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Eastern Tributaries
of the Lower Green River

Enhanced Reconnaissance Report

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KING COUNTY DEPARTMENT OF
NATURAL RESOURCES AND PARKS

King County
Surface Water
Management
Everyone lives downstream

THE GREEN RIVER WATERSHED MANAGEMENT PROGRAM

This report is one of the first products of the King County Surface Water Management (SWM) Division's Green River Watershed Management Program. This Watershed Management Program is an integrated program of activities undertaken to improve the health of the surface water resources in this watershed. Issues affecting the Green River and its tributaries are extremely complex, and a large number of jurisdictions and other agencies have ongoing surface water projects and programs of various types, sizes, and geographic focus. Rather than initiate yet another program to produce an overall "basin plan" for the entire Green River watershed, the scope and status of these ongoing activities (both within and outside of SWM) are being assessed to determine gaps in our collective knowledge. This assessment is now leading to focussed efforts on high-priority activities such as this Enhanced Reconnaissance report.

The Watershed Management Program thus establishes a systematic framework for coordinating SWM's ongoing work efforts in the Green River watershed. It can supplement these ongoing activities with other specific projects, such as this report, that are necessary to manage the Green River system as a whole. It also provides a formal means of forging partnerships with other jurisdictions, as well as with the federