shore of pond; wetland vegetation around pond removed and replaced with grass; muddy brown water coloration;

IC19 -- Some brush dumped in wetland; bisected by gravel road; horse trails around wetland; residential access on one side; limited filling of wetland; scouring near gravel road;

IC20 -- Light and scattered garbage; abandoned camper; widespread intrusion by motor vehicles that is moderately damaging to wetland vegetation;

IC22 -- Residential development surrounds open water edge;

IC51 -- Light and scattered construction debris and piping in wetland; three of four sides are filled and graded with 18-21 feet of material for a commercial park with very damaging effect on wetland vegetation;

IC53 -- Some large concentrations of garbage and mixed household trash; commercial area on northwest corner with light damage to wetland vegetation; widespread filling above seasonal high water level for commercial area;

IC55 -- Light and scattered concentrations of wood scraps;

IC57 -- Wetland is private pond and has been drained with severe effect;

EFIC1 -- Light and scattered discarded cans and bottles; isolated foot intrusion; evidence of sediment deposits near inlet;

EFIC2 -- Light and scattered discarded cans and bottles; moderate human intrusion by foot; virtually no buffer; surrounded by Interstate 90, pasture, tree farmland, and residential land;

EFIC3 -- Litter from motorists on adjacent Interstate 90; human intrusion throughout and very damaging effect on wetland vegetation; most of wetland converted to pasture and backyard; some of wetland fenced in; evidence of attempt to fill wetland with widespread fill in shallow water;

NFIC1 -- Light and scattered mixed household trash; retention-detention pond on edge and extending into wetland approximately 30 feet; trend toward long-term water level increase

that is moderately damaging to wetland vegetation; sediment deposits in intermediate depths of wetland near inlet;

NFIC2 -- Sediment deposits in shallow water near inlet; shallow scouring very near inlet;

NFIC3 -- Some small concentrations of yard trimmings, litter and household trash;

NFIC4 -- Some large concentrations of auto parts, gas cylinders, and plastic bottles; development occurring on two sides of wetland with a road and power lines on other two sides;

NFIC5 -- Litter and larger debris in wetland; gravel trail surrounding wetland; intrusion throughout by heavy foot travel and light motorized vehicles resulting in moderate damage to wetland vegetation;

NFIC7 -- Light and scattered litter; intrusion by heavy foot and light motorized travel that is moderately damaging to wetland vegetation; limited filling related to roadways through wetland;

NFIC9 -- Some large concentrations of litter from Interstate 90 and East Lake Sammamish Parkway; abutted by fencing and highway.

10.4.8 Wetland Water Quality Conclusions

In the future, sub-basins closer to Issaquah and Lake Sammamish are projected to undergo considerable commercial, multiple family and high density residential development. Upland areas are expected to be influenced more by low density residential use. Important exceptions to this trend are upland sub-basins in the Tibbetts, McDonald, and North Fork Issaquah Creek basins, where considerable high density residential construction is predicted to occur. Previous research has shown that such levels of development are associated with certain decreases in the water quality of wetlands, accumulations of pollutants in their soils, promotion of invasive vegetation, and various evidence of human presence that degrades wetlands functionally or aesthetically. Water quality deterioration and pollutant accumulation result from drainage of urban stormwater into wetlands, while effects on vegetation are thought to stem largely from changes in the depths, frequencies, and durations of inundation accompanying urban hydrology.

The identification of wetlands and their drainage patterns revealed that relatively few are placed in key positions to intercept runoff from large portions of one or more sub-basins. Among these sites are Issaquah Creek Wetlands 5 and 13, East Fork 3 and 2, and North Fork 5 and 7.

Estimates were made of the loadings of solids (TSS), a nutrient (TP), a metal (Pb), and a bacterial indicator (FC) to the planning area wetlands under current and projected future conditions. Half the wetlands are predicted to receive a several-fold increase in total loadings, unless actions are taken to prevent the release of pollutants or to interrupt their transport.

10.5.0 KEY FINDINGS

- Large, uninventoried riparian wetlands exist along reaches of mainstem Issaquah Creek and Carey Creek.

- Fragmentation of wetland and stream habitats will become a significant problem as the basin urbanizes. An example of where this has already occurred exists in the North Fork sub-basin at Yellow Lake (Wetland 5).

- Loadings to approximately half of the wetlands in the Issaquah Creek basin planning area are projected to at least double if expected development occurs without any provisions to protect water quality.

- The identification of wetlands and their drainage patterns revealed that relatively few are placed in key positions to intercept runoff from large portions of one or more subcatchments. Among these sites are Issaquah Creek Wetlands 5 and 13, East Fork 3 and 2, and North Fork 5 and 7.

- The wetlands are predicted to receive a severalfold increase in total loadings unless action is taken to prevent the release of pollutants or to interrupt their transport.

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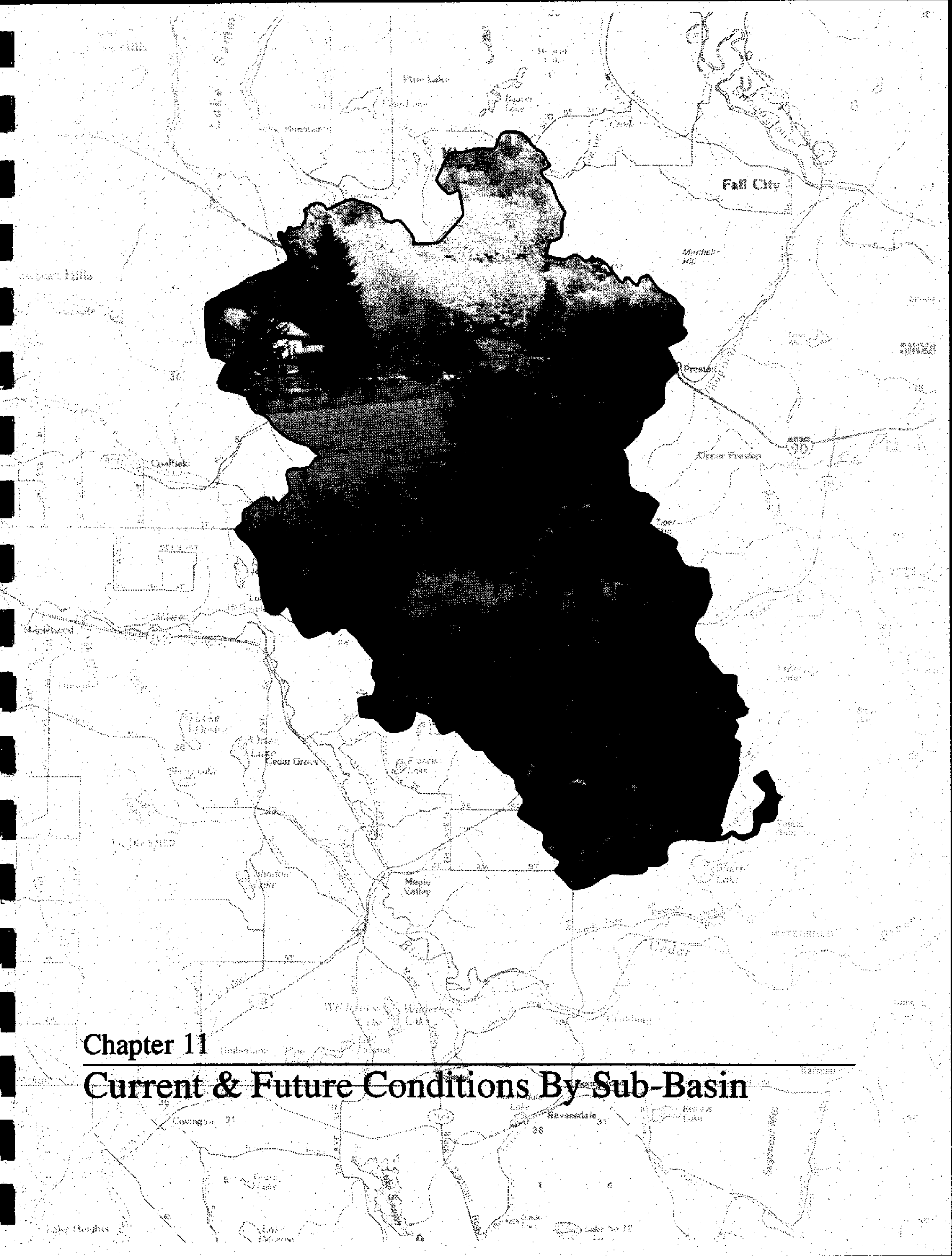


Chapter 11

Current & Future Conditions By Sub-Basin

CHAPTER 11: CURRENT AND FUTURE CONDITIONS BY SUB-BASIN

11.1.0 INTRODUCTION

The Issaquah Creek Basin planning area incorporates the Tibbetts Creek basin and eight major stream sub-basins of the Issaquah Creek system, each of which is characterized by unique natural features with respect to geology, hydrology, and habitat. When exposed to varying land use and storm patterns, each exhibits its own range of responses that will determine effective solutions for the area. This chapter contains a summary of conditions in each of the Tibbetts Creek basin and these eight sub-basins: North Fork Issaquah, East Fork Issaquah, Fifteenmile, McDonald, Holder, Carey, Middle Issaquah, and Lower Issaquah Creeks. Holder and Carey Creek sub-basins have been combined in this chapter and named Upper Issaquah sub-basin. Each sub-basin section presents findings and perspectives combining information from several disciplines, including geology, drainage and flooding (hydrology), stream habitat (biology), water quality, and land-use planning, which are presented separately in Chapters 3 through 10.

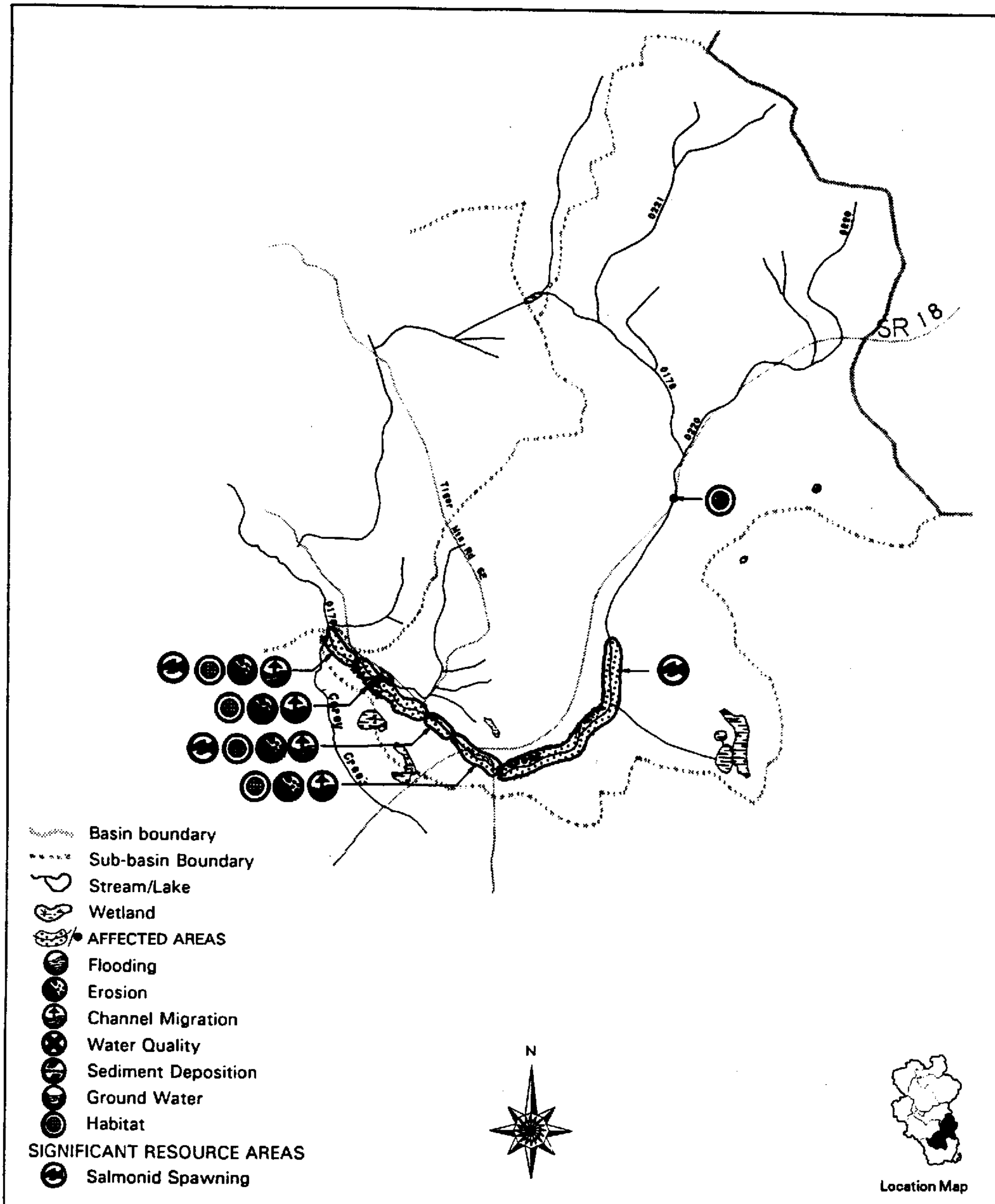
11.2.0 HOLDER AND CAREY (UPPER ISSAQUAH) CREEK SUB-BASIN

11.2.1 Description of Sub-basin

Holder and Carey Creeks form the headwater tributaries of Issaquah Creek (Figures 11-1 and 11-2). The two stream systems, which join to form mainstem Issaquah Creek, represent a hydrologic unit referred to here as the Upper Issaquah Creek sub-basin. There are both noteworthy similarities and differences between the Holder and Carey Creek systems. The following discussion points out these distinctions where they exist.

This Upper Issaquah sub-basin covers an 11,539 acre area (18 square miles) and is characterized by largely undeveloped, forested lands with steep upper reaches, and scattered livestock farming in the lower-gradient, downstream reaches. Both Holder and Carey Creeks' systems still bear the residual impacts of historical land-use activities, including mining and logging.

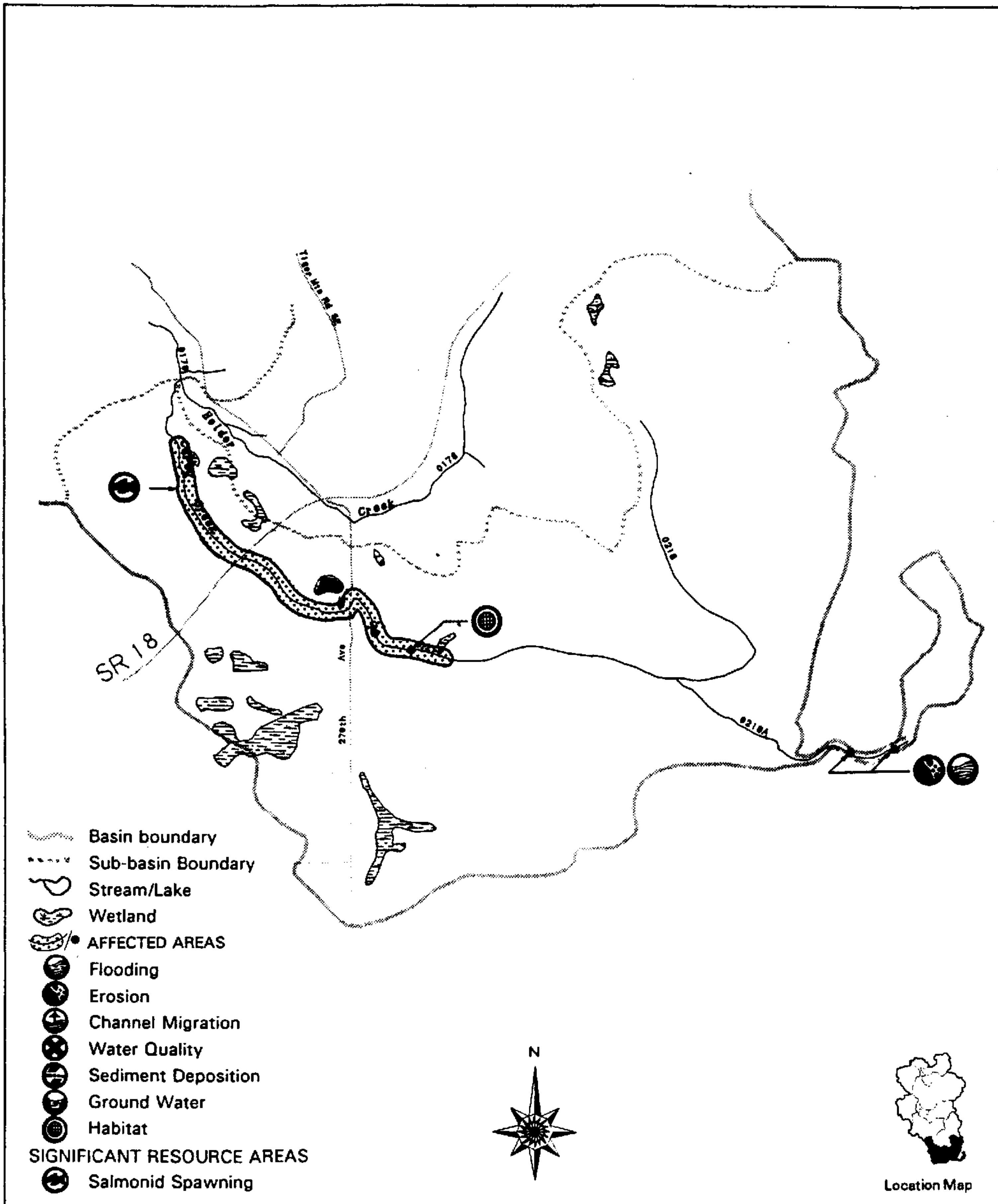
Future land uses suggest there will be a major reduction of forest lands in the Upper Issaquah sub-basin, from the present 80 percent to 50 percent. There will be a corresponding increase in grassland and impervious surfaces, which will contribute to higher velocity in surface-water flows and the non-point pollution conditions that generally accompany urbanization.



HOLDER CREEK SUB-BASIN CONDITIONS

Issaquah Creek Basin Planning Area 0 1/2 1 Mile

Figure 11-1



CAREY CREEK SUB-BASIN CONDITIONS

Issaquah Creek Basin Planning Area 0 1/2 1 Mile

Figure 11-2

11.2.2 Current and Future Sub-basin Conditions

Flooding

Flooding problems are not common or serious in the Carey Creek system, which is still largely undeveloped. Large riparian corridors that line the channel of Carey Creek in many places provide extensive overbank areas for flood waters. In addition, the Carey Creek system contains two of the more extensive wetland networks in the Upper Issaquah sub-basin, with one immediately above and one below the Issaquah-Hobart Road.

Only one specific instance of flooding has been observed in the Carey Creek system. This occurred during the November 1990 storms at the point where Carey Creek crosses Taylor Road (SE 208th Street). Some erosion damage also was reported at the bridge crossing of Issaquah-Hobart Road during the November 1990 storm. Although out-of-bank flows have been modeled in the reach below SR 18, no roads or habitable structures are affected.

Streambank erosion and pasture flooding are common in Holder Creek in the reach between SR 18 and the confluence of Carey and Holder Creeks. However, in this same reach of Carey Creek, there are few erosion and no documented flooding problems.

Hydrologic modeling suggests that flow frequencies in the Upper Issaquah sub-basin formed by Holder and Carey Creeks will increase an estimated 26 percent, from the present 2- to 100-year average peak annual flow frequencies of 1,413 cfs to 1,784 cfs. Consequently, more serious and frequent flooding could emerge as a problem in this sub-basin, particularly if future development encroaches on the stream corridor.

Erosion and Sedimentation

Along Carey Creek, there have been almost no significant sediment problems reported during recent studies carried out by reconnaissance or basin planning field staff. For the most part, recruitment of gravel in the upper reaches is followed by progressive deposition and downstream fining of the bed sediment as the channel reaches the valley floor. As the channel approaches its confluence with Holder Creek, the bed is largely sand. The absence of significant development along the channel and in its tributary area has maintained an overall balance between water and sediment discharge. The result is that problem conditions are absent and that aquatic habitat is excellent.

Only one problem, in the extreme southeast corner at RM 3.9 on Carey Creek, was noted in this sub-basin after the November 1990 storm. At this point, tributary 0219A (a diversion from the old mining town of Taylor in the Cedar River watershed) enters Carey Creek. This channel shows clear evidence of severe recent scour to a depth of about 1 foot throughout its length of several hundred yards. The cause of this erosion appears to be related to a siphon that carries

the diversion of Taylor drainage under SE 208th Street and under Webster Creek to its confluence with Carey Creek. During the November 1990 storm, the culvert plugged with debris and sediment, causing the stream to overflow into the diversion channel below the siphon outlet. Flow in this diversion channel was substantially increased, causing the bed to scour. A portion of the diversion ditch bank just upstream of the scour point failed as well, resulting in deposition of sediment into the woods as the stream flowed through the breach.

Holder Creek is showing significant signs of sediment-related problems, particularly sediment imbalance. These problems are localized and concentrated largely in the higher elevations where logging and SR 18 affect a proportionately greater amount of the tributary area. Channels here display zones of local incision and deposition, which in turn initiate bank failures from either oversteepened slopes or lateral channel migration.

Below the confluence of tributaries 0178 and 0220, the impacts of the upper basin are progressively modulated by the increase in drainage area and the largely intact forested corridor, which contribute copious amounts of woody debris to the channel, thereby helping to stabilize its form. These conditions depend on a coherent corridor and limited flow increases, both of which were becoming less certain by 1990. This situation has emerged since the 1987 Basin Reconnaissance, when field staff found only one erosion problem, just downstream of the Issaquah-Hobart Road crossing. This problem site appears to be a the consequence of artificial channel constriction and the increases in flow depth and velocity it has produced.

Below the Issaquah-Hobart Road, the Holder Creek channel follows a pattern similar to Carey Creek, with progressive downstream fining. The gradient change is less abrupt on Holder Creek, however, with the degree of fining less and the bed predominantly gravel to its confluence with Carey Creek. Lateral migration of the channel is significant in this zone of progressive fining (and progressive deposition of coarser sediment). As a result, localized bank erosion is common.

Habitat

For much of its length, Carey Creek is the quintessential salmon stream, with large, deep pools, well-anchored with abundant large, woody debris, and gravels that form extensive spawning beds. The riparian corridor, broad and well-vegetated (primarily by deciduous species), often forms large riparian wetlands and floodplains. At about RM 4.2, the stream encounters Carey Creek Canyon and becomes an abrupt series of cascades that mark the upper limit of anadromous migration. Most salmon production seems to occur in the lower reaches of Carey Creek, where low gradients, riparian corridors, and diverse stream beds are conducive to spawning and rearing. Even so, a 1989 stream survey identified few adult salmon here, a fact probably explained by the limited escapement of chinook and most coho salmon upstream at the state hatchery. Carey and Holder Creeks appear to be underutilized by anadromous salmonids, given

the quality and abundance of habitat. Steelhead do use the area, as do searun cutthroat and resident rainbow. Dolly Varden also have been observed in these streams.

Habitat conditions are less ideal in the middle and upper reaches of Carey Creek. From RM 2.4 to 4.2, the channel is steeper, has a high width to depth ratio (an indication of high sediment transport), and lacks pools and riffles necessary for fish production. These, together with the presence of an 8-foot-diameter culvert at about RM 3.2 that lacks baffles for fish passage, explain the lack of fish found during field observation.

Upstream, Carey Creek assumes a brief pool:riffle character before it steepens to boulder cascades and a staircase profile. A possible chinook redd was observed in this small, flat reach during November 1990. LWD is common throughout this upper reach and forms numerous debris jams, trapping sediment and providing some velocity attenuation. At RM 4.2, a series of cascades marks the upper Carey Creek Canyon and the limit of anadromous migration.

The uppermost reach above the 30- to 40-foot-high waterfalls begins as a steep, boulder cascade stream as it passes through the canyon. Small and shallow pools are formed behind obstructions or at drops. No anadromous fish can reach this area, and no resident trout were observed during the survey. Other forms of animal life abound, however, and elk sign was clear and abundant on the slopes above the canyon.

At the upper end of the canyon, Carey Creek flattens abruptly, and the valley broadens from less than 200 feet wide to over 600 feet wide. This broad swale continues for another half mile or so and collects several small streams that form the headwaters of Carey Creek. This section of the stream is well-suited to trout, having small gravels in patches and occasional deep pools (however, no fish were observed during surveys). The corridor is well-vegetated with deciduous trees, mostly alder and big leaf maple; some cedar and hemlock remain. Many large cedar stumps are found in the riparian zone, indicating a harvest much earlier this century. The upper swale appears to be a continuous riparian wetland and should be surveyed prior to completion of the basin plan.

In Holder Creek, stream habitat is being affected by an apparent delayed stream response to past logging practices exacerbated by current logging activities in the upper reaches above the Issaquah-Hobart Road, and by loss of riparian habitat in the lower reaches. The upper reaches of the stream are generally very steep with gradients typically greater than three percent and substrate dominated by large cobbles and boulders. These larger substrates assist in stabilizing the overall stream bed and creating small pocket water suitable for limited rearing of salmonids. However, the lack of larger channel stabilizing elements, such as LWD, increases the overall erosive energy of storm runoff by reducing the amount of energy dissipation in the system. This is especially true in lower Holder Creek below the Issaquah-Hobart Road, where stabilizing elements, such as large conifer trees, have been almost completely removed from the riparian zone. Alder presently dominates the woody vegetation in upper Holder Creek. Its benefits are short-term, because the wood decomposes in 3 to 5 years.

Valley and stream channel constriction caused by the construction of SR 18 also may be causing some localized bank stability problems, particularly at RM 15.8, where a left bank slide is visible from the road. Runoff from SR 18 is exacerbating these storm-generated problems downstream of roadway outfalls.

The habitat in the lower reaches of Holder Creek has been affected by major erosion below the Issaquah-Hobart Road, as discussed under "Sedimentation and Erosion." In addition, the riparian habitat throughout this reach has low complexity and is much reduced in suitability for salmonids. In addition, there are also numerous erosional problems caused by lateral channel cutting in pasture areas throughout the reach; some of these cuts are almost 10 feet deep and exhibit much recent activity.

Of particular interest in the upper Holder Creek system is the apparent diversion of about one square mile of headwater basin area from this system into the Pheasant Creek (0178E) watershed. The date of this diversion is unknown, but it appears to be quite recent judging from the lack of a well-formed streambed. The diversion may have been somewhat inadvertent: Two culverts lie in a shallow saddle within about 150 feet of each other at milepost 2.4 of the East Tiger Mountain Road. Flow may divert to either culvert depending on the sediment deposition from the upstream channel. At this writing, flow is entering the westernmost culvert, once probably something of a relief valve for the main channel farther to the east.

The lower reaches of Carey Creek show promise for continuing to provide excellent habitat for anadromous fish, if the riparian zone remains intact. Conditions would remain stable here, and conifers will become an increasing portion of the LWD (a major stabilizing factor) as they mature. Holder Creek's habitat conditions will continue to be problematic due to the absence of LWD and diversity in steam channels and the riparian corridor, as well as to erosion in numerous locations throughout the system.

11.2.3 Key Findings

- Flooding is minimal in the Carey Creek system. One site was located during the November 1990 storm at the intersection of Taylor Road and SE 208th Street, where a tributary to Carey Creek crosses Taylor Road. Another site exists at the bridge crossing of Issaquah-Hobart Road.

- In Holder Creek, streambank erosion and pasture flooding occur in the reach between SR 18 and the confluence of Carey and Holder Creek.

- Hydrologic modeling suggests that as the Upper Issaquah sub-basin builds out, flow frequencies will increase about 26 percent over their present levels. As a result, more frequent and serious flooding could occur in this sub-basin.

- There is clear evidence of severe recent scour to a depth of about 1 foot for several hundred yards at RM 3.9, where tributary 0219A enters Carey Creek. The problem, found after the November 1990 storm, was a culvert plugged by debris and sediment coming from upstream. The Carey Creek system is otherwise relatively free from erosion and sedimentation problems.

- Holder Creek exhibits more significant signs of sedimentation problems, particularly sediment imbalance. Most of these are localized and concentrated in the higher elevations, where logging and SR 18 affect a large part of the tributary area.

- Carey Creek has generally excellent habitat conditions for salmon and other salmonids, except where steepness impedes passage or otherwise localized problems exist. An artificial obstruction exists in the form of an 8-foot-diameter culvert at about RM 3.2 that lacks baffles for fish passage.

11.3.0 MIDDLE ISSAQUAH CREEK SUB-BASIN

11.3.1 Description of Sub-basin

The Middle Issaquah Creek sub-basin covers an area of 3238 acres, 80 percent of which is presently forested (Figure 11-3). The sub-basin is mainly in agricultural and low-density single-family residential land uses at present, except for a small quarry on the sub-basin's southwestern boundary. Future land uses will allow for a major increase in low-density single-family residential development. When the basin is built out, forest land is expected to be reduced to half of its present amount.

The sub-basin contains one of three major zones of stream migration, especially significant for its proximity to developed areas. These processes will continue and will threaten homes and other structures built in affected areas.

The middle reaches of mainstem Issaquah Creek form a moderate gradient system that supports a regionally significant salmonid fishery in spite of low-level land-use impacts from livestock farming, road building, and floodplain encroachment.

11.3.2 Current and Future Sub-basin Conditions

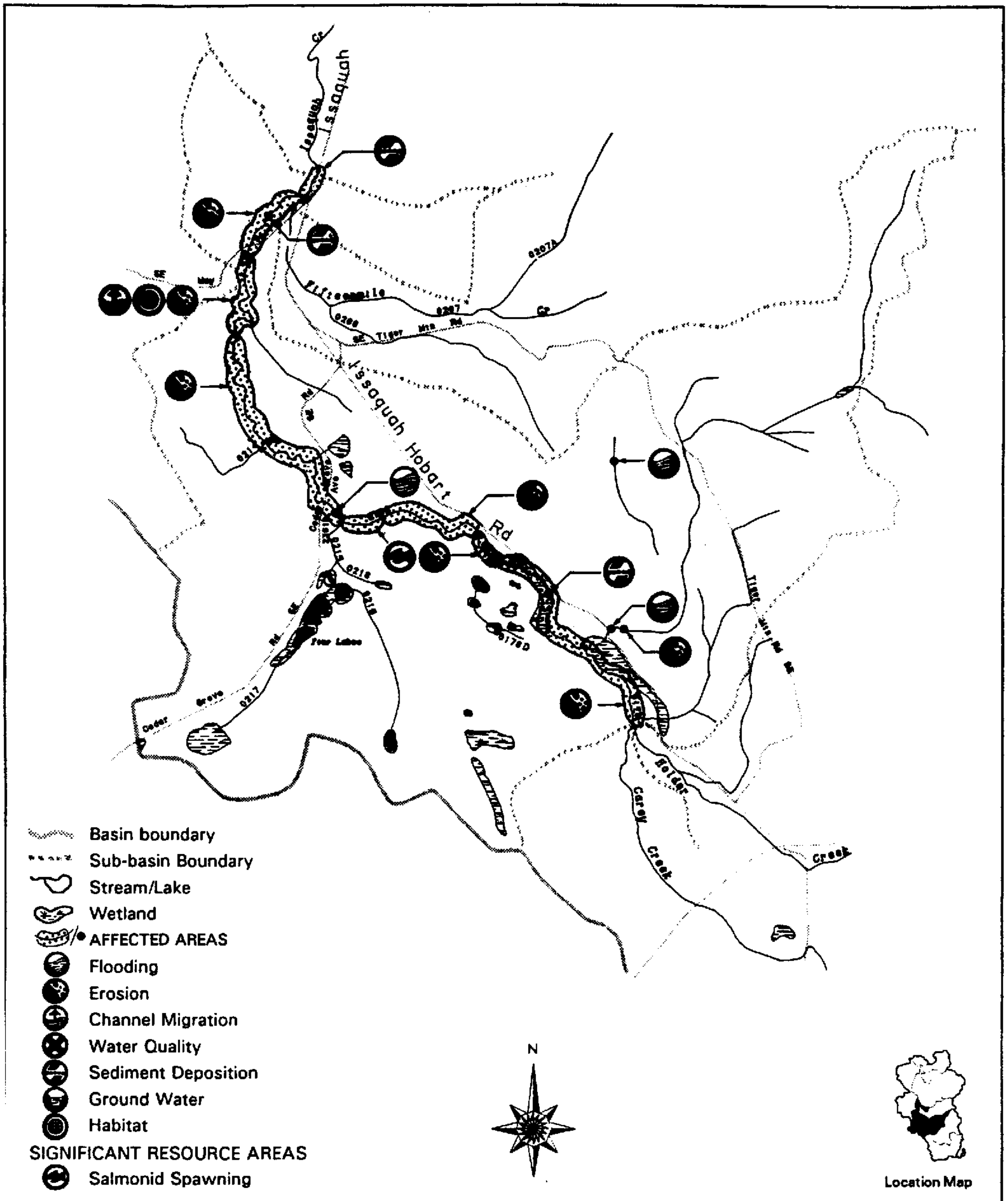
Flooding

There has been a history of both lowland and localized flooding of upland culverts in this sub-basin, particularly at the Mirrormont development and at the confluence of Issaquah (0178) and Pheasant (0178E) Creeks. In 1986, Roads Maintenance replaced an undersized culvert under SE 152nd Street after it flooded. In 1988 King County Surface Water Management Division constructed the Mirrormont CIP project to improve a local drainage system in the plat of Mirrormont that had caused localized flooding. Most recently, residents replaced a culvert on Pheasant Creek after a sediment blockage during the January 1990 storm washed out a private road.

Streambank erosion and pasture flooding occur in places along the entire reach of Issaquah Creek in this sub-basin.

Development over the next 10 to 25 years is expected to reduce forest land by 50 percent in the sub-basin and replace it with impervious surfaces and grass. Modeling shows that the current 2- to 100-year average peak annual flows of 2,006 cfs in this sub-basin will increase to 2,553 cfs, a 27 percent increase, as a consequence of these changes. These increases in surface water flows will accelerate flooding in present problem areas, as well in presently flood-free areas.

For example, the crossing of SE 156th Street over the mainstem of Issaquah Creek is expected to flood during extreme storm events under future land use conditions. In addition, streambank



MIDDLE ISSAQUAH SUB-BASIN CONDITIONS

Issaquah Creek Basin Planning Area 0 1/2 1 Mile

Figure 11-3

erosion has been reported in 1990 and 1991 in the Four Creeks Ranch area and will likely continue, because residential structures have been constructed in the zone of active channel migration.

Erosion and Sedimentation

This sub-basin contains the most potentially damaging zone of channel migration in the Issaquah Creek planning area. This natural phenomenon is of special concern here because of the creek's proximity to human development. Whereas flooding is currently limited to a relatively narrow zone adjacent to the creek, channel migration can affect a broader region in that the present flow is sufficient to erode modern and glacial sediments alike.

The main channel of Issaquah Creek actively migrates throughout much of this sub-basin, with numerous examples of lateral channel shifts from the two 1990 storms of a few feet up to several tens of feet. Although examples of such movement are scattered throughout this reach, the most damaging have occurred in the Four Creeks Ranch area (RM 9.6-8.3), where development has encroached upon a zone of active channel migration. The most severe erosion problem here shifted the active channel to within a few feet of a house foundation during the November 1990 flood, following a pattern of channel migration evident over the preceding decades. Just upstream, longer-term channel migration has left steep embankments along the right bank, a portion of which failed catastrophically in March 1991 and temporarily dammed the main channel.

Sediment movement along Middle Issaquah Creek is relatively consistent. The largest gravel contributed by Holder Creek does not travel much past the 252nd Avenue SE (Getschman Road) bridge, as the channel drops off one glacial-age terrace onto a lower surface with a flatter gradient. Beyond this point, however, bed sediment does not vary systematically, although the effects of agriculture and suburban development are reflected by an increasing sand and silt load in the downstream direction. The channel again steepens as it approaches and passes through the Four Creeks area, primarily as the flow accommodates the additional sediment load delivered by lateral tributaries. In this area, the floodplain of Issaquah Creek is confined by a terrace that is only a few feet higher than the level of relatively frequent inundation. The fact that the channel has degraded almost 1 foot in the last 15 years at the Four Creeks bridge (229th Drive SE) suggests that this terrace, upon which a number of houses are built, may be a floodplain only recently abandoned by the river.

The January and November 1990 storms produced several problem sites along lateral tributaries in this sub-basin. Most were associated with concentrated flows and sediment transport off the slopes of Tiger Mountain. These included a few minor blockages of SE Tiger Mountain Road by water, sediment over 230th Avenue SE above Cedar Grove, and sediment on the road at the entrance to Mirrormont. The most severe of these problems is a large ravine, apparently initiated during the January 1990 storm and expanded again in November, adjacent to the

Issaquah-Hobart Road just southeast of 252nd Avenue SE. The water originates in a road ditch and culvert system along SE 159th Street in Mirrormont and then drains down an easement to the Issaquah-Hobart Road. In both storms, the system on the upper roadway overtopped, and the runoff was then sufficiently energetic to erode the steep hillside downslope. Deposition at the base of that slope blocked the Issaquah-Hobart Road during both January and November.

The processes associated with stream migration show no sign of abating in this sub-basin. Localized armoring of the bank at a few select locations will tend to distort the pattern of meander migration, potentially increasing the impact on those banks remaining unprotected. Increasing flows throughout the sub-basin are likely to increase the rates at which erosion and sedimentation of lateral tributaries, and migration of the main channel, will occur.

Habitat

The gradient throughout the long reach of the Issaquah mainstem (RM 3.5 to RM 11.4) is less than 1 percent, and the meandering channel is less sinuous than below the city. Gravels are free of fines and unconsolidated, providing excellent spawning conditions. An uneven pool:riffle character predominates, and riffles appear to be slightly more frequent due to the rare and uneven appearance of LWD in this reach. Braiding is apparent in many sections, particularly near RM 5.9, RM 7.0, RM 9.6, and RM 10.5, and these areas provide excellent summer rearing habitat and refuge from high winter flows for juveniles.

Several recently placed projects, constructed to stop further bank erosion caused by the 1990 storms, have rendered portions of the creek sterile. These occur at the confluence of tributaries 0207 and 0178; tributary 0178 at RM 7.5; tributary 0203A at RM 0.3. Additional projects affecting stream habitat are found along the mainstem between RM 7.4 and 7.7, through the Four Creeks development, at the mouth of McDonald Creek, and on an unnamed tributary (0217A) to Issaquah Creek.

The riparian corridor through this reach of mainstem Issaquah Creek is extensive and dominated by deciduous species. The corridor varies from a width of 30 to 50 feet per bank to over 200 feet per bank, interrupted by pastures, highways, and residences. Alder, cottonwood, Oregon ash, and willow dominate the canopy. Salmonberry, snowberry, elderberry, and Indian plum dominate the shrub layer. Evergreen violet, swordfern, youth-on-age, and nettle are represented in the ground layer. Cedar, hemlock, and fir are rare and discontinuous, but evidence of their historic presence is provided by the many large stumps, now sprouting saplings or huckleberry.

The riparian corridor throughout this long 7.9-mile reach, from May Valley Road to the Holder/Carey forks contains large forested wetlands, unmapped during the King County inventory. These wetlands serve as floodwater and sediment storage areas during the winter and may act as stream recharge areas during other seasons. Riparian wetlands often also act as organic storage areas, entraining woody debris and other organic material that is then swept back

into the stream during a subsequent flood to become a food supply for aquatic insects. These wetlands have been mapped preliminarily (see WETLANDS, Chapter 10), but they remain to be inventoried and evaluated.

11.3.3 Key Findings in Middle Issaquah Creek Sub-basin

- Multiple flooding and culvert wash-out problems have been common in the Mirrormont development. The culvert under SE 152nd Street and downstream residence have a history of flooding since a new plat was constructed upstream in 1986. A drainage system replacement in 1988 has reduced problems near the main entrance road. Along tributary 0178E, residents replaced a culvert under 261st Avenue SE after a sediment blockage during the January 1990 storm caused the private road to wash out.

- Streambank erosion and pasture flooding occur in places along the entire reach of Issaquah Creek in this sub-basin.

- This area incorporates zones of active, naturally occurring channel migration. Future increases in flows and sedimentation are likely to increase the migration rate, which can severely impact near-stream development. In particular, the main channel of Issaquah Creek has shifted within a few feet of a house foundation in the Four Creeks Ranch area (at RM 8.4) during the November 1990 flood.

- There is generally good habitat in this sub-basin. Exceptions occur at several locations (e.g., at the confluence of tributaries 0207 and 0178; tributary 0178 at RM 7.5; and on tributary 0203A at RM 0.3), where projects were placed after the 1990 storms to stop bank erosion.

11.4.0 McDONALD CREEK SUB-BASIN

11.4.1 Description of McDonald Creek Sub-basin

The McDonald Creek sub-basin covers 3,200 acres (5 square miles) in the southeast portion of the Issaquah Creek planning area (Figure 11-4). Headwaters of McDonald Creek (also called Mason Creek) originate on Squak Mountain, on the south side of the main valley at Lake McDonald, and in the Cedar Hills upland. The creek and its five tributaries comprise approximately 7 miles of channel that drain the broad valley lying between the Cedar River plateau and Squak Mountain.

The main channel is a relatively low-gradient system. Drainage is characterized by extensive wetland areas that have experienced filling and draining for agricultural and residential development. The McDonald Creek valley has been the historical recipient of sediment from the steep mountain tributaries that drain into it. This process has been escalated by upstream development, forestry practices, and construction in the floodplain. The creek has been channelized for 1.7 miles as it passes through the flat upper valley that parallels May Valley Road. The channel in this area is uniformly straight.

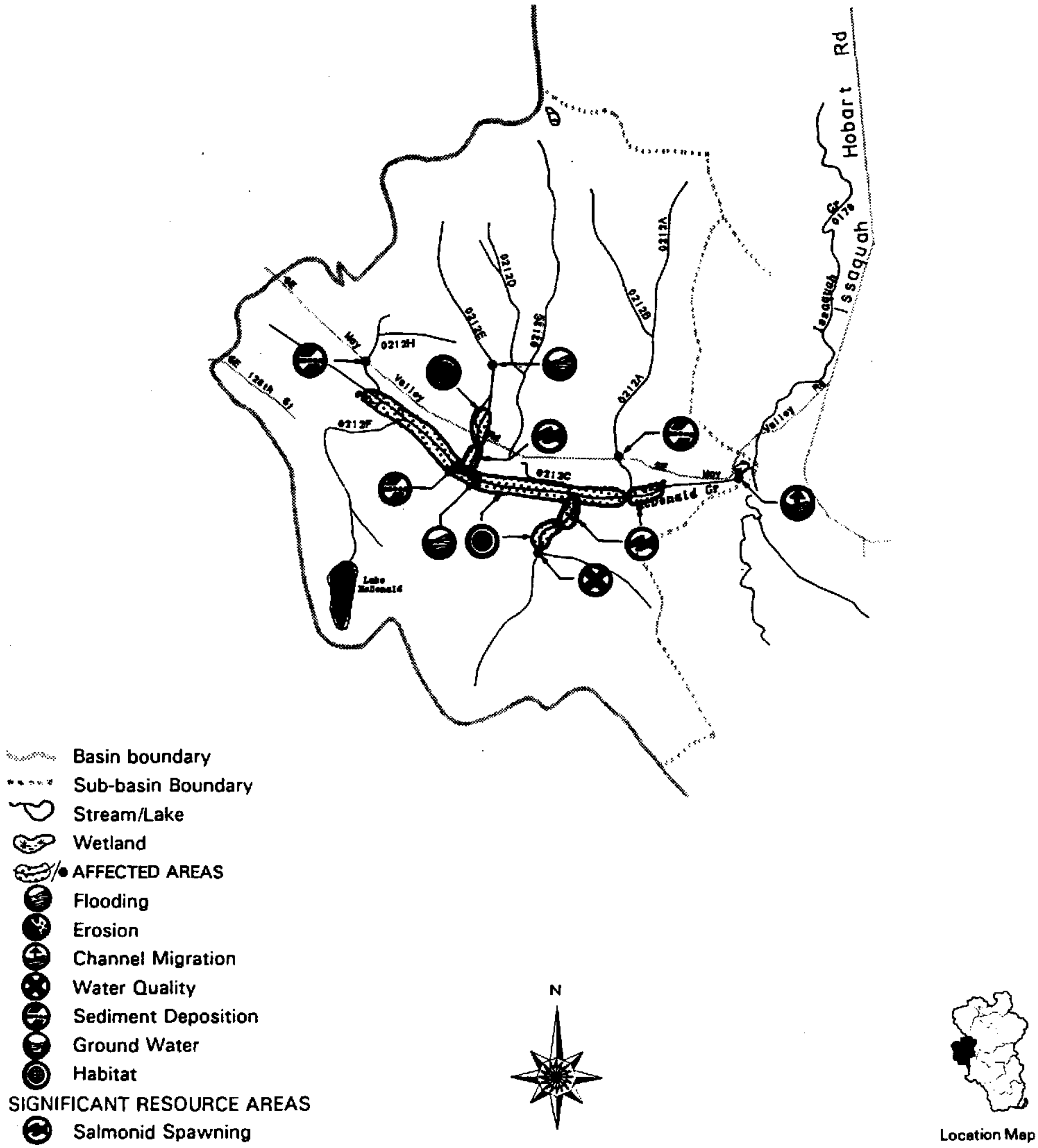
The area near McDonald Lake is one of three major regions in the Issaquah Creek planning area designated for urban development by the 1985 King County Comprehensive Land Use Plan (Yellow Lake and the Cougar and Squak Mountain areas of Tibbetts Creek basin being the other two). Forest lands will be reduced from their present 75 percent to an estimated 15 percent of the sub-basin in the process of development, and peak annual flows can be expected to increase dramatically. The Cedar Hills land-fill facility is partially located in this sub-basin.

11.4.2 Current and Future Sub-basin Conditions

<u>Flooding</u>

Flooding in this sub-basin is significant and has occurred in two main locations. The first is in the High Valley subdivision, located a few hundred yards north of SE May Valley Road along tributary 0212E, which has experienced localized flooding due to restricted culverts. The other site is in the Sunset Valley Farms subdivision, where at least one residence reported flooding twice during 1990 storms and, again, in April 1991. The Sunset Valley Farms is situated in a broad floodplain along McDonald Creek, portions of which are expected to extend an additional 450 feet in width as the sub-basin builds out.

Surface water flow is expected to increase significantly in this sub-basin as development occurs and natural features are replaced with impervious surfaces and lawns. When the sub-basin is built out, the current average 2- to 100-year peak flows of 226 cfs will increase to an estimated 358 cfs, a 58 percent increase. The large, projected increases in future flows will substantially



MCDONALD CREEK SUB-BASIN CONDITIONS

Issaquah Creek Basin Planning Area 0 1/2 1 Mile

Figure 11-4

aggravate those areas already flood-prone, as well as areas that are now flood-free. A site of particular future concern is the area occupied by houses upstream of 208th Avenue SE. The Sunset Valley Farms and other residential developments along the valley floor also will continue to be affected by flooding.

Erosion and Sedimentation

There is a fairly high natural sedimentation process in this sub-basin, owing to a system of steep lateral tributaries that feed a lower gradient main stream. Over the last several thousand years, the 0212 tributaries have built an alluvial fan almost 1 mile wide and over 2,000 feet long between the foot of Squak Mountain and McDonald Creek. This is a zone of pervasive, chronic sediment deposition, because the dramatic change in stream gradient mandates an equivalent change in transporting ability. Constrictions in the flow path, such as culverts under SE May Valley Road, serve to localize that deposition and amplify its impact. Similarly, increased runoff in the upland channels from hillside clearing and development activity does not change the overall processes occurring but can increase their rate. As a result of these increases, a greater load of sediment is now being delivered to the downstream system. In this sub-basin, these effects are being expressed by accelerated infilling of the main channel, particularly through the plat of Sunset Valley Farms.

Development adjacent to downstream tributaries will continue to experience the effects of naturally severe sedimentation, as tributaries deposit the sediment loads they carry from steeper, higher elevations. The level of development now beginning to occur in this sub-basin will significantly accelerate the natural sedimentation processes in this sub-basin.

Habitat

McDonald Creek is used by anadromous and resident fish. As tributaries 0212C and 0212E pass across the valley floor, the gradient lessens and conditions occur that favor salmon use of the stream for spawning. Coho use these streams from December through April for spawning and rearing, exiting the channels as they dry up in early summer. During the January 1990 storm and the last series of storms in November 1990, much sediment was delivered to the valley by these tributaries, causing channels to be scoured and widened and burying the lower reach of 0212E, which contains a habitat restoration project. Much of this sediment probably will be carried through the main channel by succeeding storms and into McDonald Creek. The creek's main channel, however, is quite flat, and the stream lacks the power to transport sediment of this size and volume.

Coho also uses the lowermost reach of tributary 0212I, which flows across the valley floor; cutthroat reside in its mid-reaches. This is a perennial stream that marks the upper limit of summer flow in McDonald Creek at RM 1.0. Tributary 0212I regularly receives drainage from

settling ponds at Cedar Hills landfill and, in a matter of minutes, turns from clear to khaki color. This material is a fine, suspended sediment from erosion on the landfill site. Its apparent release from the ponds only weakly coincides with rainfall.

At about RM 0.75, the gradient of McDonald Creek increases as the stream falls toward Issaquah Creek. The bed changes abruptly to gravel at the confluence with 0212A (a major gravel source). The stream assumes a low-gradient riffle character with pools at outbends and at obstructions, and the corridor becomes densely wooded. Coho use this reach extensively.

Water Quality

Metro's supplemental storm monitoring data for 1989-1990 revealed that McDonald and Tibbetts Creeks had the poorest measured water quality of all sites sampled in the Issaquah Creek system. Fecal coliform concentrations during storm events exceeded water quality standards on McDonald Creek by a factor of 15. Total phosphorus concentrations exceeded recommended guidelines (50 mg/L) at this and the other four sites measured during storm events in this time period.

11.4.3 Key Findings

- Naturally high levels of sedimentation in the sub-basin are being worsened by human activities associated with clearing and development. Constrictions in the stream (such as presented by culverts under SE May Valley Road) amplify sedimentation and flooding problems in several locations.

- Localized flooding has been reported in the High Valley subdivision. Residences in the Sunset Valley Farms subdivision reported flooding during the two 1990 storms and, again, in April 1991.

- Habitat conditions vary in this sub-basin. Tributaries 0212E and 0212C have reaches adequate for coho spawning and rearing December through April when flows are sufficient. Coho also use middle and lower sections of tributary 0212I.

- Instream habitat has been damaged by sedimentation in many places, such as in the lower reaches of tributary 0212E, where a habitat restoration project was filled with sediment during the 1990 storms.

- Metro's supplemental storm monitoring data for 1989-90 found some of the worst water quality in the Issaquah Creek system in McDonald Creek. Fecal coliform levels and phosphorus concentrations exceeded state recommended guidelines at one site in this sub-basin during storm events during these years.

11.5.0 FIFTEENMILE CREEK SUB-BASIN

11.5.1 Description of Fifteenmile Creek Sub-basin

The Fifteenmile Creek Sub-basin is 2,928 acres covering approximately 4.6 square miles in the eastern central Issaquah Creek basin (Figure 11-5). The creek has its headwaters on the southeastern slope of West Tiger Mountain. The mainstem, its three main tributaries, and several smaller ones comprise nine miles of stream channel, most of it high gradient and dominated by boulder and cobble cascades.

Ninety-five percent of the basin is presently covered by forest. This is expected to be reduced to about 72 percent under modified land uses these next 10 to 25 years. Peak annual flow frequencies presently average 351 cfs; that is expected to increase to 401 cfs when the sub-basin builds out -- a 14 percent increase.

11.5.2 Current and Future Sub-basin Conditions

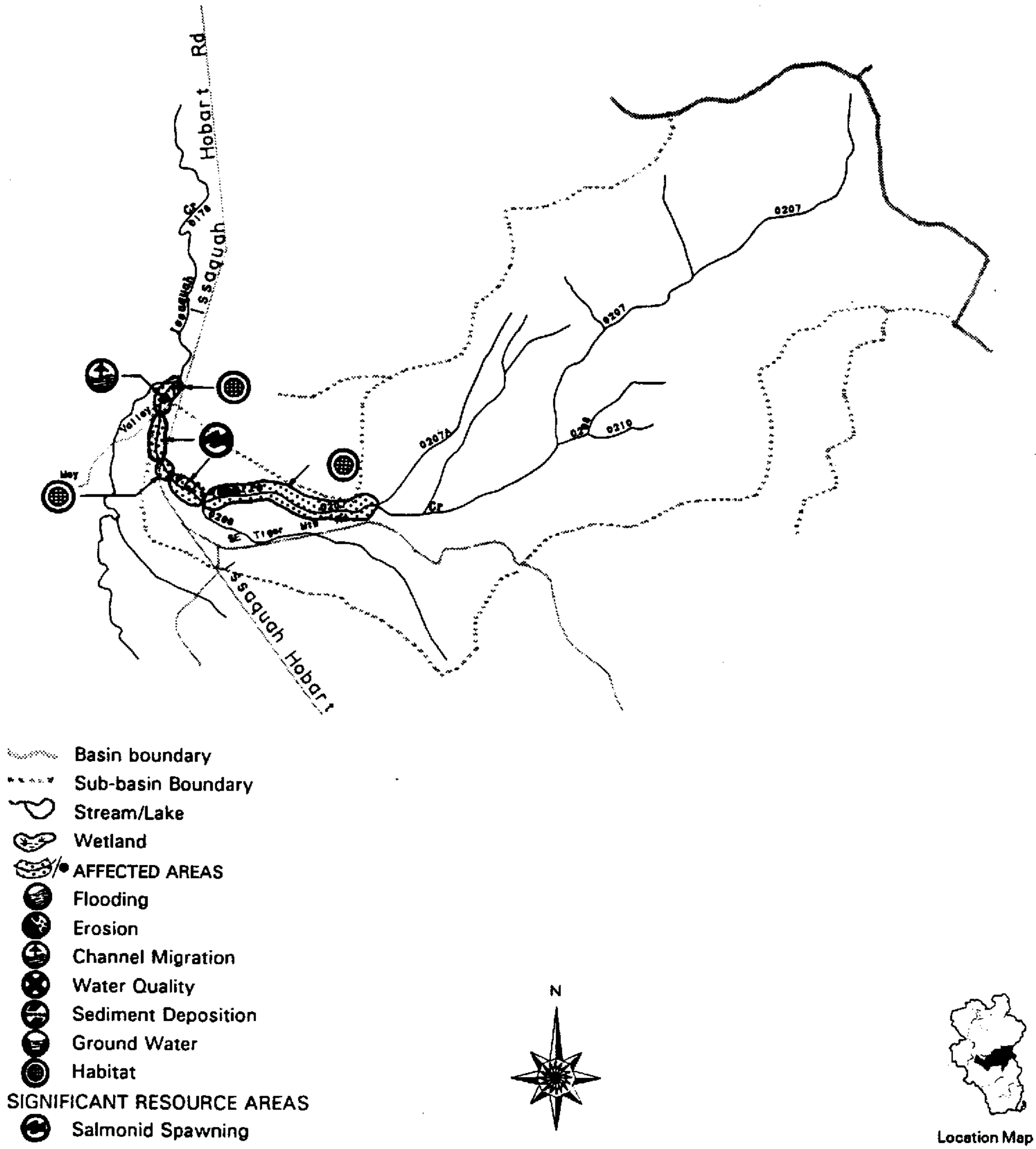
Introduction

With an average slope approaching 10 percent, this is one of the steeper sub-basins in the Issaquah Creek basin plan area. Consequently, the sediment transport within the channel also is most vigorous. Specific problems in this sub-basin are predominantly the result of its geography and the high energy of the Fifteenmile Creek.

Human-induced problems will continue to play a minor role in surface water problems in this sub-basin. Of all the sub-basins in the planning area, Fifteenmile Creek will have the least change in its land use patterns. This defines the sub-basin as a more stable area in terms of impacts from growth and the usual accompanying problems for natural systems. Still, the sub-basin is not presently problem-free; conditions found there now will need to be addressed, as will those additional ones anticipated in the years ahead.

Flooding

In spite of both natural- and human-inspired erosion and sedimentation conditions, there have been few reports of flooding in this sub-basin. This probably is explained by the relatively low rate of development that still prevails here; this condition is likely to continue.



FIFTEENMILE CREEK SUB-BASIN CONDITIONS

Issaquah Creek Basin Planning Area 0 1/2 1 Mile

Figure 11-5

Erosion and Sedimentation

One consequence of high-velocity flows is scour of the channel down to bedrock, a condition ubiquitous in the upper half of the sub-basin. As the channel moves out over its lower slopes, zones of both deposition and erosion become common.

High flows also cause damage to human-made structures. The January 1990 storm washed out a private culvert and associated fill on 252nd Place SE that provided sole access for 15 houses.

Localized areas of channel erosion, common throughout the system, are problematic in the vicinity of 240th Avenue SE, where development is encroaching on the stream corridor. The most immediate threat to a residence exists at the mouth of Fifteenmile Creek, where the channel flows through backyards and adjacent to a house. Bank armoring has been largely, but not completely, successful in minimizing the effect of large sediment deposits and the subsequent impact on homes and yards around it. The November 1990 storm resulted in additional channel migration in this area, however.

Wherever a steep channel, like that of the Fifteenmile Creek, meets a lower-gradient channel (e.g., Issaquah Creek), deposition of sediment load is almost unavoidable. This condition underlies the problem described above at the mouth of Fifteenmile Creek. This particular site, as well as others where steep channels and lower-gradient streams meet, should be monitored for change. In this sub-basin, future changes are likely but may be more a result of the normal dynamics of a natural stream system than of human disturbances within the watershed.

Habitat

A barrier to anadromous fish exists at RM 1.5 in the form of a bedrock cascade topped by an abandoned water supply dam of some 20 feet high. The reaches of the stream below the barrier are characterized by gradients of 1 to 1.5 percent and a shallow terrace or staircase profile, essentially a high-gradient riffle. The distance between steps is about two to three stream widths, and the steps are anchored with large cobbles and, occasionally, boulders. Habitat units here are small in size and not at all diverse. Despite the continuous presence of a well-vegetated riparian corridor, the presence of large woody debris is rare and unevenly distributed -- a condition owed to both natural and human factors. Of the latter, logging practices are a primary factor in that they include both the removal of logs and the burning of remaining woody debris in harvested areas. Little hydraulic diversity can occur when such large roughness elements are missing (or are homogenous in size and distribution). These conditions make habitat in this creek best for steelhead and searun cutthroat, rather than salmon.

Recent storms have moved large amounts of sediment in Fifteenmile Creek, some from channels at higher elevation, some from a culvert washout and major fill failure during the January 1990 storm. Whatever the origins, sediments fill and degrade instream habitat.

The amount and quality of instream habitat in the sub-basin will continue to be compromised by instability of the Fifteenmile Creek and its tributary channels and by the absence of large woody debris. While this will limit the use of streams by salmon, many streams should remain suitable for other salmonids.

11.5.3 Key Findings

- High flows during storms in January 1990 washed out a private culvert and road fill on 252nd Place SE. This has increased sedimentation downstream.

- Channel migration is affecting developed property at the mouth of Fifteenmile Creek. Bank armoring has been partially successful in reducing the threat, but the November 1990 storm produced additional channel migration and the continuing need for further bank protection.

- Flooding has not been a major problem in this sub-basin. This is expected to remain true under future land uses.

11.6.0 EAST FORK ISSAQUAH CREEK SUB-BASIN

11.6.1 Description of Sub-basin

East Fork Issaquah Creek originates on the north slopes of Tiger Mountain and flows down steep mountain sides in a relatively narrow channel to its confluence with the mainstem in a much broader valley below (Figure 11-6). The East Fork Issaquah Creek is a relatively energetic stream throughout most of its 7.2 miles' length. In its middle and upper reaches, this is expressed by numerous examples of recent bank erosion. As the creek emerges from this confining valley onto the floor of the main Issaquah Creek valley, much of the sediment eroded from upstream in the last several thousand years has formed a lobe-shaped alluvial fan underlying about 100 acres of the City of Issaquah, just west of the East Sunset Way interchange.

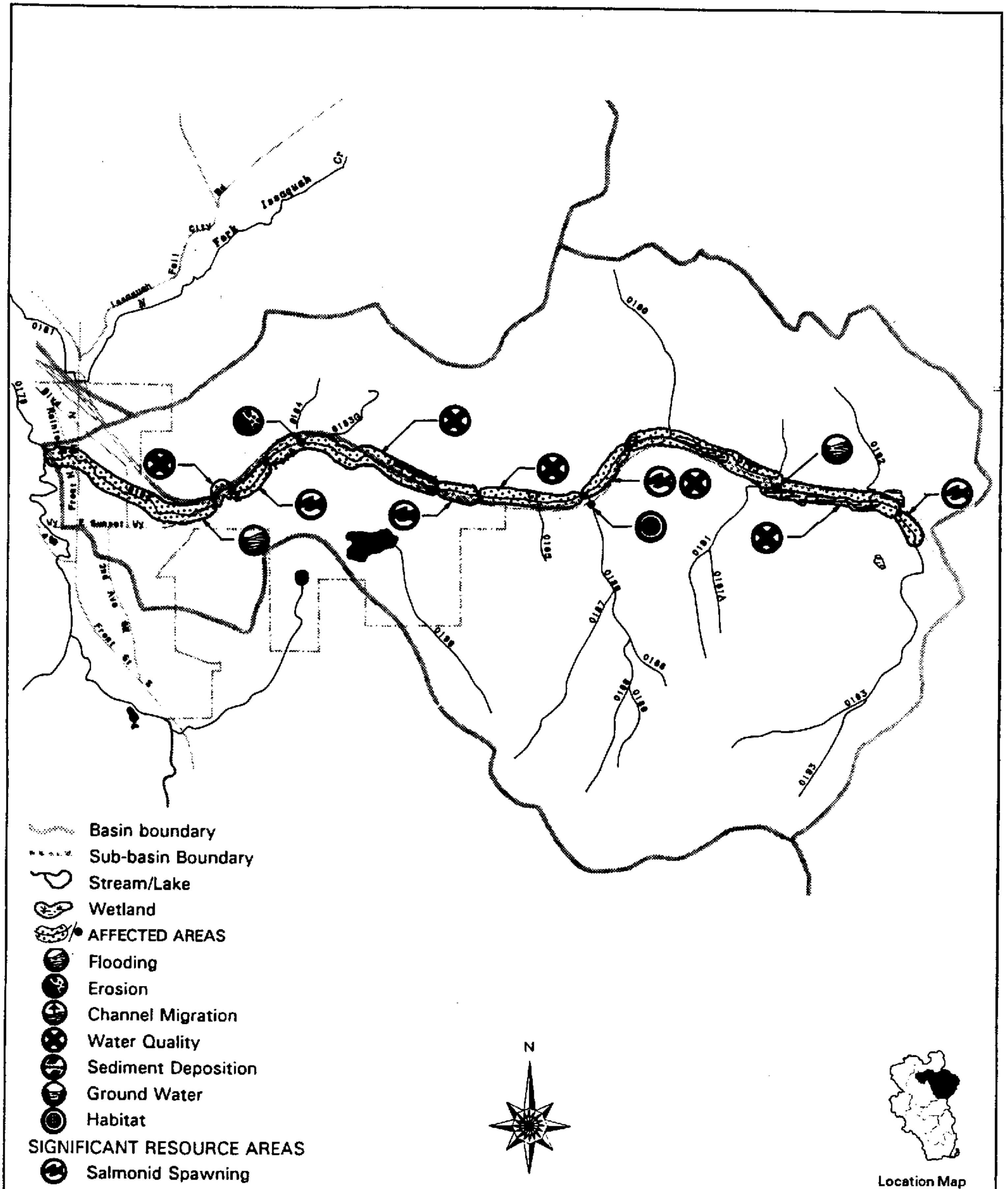
11.6.2 Current and Future Sub-basin Conditions

Introduction

The East Fork probably has seen greater physical alteration than any in the Issaquah Creek system, beginning with its early use as a log flume for the transportation of logs during the 19th Century. Early logging practices were generally destructive to forests and streams. In the East Fork area, logging denuded many hillsides in upland forests, loosening and sending sediment into streams. Transportation of the logs was also destructive, first to hillsides as logs were pulled across or slid down them, taking vegetation with them. Then, streams were altered to facilitate log transport. Sections of the stream bed were floored with timbers, and temporary splash dams were constructed. Logs then were stored in the impoundments behind dams. When sufficient numbers of logs were assembled, the dam supports were pulled away, and the rush of water carried the logs downstream to the mill or another holding area.

The effect of these practices on the stream was catastrophic, as the torrent of debris ripped through the channel stripping bed and banks of gravel and vegetation. There is still evidence of these practices along steep, vertical banks of the East Fork, where the unusually large size of the bed material and the large width-to-depth ratio indicate the channel has not yet fully recovered.

Present-day forest practices have improved only by degree, for the most part. A notable exception is occurring in the Tiger Mountain State Forest, where innovative forest management techniques are being tested. (These techniques include a 2000-acre conservation area in which wildlife and landscape management principles are major concerns.) Forest practices regulations require buffers on certain stream channels, but these are inadequate to protect riparian and instream resources from the direct effects associated with logging. In addition, small stream systems may have a difficult time resisting and recovering from mass alterations.



EAST FORK ISSAQUAH SUB-BASIN CONDITIONS

Issaquah Creek Basin Planning Area 0 1/2 1 Mile

Figure 11-6

Another source of problems for this stream system grew out of the construction of Interstate 90 in the 1960s. During construction, the creek was diverted and confined in many locations. Runoff from I-90, neither detained for water quantity control nor treated for water quality control, adds to the impacts on the system. As residential development expanded along the lower channel, the stream was armored and further constricted to facilitate home and road construction.

Flooding

Field investigation revealed that the East Fork Issaquah Creek is one of the streams in the Issaquah Creek planning area at greatest risk of serious flooding. The East Fork basin has two distinct flood areas. One area, in the upper portion of the creek above High Point Road, experienced overbank flooding in pasture areas during the January and November 1990 storms. The westbound lanes of I-90 also experienced water over the roadway during the November storm. The second area, below the Sunset Way entrance to I-90 in the lower part of the creek, flooded homes, yards, and roads during both storms.

The lower mile of the East Fork is constrained significantly by residential, commercial, and industrial structures in the floodway and floodplain. Consequently, flooding is causing major damage to these structures.

Under projected unmitigated land-use changes in the East Fork Issaquah Creek sub-basin, 2- to 100-year peak annual flows of 668 cfs are expected to increase by 22 percent. Floodplain modeling on the East Fork predicts that as many as 27 residences and one commercial building could be at least partially flooded by 100-year future flood conditions. (The 2- to 100-year peak annual flow estimate represents the average of the 2, 5, 10, 25, 50, and 100-year flow rates.) Depth of flooding could increase by as much as 0.7 feet, and the floodplain width is predicted to increase by as much as 180 feet in the lower portion of the stream, under future land use conditions without mitigation.

Erosion and Sedimentation

Local bank erosion in the upper reaches of the East Fork is common, particularly where the reconstructed channel has been excessively confined by adjacent roadway fills. Erosion also is evident on many of the northern tributaries that flow steeply off Grand Ridge, especially those from recently logged areas. Deposition of eroded sediment is not presently causing significant conveyance problems, except near the mouth of the creek at the Rainier Boulevard North bridge. However, zones of substantial sand deposition, found throughout the system, above the I-90 High Point interchange probably reduce the habitat value of this stream.

Habitat

Habitat in the East Fork system is in generally good condition and supports steelhead and resident anadromous strains of cutthroat trout throughout the system, as well as significant runs of sockeye, coho, and some chinook salmon in the lower reaches. Salmon are prevented from moving farther upstream than RM 5.5, where a water intake dam has been constructed. This dam probably has only limited effect on fish production as stream gradients above the dam are quite steep, ranging up to 10 percent, and habitat is more suited to trout. Below this barrier, fish habitat is generally quite good, except for some channelized reaches in the lower portion of the stream within the City of Issaquah.

From RM 4.4 to RM 5.0, the creek flows through a wetland within which stream flow is subsurface during extreme low-flow periods of summer. The creek itself, however, particularly from RM 2.3 to RM 3.2, where the stream and road are at their maximum distance apart, offers some excellent habitat. In this stretch, there are some outstanding pool and riffle habitats, lacking only in some large organic debris for additional complexity; boulder and cobble substrate provide good stability. This stream corridor is protected by a King County park that eventually will be part of a trail system extending to Snoqualmie Pass. The corridor also provides an excellent forest canopy, which, as the conifers mature, should provide even better habitat conditions. Park development, however, must be carefully planned to minimize human impact. Downstream, at RM 1.9, an extensive gravel bed provides excellent sockeye spawning among the boulders and logs.

Habitat in the East Fork system is threatened primarily by potentially erodible slopes in the upper tributaries on Tiger Mountain and by constriction of the stream bed produced by I-90 construction. The lower reaches of the East Fork extending from RM 0.0 to 0.4 has been extensively altered by urban development in the city of Issaquah. Here, as well, confinement of the channel has reduced stream bed stability and habitat complexity. Hardened banks will caused continued downcutting of the stream beds. Additional development upstream could intensify these channel problems and threaten habitat. However, presently large numbers of salmon spawn in this reach.

11.6.3 Key Findings

- o While other surface water problems have not been severe in this basin, there are areas that have experienced flooding. Area of flood damage include pastures just above High Point Road, the westbound lanes of I-90 below the Sunset Way entrance, and the floodplain of the East Fork Issaquah Creek between I-90 and the East Fork's confluence with the mainstem.

- o East Fork streams still show damage from logging practices of the last century. Evidence includes large width-to-depth ratio and the presence of large-sized bed materials

in many reaches. In some reaches, sedimentation and destruction to habitat have been the major consequences.

- Current regulations governing forest practices are still insufficient to protect East Fork Issaquah stream channels--the most heavily altered in this basin--from future harm.

- Except for those reaches damaged by logging practices, habitat in the East Fork system is generally good and supports large runs of salmon and other anadromous fish. Exceptionally good habitat exists between RM 2.3 and 3.2 where the creek is at its maximum distance from I-90.

11.7.0 NORTH FORK ISSAQUAH CREEK SUB-BASIN

11.7.1 Description of Sub-basin

The North Fork Issaquah Creek sub-basin covers 2,855 acres (4.5 square miles) of mainly low elevations (Figure 11-7). The North Fork Issaquah Creek, also known locally as Jordan Creek, begins at Yellow Lake and on the forested slopes of Grand Ridge; the creek flows 3.7 miles to its confluence with mainstem Issaquah Creek at River Mile 1.9. The North Fork creek, which occupies a prehistoric glacial meltwater channel, is a low-gradient stream fed by four much steeper lateral tributaries. The lower North Fork channel, in contrast, cuts down at the edge of the valley, dropping 200 feet at a 10 percent gradient to the mainstem Issaquah Creek valley floor.

The headwater catchment of the North Fork Issaquah Creek is being developed rapidly into a dense residential area, one portion of which is Klahanie, a planned development that surrounds Yellow Lake and its satellite wetlands. A second proposed development is Grand Ridge Estates, a parcel of 1875 acres on Grand Ridge. The Grand Ridge area is currently designated rural in the 1985 King County Comprehensive Plan. The area is also part of the current East Sammamish Community Plan update. Reclassification of the Grand Ridge area to urban has been proposed.

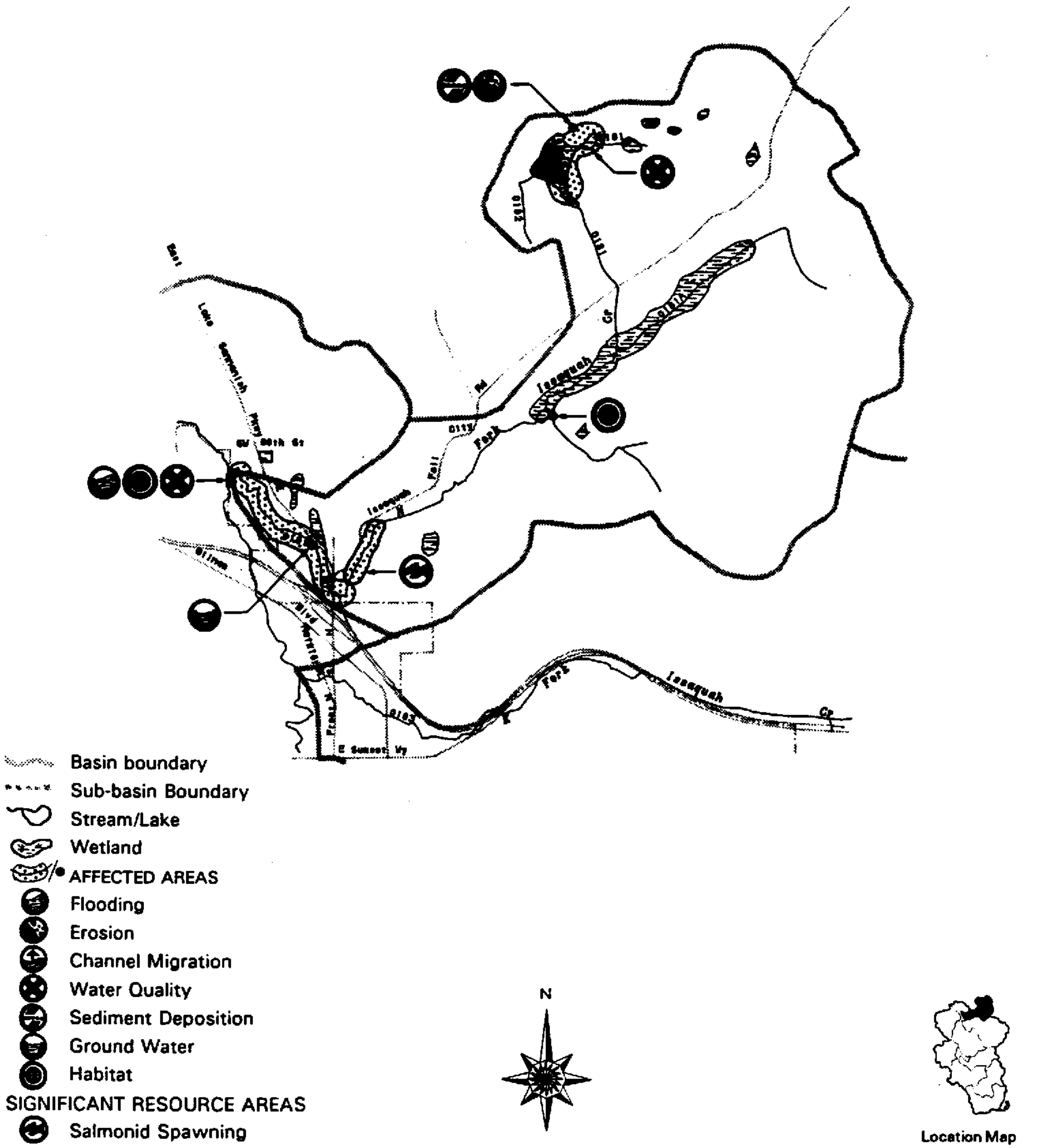
The largest and most diverse wetland systems in the Issaquah basin are located in the North Fork drainage. Residential, commercial, and mining development have partially degraded these wetlands and associated streams.

Approximately 72 percent of the sub-basin is presently covered by forests. Other major land uses are high-density single-family residential subdivisions and gravel mining. The 1985 King County Comprehensive Plan designates the portion of the North Fork Issaquah Creek sub-basin north of the Issaquah-Fall City Road for high-density and medium-density single-family housing. The area south of the road is designated primarily rural. When the sub-basin is fully developed in the next 10 to 25 years, the amount of land in forest will drop from its current 72 percent to only approximately 5 percent. In that same time period, impervious surfaces will increase from their present 3 percent level to approximately 18 percent.

11.7.2 Current and Future Sub-basins Conditions

<u>Introduction</u>

Peak annual flows are presently lower in the North Fork Issaquah Creek than in either the Tibbetts Creek system or the other sub-basins of the Issaquah Creek system. Two-year peak annual flows are 73 cfs, while 100-year peak annual flows are modeled at 260 cfs. Low levels of development (except for the Klahanie development), together with natural drainage systems



NORTH FORK ISSAQUAH SUB-BASIN CONDITIONS

Issaquah Creek Basin Planning Area 0 1/2 1 Mile

Figure 11-7

in the form of intact wetlands and large areas of forest and other natural groundcover in the sub-basin, explain these low peak annual flows. However, these flows are expected to increase dramatically (about 80%) as the sub-basin builds out these next 10 to 25 years.

Flooding

At present, flooding is confined largely to the lower portion of the channel below East Lake Sammamish Parkway SE. The gradient in this portion of the stream is relatively flat, and residences are constructed close to the banks of the channel. Roads and buildings in the area have been built close to the natural grade, and many may be affected by beaver dam building in this lower reach.

The incidence of flooding can be expected to increase in some areas of the sub-basin as natural ground cover is eliminated and replaced with impervious surfaces, lawns, and other artificial surfaces. Modeled flow frequencies under future land use designations predict that two-year peak annual flows will increase from 73 to 135 cfs, while the 100-year peak annual flows will increase from 260 to 463 cfs. Percentage increases in discharge ranges will be highest in this sub-basin, where catchment flow increases will exceed nearly 80 percent of their present amounts.

Three residences below East Lake Sammamish Parkway SE are at risk of being flooded during the 100-year flood under future conditions. Commercial buildings recently permitted along 221st Place SE will be constructed above the 100-year floodplain elevation for this creek.

Erosion and Sedimentation

The upper channel of North Fork Issaquah Creek flows through an extensive riparian wetland that acts as a repository for sediment eroded from surrounding uplands, most notably the Klahanie development around Yellow Lake. Land clearing here with poor or nonexistent erosion control since 1986 (and continuing at least as recently as 1990) has continuously discharged fine sediment to the lake and downstream tributaries to the North Fork. Additional clearing on the south side of the valley, on Grand Ridge, also has added to the sediment load.

The stream corridor between Yellow Lake and North Issaquah Wetiand 7 is easily eroded and already showing signs of erosion. As it passes into the wetland, the channel lacks definition and often flows sluggishly through the thick vegetation. Tributaries 0181A and 0181B also flow into Wetland 7. During the November 1990 storms, these channels unloaded large volumes of gravel into the wooded floodplains bordering them. The streams braided and shifted as they deposited their bedload.

Below RM 1.6, where the stream cascades over a 15-foot bedrock falls and descends steeply to the valley floor, boulders and large logs help to stabilize the stream. However, as the stream proceeds past the Lakeside gravel pit, some constrictions from road crossings have induced either erosion of abutments. However, no major erosion or sedimentation problems on this tributary are presently evident.

The channel of tributary 0181C, altered as part of a development proposal, experienced severe damage during the 1990 storms. Damage included erosion, large drops in the bed, and scouring around and under weirs. The new channel is built partly in sandstone, and structures placed on this substrate fared poorly during the storm; most are in need of repair. Downstream of these structures, the stream is downcutting through till and gravel and exhibits the signs of instability manifested in urban streams.

One potentially significant problem exists at the site of the Lakeside Sand and Gravel Company. Lakeside's sediment ponds are perched very close to a hillside leading down to the North Fork valley. Their seepage appears to have initiated at least one significant debris flow into the North Fork at about RM 1.5. Additional failures are also possible, both because seepage will continue and because the capacity of the ponds is being used up. In particular, the confining berm may not be adequate to withstand shaking from a major earthquake; it would almost certainly benefit from evaluation and possible redesign.

Habitat

The North Fork Issaquah Creek exits Wetland 7 and enters its canyon at about RM 1.6 over a 15-foot-high falls and a series of bedrock cascades that are the upper limit of anadromous migration. Coho carcasses were found at the base of this cascade in 1989. Large woody debris is common below the falls, but it seems too easily moved to provide much stability for habitat. The North Fork provides some spawning habitat for coho and sockeye salmon, but the gradient in the canyon precludes the formation of spawning riffles of sufficient size for salmon. The lower reaches provide rearing and feeding habitats for juvenile salmonids and may act as refuge areas during floods.

Field investigation revealed that high-quality riparian habitat is essentially absent in the last 200 yards of the North Fork, where it flows through a residential area. Other concerns in the lower North Fork include the possibility that shallow ground water withdrawal in late summer from water supply wells could reduce pool habitat for rearing salmonids. Fish also could be threatened by fluctuations in temperature brought on by low water flows. These last conditions would exacerbate any water quality problems in the lower system, producing disasters like the 1990 events that resulted in high mortalities of juvenile salmonids. These problems clarify the close hydrologic connection between surface and groundwater in the North Fork sub-basin.

As development continues near Yellow Lake, wetland area habitat will be lost for some species, such as herons and wood ducks. Other species, such as grebes, kingfishers, and otters, that require corridors for travel from wetland to another, can be expected to survive only at reduced levels.

Another concern is the increase of impervious surfaces tributary to wetland areas and subsequent impacts to natural upland infiltration processes. The conversion of interflow to surface flow may divert waters away from a wetland altogether. North Fork Wetlands 5 and 7 are both susceptible to this condition.

Water Quality

The State Department of Ecology (DOE) and City of Issaquah Public Works Department investigated major fish kills that occurred on the North Fork during storm events in late March and early April 1990. Water and tissue samples, taken from fish in the storm drainage system entering the North Fork at RM 0.2, were found to contain high concentrations of pollutants including metals, ammonia, sulfides, 1.2 Benzenedicarboxylic Acid, and Diisonyl Ester. They believe these substances acted in combination with low hardness to cause the juvenile salmonids' death.

Issaquah Salmon Hatchery Management believes that toxic conditions exist year-round downstream of RM 0.2 but are noticed only after fish release (and death) occurs. Two in situ fish bioassays using juvenile coho were used to evaluate the year-round toxicity in fall 1990, and in both cases fish in cages downstream of the outfall (RM 0.2) died shortly after placement in the stream. Fish placed in cages upstream of the outfall remained healthy.

A source identification sampling program, initiated in April 1990 under the auspices of State DOE and the City of Issaquah Public Works Department, will facilitate development of a plan for improving water quality in the North Fork at RM 0.2. This is essential for fish survival at, and below, this point.

During supplemental storm water quality sampling in the Issaquah Creek basin (April 24, 1990), one sample was taken from a drainage ditch in front of the Lakeside Sand and Gravel property along East Lake Sammamish Parkway. The sample revealed that the levels of phosphorus, suspended solids, turbidity, and copper exceeded recommended standards. The gravel mining operation has been a historical source of sediment and pollutants to the North Fork Issaquah Creek.

Wetlands 5 (Yellow Lake) and 7 are rated unique/outstanding because of their nearly equal proportions of open water to dispersed vegetation. Yellow Lake has had large portions of its surrounding forest cleared in the last 10 years. This urban encroachment has produced major sediment sources for the wetland and its streams during construction. Investigators found a

sediment plume visible in Yellow Lake -- the result of stormwater runoff -- in spite of a filter berm (erected in the wetland). In addition, developers have built a viewing dock into the wetland and a trail system near its edge. Trash and debris are collecting in this once pristine wetland. These conditions threaten both habitat and natural filtration processes associated with good water quality. They also have downgraded the area's aesthetic qualities.

11.7.3 Key Findings

- Three existing residences along the lowest reach of the North Fork below East Lake Sammamish Parkway SE are expected to experience flooding under future unmitigated 100-year flow conditions.

- Tributary 0181C flooded in its lower reaches in the November 1990 storm, severely damaging channel and drainage structures. The channel had been altered as part of a housing development. The new stream bed, built partly in sandstone and bedrock, and the structures placed in this substrate need repair.

- Urbanization has worsened the sub-basin's water quality. Samples taken in the North Fork at the Front Street on-ramp to I-90, and on the creek near the Lakeside gravel facility, reveal that the levels of phosphorus, suspended solids, turbidity, and copper exceed recommended standards. Nonpoint pollution, including grease, oil, metals, fecal coliform, and nutrients are concentrated in storm drains during storm events. Fish kills along the North Fork in 1990 have been one of the consequences.

- The destruction to riparian habitat surrounding Wetland 7 and its satellite wetlands has resulted in overloads of sediment to these natural filters, as well as a loss of fish and other wildlife dependent on the water and adjacent habitat.

- Seepage appears to have initiated at least one major debris flow into the North Fork near RM 1.5, at the site of the Lakeside Sand and Gravel Company's sediment ponds. The ponds are perched very close to a hillside above the creek valley. The possibility of additional seepage and berm failure is compounded by the berm's likely insufficient strength to withstand a major earthquake.

11.8.0 LOWER ISSAQUAH CREEK SUB-BASIN

11.8.1 Description of Basin

The Lower Issaquah Creek sub-basin covers an area of 5708 acres in a large, irregularly-shaped area that begins in the narrow valley between Squak and Tiger Mountains, just upstream of the City of Issaquah (Figure 11-8). The City of Issaquah and its peripheral development dominate much of this sub-basin, which has been severely altered by both natural processes and human activities over the last decades. Most important among the natural processes are stream channel migration, particularly in Issaquah Creek's lower reaches, as well as high levels of sedimentation and flooding. Historic and present development has exacerbated these conditions, and the sub-basin is confronted by a future in which existing problems will worsen as stream flows increase.

11.8.2 Current and Future Sub-basin Conditions

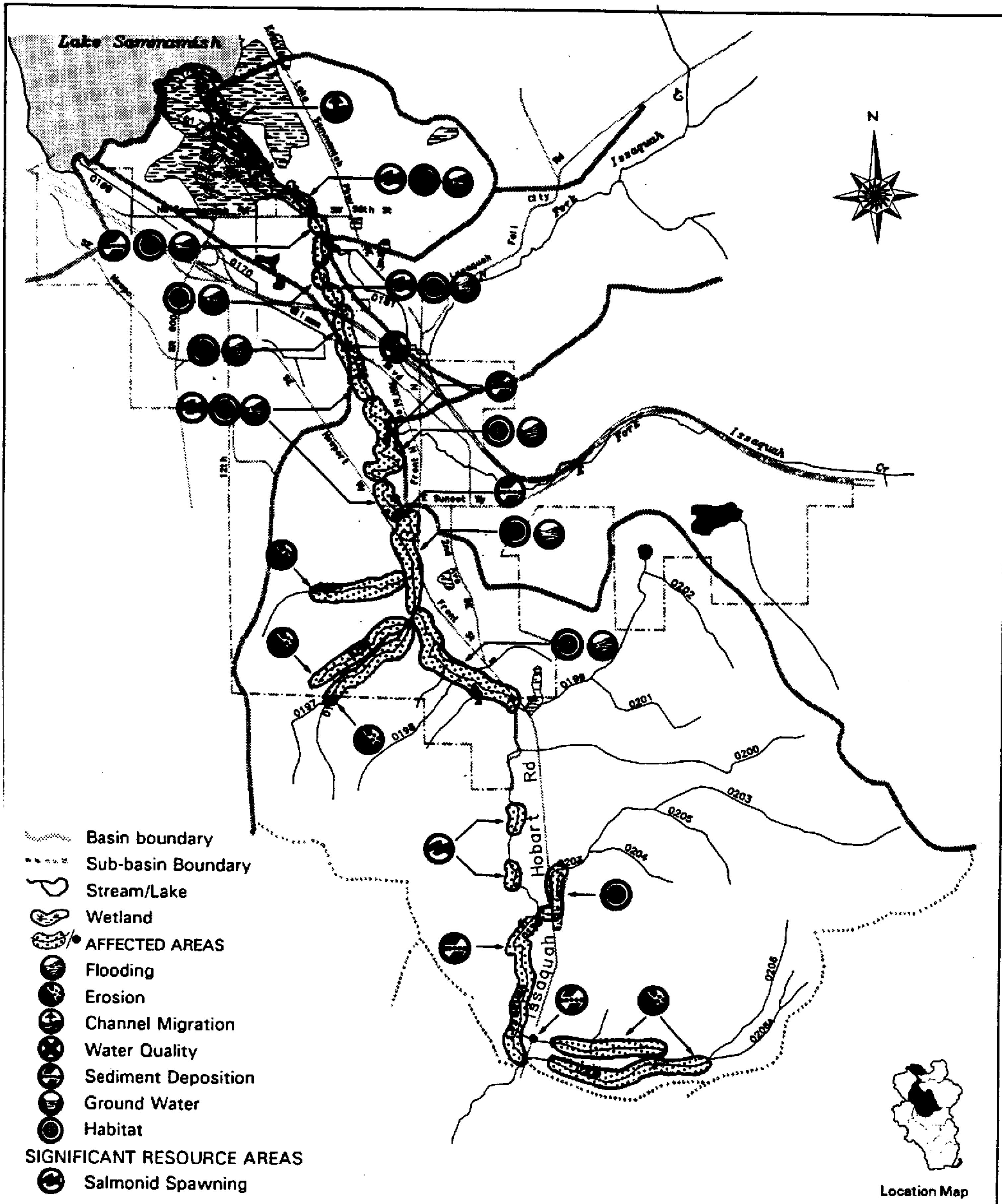
__Flooding__

Lower Issaquah Creek sub-basin experiences the most serious flood damage of any sub-basin in the Issaquah Basin Planning Area. Property losses from flooding are among the most extensive in the County. Pasture and yard flooding, as well as bank erosion, occur during major storms along Issaquah Creek from the confluence of McDonald Creek to SE Sycamore Place. Culverts conveying No Name and Nudist Camp Creeks under the Issaquah-Hobart Road clogged with sediment twice during 1990, closing the road. Other stream culverts in this portion of the sub-basin require frequent maintenance.

The stream channel adjacent to Front Street South frequently overflows its right bank, flooding several houses at 2nd Avenue SE. Single- and multi-family residences from SE Sycamore Place to Gilman Boulevard are sandbagged during major storms to minimize flood damage. The worst damage occurs in the reach between Clark Street and NW Holly Street. The Washington State Department of Fisheries hatchery at Sunset Way has sustained both property damage and loss of fry at least three times since January 1990. Flooding of roads regularly occurs at Clark Street, Front Street S, and Gilman Boulevard.

At least two private property owners along this reach have constructed flood walls around their properties. These walls may cause accelerated bank erosion and a rise in water surface elevation during high flows, particularly when they are in the floodway or a high-velocity portion of a flood flow. The extent of the effects of the flood walls on future conditions will be difficult to assess until the walls have been included in the Issaquah Creek floodplain modeling.

Increased flows will cause corresponding increases in floodplain elevations. Additionally, if current land uses continue to intensify adjacent to the creek, more people will be exposed to



LOWER ISSAQUAH SUB-BASIN CONDITIONS

Issaquah Creek Basin Planning Area 0 1/2 1 Mile

Figure 11-8

flooding hazards, and property damage will increase. As property owners take individual actions (e.g., constructing flood walls) without consideration of floodplain and floodway hydraulics, additional impacts, such as local increases in flood elevations or erosion, will be experienced on adjacent properties and all along the stream channel.

Erosion and Sedimentation

The lowermost 7 miles of Issaquah Creek, together with its local tributaries, include some of the most diverse and active channel conditions in the basin. Channel infilling, bank erosion, and migration are all active in portions of this sub-basin, particularly at the upstream end of this sub-basin and downstream of SE 56th Street in Lake Sammamish State Park. Even more significant than the absolute rate of activity, however, is the proximity of developed land uses to the channel's activities. In particular, channel migration in the Sycamore development is consuming the setbacks of houses from the stream at a rate that would eliminate them altogether in the next few decades. Infilling of the channel through the city of Issaquah is reducing flood capacity, a growing problem primarily because of the severe encroachment into the floodplain of Issaquah Creek by a number of roads and houses.

Lateral tributaries flowing off Squak Mountain, particularly those on the northeastern side (0194, 0195, and 0196) carry significant amounts of sediment into Issaquah Creek. This may be the result of significant headwater development with minimal or no detention. Tributaries off Tiger Mountain, particularly 0200, also suffer bank erosion and downstream deposition. For example, where tributary 0203 is diverted for 1,000 feet along the Issaquah-Hobart Road, deposition is artificially localized by the abrupt decline in gradient. This site, where overtopping of the channel onto the highway occurred during both the January and November 1990 streams, requires regular dredging.

Sediment load has a direct effect on operation at the State fish hatchery. Coarse sediment descending Cabin Creek (tributary 0194) has contributed to partial clogging of the main hatchery water intake, just downstream of the confluence with Issaquah Creek, several times in the last 5 years. This reduces the water supply to the hatchery, threatening the incubating eggs and juvenile salmon. A small settling pond at the mouth of Cabin Creek has been only partially able to lower the volume of sediment carried by this tributary. Another, more pervasive threat to the hatchery has arisen from the quantity of fine sediment carried by the flood flows of Issaquah Creek. Silt-sized particles too small to settle out once they have become entrained, settle on the incubating eggs and can cause suffocation if not washed off. During major floods, this can occur for up to several days at a time.

No Name and Nudist Camp Creeks contribute the major sediment load to the valley of the lower Issaquah Creek. Sediment originates in their headwaters where extensive recent logging has induced erosion in steep channels. The pattern of historic stream-channel braiding suggests that

one or both of these channels episodically contributed to sediment in Issaquah Creek, even before recent logging.

Problems of erosion and deposition in the steep tributaries, and migration and infilling of the mainstem, are largely driven by the magnitude of flows in the channel. Development-induced flow increases, therefore, are likely to accelerate the rate of these processes when effective mitigation efforts are lacking.

Habitat

The section of the mainstem from its confluence with Lake Sammamish to SE 56th Street (RM 1.2) serves primarily as transport and rearing habitat for salmonids and provides spawning areas for bass, perch, and suckers from the lake. Through this reach, mean stream width is over 30 feet, and pools often exceed 6 feet in depth and 2000 square feet in surface area. The bottom is fine sand and silt. The stream flows over floodplain sediments of its own deposition; it is quite sinuous, curving back onto itself several times in the first mile. One particular bend, at about RM 0.5, appears near to being cut off as the stream erodes the deposited sediments that separate the curves. There is surprisingly little LWD in this reach, with the exception of a debris jam near the mouth and a few old submerged snags. The corridor is dominated by red alder, black cottonwood, red-osier dogwood, snowberry and a willow. Evidence of beaver and deer is common.

During the October 1989 survey, chinook and sockeye were observed building redds in the riffles at RM 0.6, where the gradient increases slightly and gravel begins to appear as bed material. Upstream toward SE 56th Street the channel assumes a pool:riffle character excellent for spawning salmon, as evidenced by the number and size of the redds and by the presence of juvenile chinook, coho, steelhead, and adult resident cutthroat and rainbow in the summer of 1989. LWD is sparse at this location, not surprising in that few conifers are found on banks and the recruitment of LWD depends on rather small deciduous trees. Large, well-anchored debris of cedar and hemlock does appear intermittently to provide the extensive hydraulic diversity that appears to be causing the channel to deepen in places and to contain sediment storage necessary for bars and riffles.

Residences line the banks above SE 56th Street (RM 1.2) and reduce the riparian habitat to less than 100 feet in most places. LWD, removed regularly by local residents, is even more sparse here. Even so, habitat is sufficient for chinook, coho and sockeye to be observed spawning throughout this reach in the 1989 survey.

Upstream of Interstate 90 (RM 2.0), to about SE 96th Street, the creek flows through the main portion of the City of Issaquah. It is joined by the North Fork at about RM 1.5, the East Fork at about RM 2.4, and by four smaller tributaries between RM 2.4 and 4.5. Quantities of broken concrete and large angular rocks used for bank protection throughout this reach have fallen into

the stream in many places, rendering banks sterile and providing little in the way of habitat for fish or riparian zone species. Tires, trash, grass clippings and other discarded human debris are also common along this stretch. Even though moderate densities of salmon species were found to spawn and rear up to the hatchery weir in October 1989, the lack of cover in this reach exposes them to predation and disturbances, and spawning success is probably reduced by an absence of LWD and shallow pools.

The Issaquah State Salmon Hatchery diverts almost all chinook and coho to its facility, allowing other species of salmon to pass upstream to spawn. Sedimentation conditions at the hatchery were discussed immediately above in the "Erosion and Sedimentation" section.

The stream flows through a sparse residential area to about SE May Valley Road (RM 7.3). Upstream of the road, Issaquah Creek flows through a predominantly agricultural area below the confluence of Holder and Carey Creeks (the beginning of the mainstem, RM 11.4). Several small tributaries flowing off Tiger Mountain enter the stream in this reach, including 0203 and 0203A, which support coho populations as well as perhaps spawning habitat for Lake Sammamish kokanee. These streams are not accessible along their whole length, however, due to steepness or to constructed barriers.

<u>Wetlands</u>

Seventeen problem sites in Issaquah Creek wetlands were identified during the conditions study. Examples of specific problems found at wetlands include small concentrations of debris and garbage at Issaquah Creek Wetlands 1, 2, 3, and 7 at the boat launch ramp and State Park. In addition, there was evidence of heavy foot traffic on Wetland 2; yard trimmings and other yard debris at Wetlands 5 and 15; filling to create a berm at Wetland 15; an abandoned vehicle at Wetland 16; large concentrations of household garbage and trash at Wetland 53; and drainage of Wetland 55. Water quality deterioration and increased loading of pollutants are the consequence of such damage to wetlands. Urban stormwater drainage into wetlands also contributes to pollution and other wetland damage.

The deterioration and loss of wetlands could continue as development continues in the Lower Issaquah Creek sub-basin. Half of those remaining are predicted to receive a severalfold increase in total loadings, unless actions are taken to prevent the release of pollutants or to interrupt their transport.

11.8.3 Key Findings

- Flooding is a serious problem in the Lower Issaquah Creek sub-basin, where residential and commercial structures have been built in the floodplain. This includes the stream channel along Front Street S, which often overflows its bank, flooding homes at 2nd

Avenue SE; and from SE Sycamore Place to Gilman Boulevard, where residences must be sandbagged during major storms.

- At least two private property owners along this reach have constructed flood walls, which may cause accelerated bank erosion and a rise in downstream water surface elevations during high flows.

- The state hatchery at Sunset Way has sustained both property damage and loss of fry at least three times since January 1990, from flooding. Sediment loads regularly affect operations at the hatchery by clogging water intake systems and depositing fine silts that suffocate incubating eggs and juvenile salmon.

- Channel migration in the Sycamore development is consuming the setbacks of houses at a rate that will eliminate them altogether in the next few decades.

- Seventeen problems at Issaquah Creek wetlands were found in the conditions study, including concentrations of garbage at Wetlands 1, 2, 3, 7, and 53. Other problems included filling to create a berm on Wetland 15, an abandoned vehicle at Wetland 16, and drainage of Wetland 55.

11.9.0 TIBBETTS CREEK BASIN

11.9.1 Description of Basin

The Tibbetts Creek basin is a region of 3,640 acres (almost 6 square miles), located one mile west of Lower Issaquah Creek (Figure 11-9). Although it forms a separate waterway, not tributary to Issaquah Creek, Tibbetts Creek shares a floodplain with Issaquah Creek in the City of Issaquah. During storms, the overbank flows from Tibbetts and Issaquah Creek systems merge on the floodplain to produce flooding at numerous locations, especially along NW Gilman Blvd. In addition, the problems present in Tibbetts Creek basin are of the same type and general intensity as those exhibited in neighboring Issaquah basin.

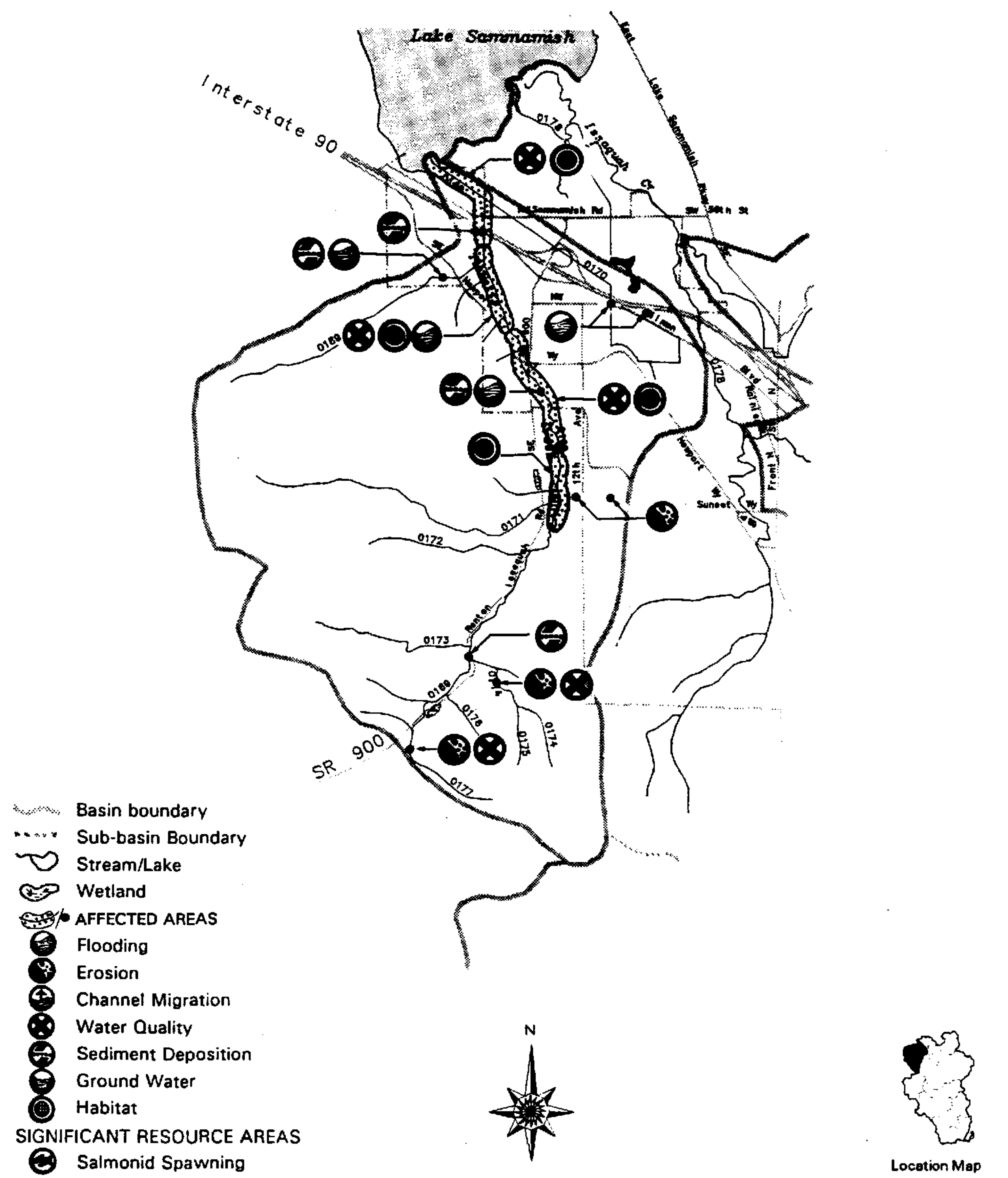
Tibbetts Creek is a low-gradient trunk stream fed by steep-gradient tributaries flowing off the surrounding uplands of Squak and Cougar Mountains. The mainstem enters its central valley, along the Issaquah-Renton Highway, near the south basin boundary at about 400 feet elevation (RM 3.6) and falls to elevation 100 feet over the next 1.9 miles (RM 1.7), for an average slope of 3 percent. The Tibbetts Creek system carries large amounts of sediment to lower elevations and deposits it on the floodplain and delta.

The 1985 King County Comprehensive Plan designates a mixture of urban, rural, and open-space land uses for the Tibbetts Creek basin. At present 80 percent of the basin is in rural land uses, primarily forestry and agriculture. One notable exception to this is the bedrock mining carried on at the Sunset Quarry on upper Tibbetts Creek. The basin will undergo major development pressure in the future, with potential accompanying impacts on natural systems.

11.9.2 Current and Future Basin Conditions

<u>Introduction</u>

There has been substantial alteration to some portions of the basin through the years in the form of stream channelization; the construction of homes (in and near the City of Issaquah), public facilities (including I-90 at the sub-basin's eastern border), and commercial enterprises (such as shopping areas and light industrial facilities between I-90 and Newport Way); and the continued mining for bedrock at the Sunset Quarry on upper Tibbetts Creek. Some of these activities have had a variety of detrimental effects on the creek and surrounding habitat and have produced problems that need to be addressed. Tibbetts Creek basin will continue to experience surface water management problems as it builds out in the next 10 to 25 years. This will include reduction of forest lands from their present 80 percent of the basin to approximately 30 percent, increased amounts of impervious surface through construction of residential and commercial structures, and roads.



TIBBETTS CREEK SUB-BASIN CONDITIONS

Issaquah Creek Basin Planning Area

0 1/2 1 Mile

Figure 11-9

Flooding

The most serious of the current problems facing the Tibbetts Creek basin is flooding. For example, the Tibbetts Creek stream bed is severely channelized where it runs alongside 19th Avenue NW, between SE 65th Street and NW Poplar Way. The commercial and light industrial buildings in the area experienced flooding at this site in the January and November 1990 storms. Afterward, property owners built a gravel berm along the east side of the creek to contain high flows and prevent flooding. While the berm's effect has not yet been evaluated through simulation modeling, it has the potential to raise water levels in the creek and cause increased flooding in downstream locations.

Flooding also occurred during the 1990 storms on Gilman Boulevard where it crosses tributary 0170 near Interstate 90. Water from this tributary is partially responsible for flooding the commercial buildings along NW Gilman Blvd.

While there has been minor flooding downstream of SE 56th Street, at Lake Sammamish State Park and nearby undeveloped land, there has been no property damage reported to date. The State Department of Transportation annually removes in excess of 1000 cubic yards of sediment from Tibbetts Creek where it crosses I-90. The Lake Sammamish State Park, through which Tibbetts Creek flows as it empties into Lake Sammamish, also incurs maintenance costs to dredge the creek of sediment. This helps prevent flooding of the park access road.

The January and November 1990 storms also produced flooding in pastures, Tibbetts Manor Park, and at a nursery above Newport Way when Tibbetts Creek overflowed banks that had been channelized. Floodwater overflowed tributary 0170, exacerbating flooding problems along NW Gilman Blvd. The main channel in this area is a deposition zone for sediment from the upper reaches of the basin, and sediment deposited during earlier storms reduced the channel's capacity. No houses, but several private bridges, were damaged above Tibbetts Manor and extensive damage occurred to some residences and numerous businesses below Tibbetts Manor.

Another major flooding area occurred in the Summerhill subdivision which is situated along tributary 0169A. This development was constructed in 1985 and built on the alluvial fan of the stream. The stream was moved to the south edge of the property into an underfit straight ditch. During the January 1990 storm, this stream overflowed the new channel and tried to reclaim its old channel through numerous homes in the subdivision, resulting in extensive damage to residences.

Hydrologic modeling predicts that maximum build out in the basin during the next 10-25 years, without onsite detention facilities for surface water runoff, will result in a 43 percent increase in peak annual flows in the Tibbetts Creek system. This will aggravate existing flooding problems and introduce flooding in previously flood-free areas. The duration of flooding will increase, as will the severity of erosion and sedimentation problems. Under current conditions,

the two-year peak annual flow is 194 cfs on Tibbetts Creek. By comparison, the 100-year peak annual flow is 521 cfs. Those figures would be 70 percent higher, as shown by modeling for future unmitigated land use.

Erosion and Sedimentation

Steepness of streambeds throughout the Tibbetts Creek basin produces a very energetic system, resulting in faster erosion and sediment transport rates than in the Issaquah system. Two quarries on the west side of Squak Mountain are the primary sources of large sediment loads to the downstream system. The lower site, an abandoned clay pit, occupies about 10 percent of the tributary area to streams 0174 and 0175. The steepness of the area, abundance of loose mine tailings in erosional contact with the two streams, and complete absence of erosion control guarantees downstream impacts. The second, active operation is the Sunset Quarry, which occupies over half the tributary area of Tibbetts Creek above SR 900. This quarry's sediment control pond has failed repeatedly, in part because the entire upstream flow of Tibbetts Creek is routed through it. Adjacent May Creek also has been affected by problems of turbidity and high sediment loads originating at Sunset Quarry. The County's Building and Land Development Division (BALD) is presently taking enforcement against the quarry.

Urban development is also creating sediment-related problems in the sub-basin. Several small tributaries receiving storm drainage from the upper reaches of the "Mountain Air" residential development on the northwest slopes of Squak Mountain are eroding, with resulting threats to downstream structures along SE 83rd and SE 82nd Streets. These also contribute to the sedimentation problems in Tibbetts Creek.

Anticipated changes in land use, based on the Newcastle community plan approved zoning, are expected to increase greatly the amount of low-density single-family housing and commercial development in the Tibbetts Creek basin in the next 10 to 25 years. This trend toward urbanization will reduce the present amount of forest land by more than half and will increase significantly the amount of impervious surfaces. In addition, the clearing of land and construction of homes and other facilities will affect the Tibbetts Creek system and basin by creating new sources of sediment.

Habitat

Current habitat throughout the drainage ranges from only fair to very poor, the result of reduced stream channel stability. The headwaters of the creek are located in the Sunset Quarry on the eastern slopes of Squak Mountain. From these headwaters, the stream drops steeply for 2 miles through a narrow valley. The Renton-Issaquah Road follows this valley, and in several places it confines the stream channel. The channel in this reach is exhibiting a high level of instability and increased substrate mobilization. Much of this may be due to sediment inputs and channel

erosion problems in several lateral tributaries and in the headwater areas. The problems have been precipitated by activities associated with the gravel mining and logging operations. Likely mechanisms for such changes include increased rill erosion, landslides and road failures, and a loss of large channel-stabilizing woody material.

At RM 2.5, the valley opens up and the stream gradient lessens considerably. The land uses here change from forestry and mining to hobby farms, all of which are having severe impacts on fish habitat. Impacts are in seen in the form of eroding banks, lack of streamside vegetation, and loss of instream habitat complexity. Many of these problems were worsened by the January 1990 storm and subsequent landowner efforts to fix perceived channel problems. This is particularly evident at RM 1.15, RM 1.22, and RM 1.5.

At RM 1.4, the creek crosses Newport Road and flows onto the historic alluvial plain formed by Tibbetts and Issaquah Creeks. The stream has been extensively impacted by urbanization and light industry associated with development along the corridor of Interstate 90. Most of the channel between Newport Road and the mouth has been straightened and confined by local development. The result is a much-reduced habitat complexity. That, in turn, results in lowered productivity for salmonids.

Water Quality

Although the State Department of Ecology (DOE) classifies all waters in the Issaquah Creek and Tibbetts Creek basins as Class AA (extraordinary) or Class A (excellent), the waters rarely meet these standards, particularly during storms. Beneficial uses of instream, small lake, and Lake Sammamish are being affected by pollutants in the form of sediment, animal feces, and phosphorus.

One of the most serious of these problems exists on Tibbetts Creek at river mile 3.0, where Kelly's Stables are located. Pastures here continue to be overutilized, with some 40 horses (total) kept on two parcels of 1-2 acres each. Although animal access to the stream is restricted, water quality continues to be degraded by runoff carrying large amounts of nutrients, sediment, and bacterial concentrations.

Tibbetts Creek water quality also is worsened by nonpoint source pollutants, including residential and commercial use of pesticides and fertilizers, and by heavy sedimentation resulting from forest practices in this heavily-wooded basin. Unpermitted logging is being carried on at two different sites in the basin.

Another serious problem exists at RM 3.5 where stormwater and sediment control ponds at Sunset Quarry continue to be inadequate or failing. An enforcement action by King County Building and Land Development (BALD) is the most recent attempt to solve this ongoing problem.

Given the degree of saturation of soils in winter, water quality will continue to be threatened if livestock pasturing is continued at the present levels and practices. Sedimentation and its associated problems also will continue to worsen through development, with gravel beds being densely infiltrated with fine silts and sands that fill pools and cause turbidity in running water during rainfall.

11.9.3 Key Findings

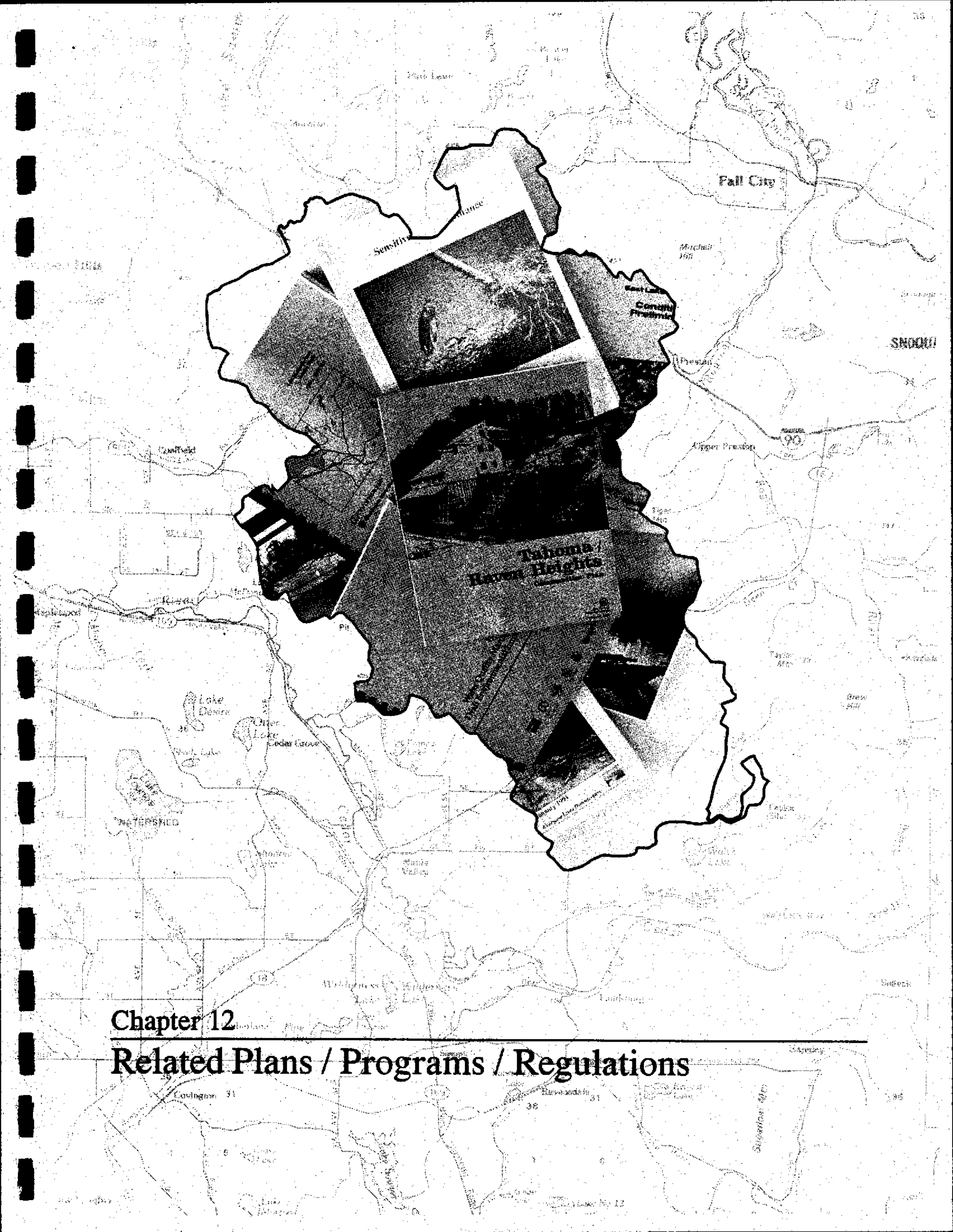
- o An ineffective sediment control pond at the Sunset Quarry is causing exceptionally high sediment loads and turbidity in both Tibbetts Creek and May Creek. A major source of the problem lies in the routing of Tibbetts Creek through the undersized sediment pond and in a general lack of effective erosion control.

- o Areas experiencing major flooding include (1) portions of the commercial area along NW Gilman Blvd., (2) pasture land and a nursery above Newport Way, and (3) the light industrial area on Tibbetts Creek between SE 65th Street and NW Poplar Way. The second site has not suffered property damage. The third site is alongside a channelized portion of the creek; as a remedy, property owners have constructed a gravel berm to prevent further localized flooding. However, the berm's effectiveness has not been tested and it may produce increased flooding problems downstream.

- o Extremely poor water quality problems exist at RM 1.8 where Kelly's Stables are located. Forty horses pastured on less than four acres here are the source of high bacterial counts, nutrients, and sediment in the creek.

- o Flooding in the Tibbetts Creek basin can be expected to increase over the next 25 years as the area urbanizes. Without mitigation, peak flows will nearly double as forests and natural vegetation are replaced with impervious surfaces and lawns. Homes and other facilities built along creek banks and in the floodplain will be affected the most seriously.

- o Salmonid habitat downstream of RM 2.5 has been negatively affected by upstream forestry and quarrying, and by lowland hobby farming. Eroding banks, lack of streamside vegetation and loss of instream habitat complexity (all worsened by the January 1990 storms) are most serious at RM 1.15, 1.22, and RM 1.5.



Chapter 12

Related Plans / Programs / Regulations

CHAPTER 12: RELATED PLANS, PROGRAMS, AND REGULATIONS

12.1.0 INTRODUCTION

This chapter discusses the role that government agencies, development activity, and the general public have in regulating and determining conditions in the Issaquah basin. Tables 12-1 and 12-2, at the end of this chapter, list local agencies (City of Issaquah and King County), federal and state agencies, tribes, special purpose districts, and other resource agencies that have vested interests, or regulatory control over, surface water management in the basin. The following section describes the roles of these various entities.

12.2.0 ROLE OF GOVERNMENT

12.2.1 Local Government

The planning area consists of 93 percent unincorporated King County and 7 percent incorporated Issaquah. The City of Issaquah is considering annexation of additional areas in the East Fork, North Fork, Tibbetts, and Lower Issaquah sub-basins. If all these areas were to be annexed it would triple the current jurisdictional area of the City.

A successful local program for surface water management should include a design manual that specifies appropriate drainage controls for new development and a landscape-based plan that includes comprehensive programs for surface water management, adequate land-use controls and regulations, adequate application and enforcement of those regulations, programs to educate the public about the impacts of their activities on surface water, incentives to encourage stream resource protection, and projects to correct existing surface water problems.

Implementation of such a comprehensive surface water management program can be a challenge for local governments. King County and the City of Issaquah are meeting that challenge with information about the impacts of development of surface water systems and the effectiveness of various basin management techniques. King County adopted a new Surface Water Design Manual in 1990 and the City of Issaquah is developing a new comprehensive facilities management plan, which includes drainage, during 1991. King County revised the Sensitive Areas Ordinance in 1990. The City of Issaquah is also developing a set of sensitive areas regulations in 1991. The Issaquah Groundwater Management Study is currently on-going and should be completed in 1991. It will include proposed groundwater regulations for King County, the City of Issaquah, and local drainage districts to implement. The effectiveness of these existing and proposed regulations and developing plans will depend on the level of priority and funding given to proper permit review, development inspections, and code enforcement within each jurisdiction.

12.2.2 State, Federal, and Tribal Agencies

Most state, federal, and tribal agencies identified in Table 12-2 have some functions in providing protection of natural resources from the effects of development and resource management activity. Typically this occurs through conditioning permits according to individual agency policies and regulations, enforcing those regulations and operating programs to manage land and water resources. For example, the State Department of Ecology, the U.S. Environmental Protection Agency, and the U.S. Army Corps of Engineers regulate water quality or wetland related actions.

Table 12-2 shows that various agencies address different resource concerns. Different agencies are guided by separate objectives that can conflict and create gaps in regulatory coverage for certain resources. Failure to correct problem conditions may result from a lack of technical capability to mitigate for development impacts. However most frequently, it is due to insufficient fiscal resources to keep pace with rapidly expanding development pressures. In some cases the multiplicity of regulations and policy objectives can lead to inconsistent management of the resources.

Precedent has been set for coordinating permit activities among local, state, and federal entities. A unifying direction to manage basin resources among these entities does not exist at the present time. The basin and nonpoint action plans present a unique opportunity to work toward that objective. The Issaquah Watershed Management Committee, whose membership includes representatives of the majority of these interested entities, provides policy review to these plans.

12.3.0 DEVELOPMENT ACTIVITY

Development activity can influence surface water conditions significantly. For example, construction practices in which erosion and sedimentation measures, and other types of best management practices (BMPs) are not properly installed or maintained can allow large volumes of soil to be washed off during storm events to nearby streams. As Discussed in Chapters 3 through 10, this eroded soil creates a myriad of problems including water quality degradation, fish kills, suffocation of fish eggs, decreases in channel depth, increases in flooding, and other aesthetic problems.

A recent study to assess the effectiveness of erosion-control BMPs on construction sites throughout King County was conducted by the King County Conservation District (Tiffany et al., 1990). Eighty-six site visits were made to sixty construction sites. The study found that three sites (5 percent) had effective controls in place during the study period. The primary reasons specified for the remaining 95 percent having ineffective control include inadequate

installation, poor timing of installation with respect to weather conditions, and insufficient maintenance.

The portions of the basin in the City of Issaquah and East Sammamish Community Planning Area have seen very active residential and commercial construction in the past five years. On the basis of the King County Conservation District findings, a likely conclusion is that the vast majority of these sites may have contributed to the erosion, sedimentation, and water quality degradation in the basin and in Lake Sammamish during this period of time.

Some of the problems in implementation of BMPs may be due to insufficient knowledge on the part of developers and construction workers. In many cases however, the information has been available, but has not been implemented in practice due to negligence by the developing parties and inadequate staffing of inspection and enforcement.

12.4.0 INDIVIDUAL ACTIONS

The condition of surface water in the basin is also very much dependent on the daily activities of the thousands of individuals who reside in the basin. The general public can improve stream quality as active stewards of the resource. The public can also take well-intentioned actions that can harm stream and wetland systems. Such activities as filling of wetlands, rerouting or armoring stream channels, removal of the organic debris and streamside vegetation that form instream habitat, excessive use of fertilizers and pesticides, and poor handling of toxic wastes and other contaminants, collectively have had a substantial impact on the streams, lakes and wetland in the basin. Most of these impacts can be addressed through education of stream and wetland property owners in best management practices.

12.5.0 COORDINATION AND PLANNING

In the future, successful surface water management programs must integrate the preventive and corrective actions of all entities in the basin. In addition to the Issaquah Basin and Nonpoint Action Plans and the specific project designs that will be contained therein (see FLOODING, Chapter 6), other coordinated studies are expected to promote a more integrated water management program. These studies are:

* <u>The Issaquah Groundwater Management Plan</u>.

    The Issaquah Groundwater Management Plan is a cooperative effort by water purveyors and local and state agencies. The plan will evaluate the quality and quantity of groundwater in the project area and identify the policies and programs needed to manage groundwater supplies and protect their quality in the future.

* Lake Sammamish Water Quality Management Plan.

A multi-agency group led by Metro conducted this study of water quality problems and management techniques for Lake Sammamish. The plan was completed in 1989 and an agreement on plan implementation was completed in 1990.

* The East Sammamish Community Plan Update and Area Zoning.

An update of the land-use plan for the northeastern part of the basin was started in 1989. This two-year planning effort will evaluate a range of concerns including surface water protection policies. It will establish land-use policies and zoning for parts of the basin. To preserve options for this long-term planning effort, interim zoning and drainage regulations were adopted in early 1990.

* City of Issaquah Comprehensive Facilities and Management Plan.

This planning program includes comprehensive plans for water and sanitary sewer service and a drainage management plan. The comprehensive planning activities will include the development of a computer based Automated Mapping/Facilities Management capability. This mapping tool will allow the City to provide the ability to construct spatially accurate graphical representation of the water, sanitary sewer, and surface drainage systems as overlays on the City's CAD-based topographic mapping system. This planning program is funded by a Flood Control Assistance Program Grant.

* City of Issaquah Critical Areas Ordinance.

The City of Issaquah has adopted an interim critical areas ordinance and is developing a new set of sensitive areas regulations pertaining to development in and protection of sensitive areas, which include: streams, wetlands, and steep slopes. Wetlands are being regulated through the proposed wetlands protection ordinance.

These planning efforts can provide a framework for future cooperative action among resource management agencies, the general public, and the private sector in the Issaquah Basin. However, it is not clear whether the monetary resources needed will be made available to implement these plans. In addition these plans rely on the basin residents to make some changes in their lifestyles. It is uncertain how faithfully residents will follow good basin management practices when it affects them personally.

12.6.0 CURRENT WATER QUALITY PROGRAMS

12.6.1 Federal

The United States Department of Agriculture (USDA) has several interdepartmental agency services, including the Agricultural Stabilization and Conservation Service (ASCS), USDA Soil Conservation Service (SCS), USDA Extension Service, and the USDA Forest Service that address water quality concerns. The ASCS provides cost-share assistance to commercial farms for the implementation of best management practices including erosion control, stream fencing and animal waste management. The SCS provides technical assistance to conservation districts throughout the nation including the State of Washington. The emphasis on water quality control by the SCS nationwide is illustrated by the recent elevation of water quality as their second priority (Washington State Department of Ecology [DOE], 1989). Under the SCS, two other programs for nonpoint source pollution control include the Small Watershed Program and the Food Security Act.

Other federal agencies that have water quality programs include the U.S. Army Corps of Engineers, U.S. Geological Survey (USGS), and U.S. Environmental Protection Agency (EPA). In the past, the USGS has conducted several stream flow surveys and has a flow gauge located on the mainstem of Issaquah Creek.

The EPA National Pollutant Discharge Elimination System (NPDES) permit application regulations for storm water discharges (which became final in December, 1990) implements section 402 of the Clean Water Act. King County will be required to develop storm water discharge permits for unincorporated and industrial areas. Additionally, as part of the permit application, a comprehensive program designed to reduce the discharge of pollutants to the maximum extent practicable (MEP), including management practices, control techniques and systems, design and engineering methods, and other appropriate provisions for storm water quality, will be submitted.

12.6.2 State

Current statewide water quality programs are summarized in Chapter 4 of the DOE's Nonpoint Source Pollution Assessment and Management Program (1989). Two state-funded studies, the Issaquah Creek Groundwater Management Study and the Issaquah Creek Wellhead Protection study, are currently being developed by the Seattle-King County Department of Public Health and the City of Issaquah, respectively.

12.6.3 Local

The Municipality of Metropolitan Seattle (Metro) conducts a water quality sampling program for lakes and streams throughout the Seattle-King County area. Metro frequently conducts or is the lead agency for many other water quality related projects including more recently, the Lake Sammamish Management Plan (Metro, 1989).

Metro provides citizen action grants for water quality enhancement and education. For example, through their grant program, lake community groups or associations can apply for funding to purchase weed removal equipment.

Metro also operates an interagency emergency response program to address water quality problems for the Seattle-King County area. the trouble call system is designed to operate as a communication network and clearing house for water quality problems. As part of the program, emergency response sampling kits are used by trained individuals to collect suspect water quality samples. This information is useful in tracking down the source of pollutants and possibly in enforcement actions.

TABLE 12-1

MAJOR KING COUNTY AND CITY OF ISSAQUAH PLANS, PROGRAMS, AND ORDINANCES AFFECTING SURFACE WATER IN THE ISSAQUAH CREEK BASIN

Plan, Program, or Ordinance	Topic	Status
KING COUNTY BUILDING AND LAND DEVELOPMENT DIVISION		
- Zoning Code Project	Zoning rewrite	In progress
- Subdivision Products section	Residential drainage review	Ongoing
- Commercial Products section	Commercial drainage review, grading permits	Ongoing
- Technical Services section	Sensitive areas review, SEPA reviews	Ongoing
PLANNING & COMMUNITY DEVELOPMENT DIVISION		
- Comprehensive Plan	Land use, Zoning	Adopted 1985
- East Sammamish Community Plan	Land use, Zoning	Adopted 1982
- East Sammamish Community Plan Update	Land use, Zoning	In progress
- Tahoma/Raven Heights Community Plan	Land use, Zoning	Adopted 1985
- Newcastle Community Plan	Land use, Zoning	Adopted 1983
- Snoqualmie Community Plan	Land use, Zoning	Adopted 1989
- Interim Zoning Ordinance in East Sammamish Plan Area	Land use, drainage	Adopted 3/90 for 24 mo.
- Sensitive Area Ordinance(SAO)	Protection for environmentally sensitive areas (e.g., wetlands, streams)	Adopted '79, amended in 1990
- Wetlands Research	Development impacts on wetlands	In progress
KING COUNTY SURFACE WATER MANAGEMENT DIVISION		
- Surface Water Design Manual	Stormwater Control	Effective 1/90
- Issaquah Creek Basin and Nonpoint Action Plans	Surface Water Management	In progress
- 6-year Capital Project List	Stormwater Control	Adopted yearly
- Drainage Investigation Unit	Citizen Complaints, Special Studies	Ongoing
- Streams Program	Habitat projects	Ongoing
- Public Involvement	Education	Ongoing

KING COUNTY ENVIRONMENTAL HEALTH DIVISION

- East King County groundwater study	Groundwater management	Ongoing
- Issaquah groundwater study	Groundwater management	Ongoing
- KCC Title 13 Revision	Septic systems	Ongoing

ISSAQUAH BUILDING DEPT.

- Issue permits, critical areas regulation	Zoning & permit administration, Critical areas review	Ongoing

ISSAQUAH PARKS DEPT.

- Trails Plan	Hiking and horse trails	Ongoing

ISSAQUAH PUBLIC WORKS DEPT.

- Issaquah Basin Plan	Surface Water Management	Ongoing
- Drainage Management Plan	Surface Water Management	Ongoing
- Wetland Protection Ordinance	Critical Areas Protection	Ongoing
- Flood Control	Surface Water Management	Ongoing
- Capital Project Construction	Surface Water Management	Ongoing

ISSAQUAH DEVELOPMENT REVIEW DEPT.

- City Comprehensive Plan	Land use & zoning	Ongoing
- SEPA Review	Permit & Project determinations	Ongoing

TABLE 12-2

ROLES OF REGIONAL AND STATE AGENCIES, TRIBES, FEDERAL AGENCIES, AND SPECIAL PURPOSE DISTRICTS IN MANAGING RESOURCES IN THE ISSAQUAH CREEK BASIN

Agency	Role
REGIONAL AGENCIES	
Metro	Monitored base flow water quality in the planning area; leads the Lake Sammamish Water Quality Management Project.
STATE AGENCIES	
Department of Ecology	Administers state and Federal water quality regulations; provides technical assistance and oversight to local governments in the administration of State Shoreline Management Act; reviews and comments on actions affecting wetlands; provides technical assistance to local governments in management of wetlands, nonpoint source pollution, and stormwater; approves local groundwater management plans.
Department of Social and Health Services	Administers drinking water standards and septic system permit requirements for large developments.
Departments of Fisheries and Wildlife	Administers regulations for activities within the ordinary high and water mark of streams and lakes.
Department of Natural Resources	Administers commercial forest practices regulations and management of the Tiger mountain conservation area.
Department of Wildlife	Administers regulations to protect endangered and threatened wildlife.
King County Conservation District	Provide technical services and public educational programs for preventing and correcting sedimentation and water quality problems from soil erosion and animal keeping practices.
Puget Sound Water Quality Authority (PSWQA)	Develops and oversees implementation plans to protect and restore water quality from point and nonpoint sources in Puget Sound and its tributary areas, including requirements for local governments to develop stormwater management programs and basinwide nonpoint source action plans; provides funding for public information and education programs.
Washington Department of Transportation	Constructs and maintains state highways, including I-90, SR 18, and SR 900.
Washington State Parks and Recreation Commission	Operates Lake Sammamish State Park.
INDIAN TRIBES	
Muckelshoot Tribe	Receiving waters in Lake Sammamish are part of the Tribes's Usual and Accustomed Fishing Grounds.

FEDERAL AGENCIES

Federal Emergency Management Administration (FEMA)	Provide technical assistance on flood prevention and management to local governments; determine requirements for participation in the federal flood insurance program; administers flood insurance funds.
U.S. Army Corps of Engineers	Administers regulations for dredging; administers regulations for projects involving placement of dredged and fill material in wetlands and waters of the United States.
U.S. Dept of Agriculture:	
-Agricultural Stabilization and Conservation Service (ASCS)	Cost shares water quality measures with commercial farms.
-Soil Conservation Service (SCS)	Provides technical service and financial assistance to commercial agricultural operators for preventing and correcting soil erosion problems.
-Extension Service	Provides technical assistance for nonpoint pollution control.
U.S. Environmental Protection Agency	Develops and jointly enforces federal wetlands regulations with the U.S. Army Corps of Engineers.
U.S. Fish and Wildlife Service	Administers resource protection regulations for federally protected threatened and endangered species; reviews and comments on actions affecting wetlands and waters of the United States.
U.S. Geological Survey	Conducts stream flow surveys and special drainage studies.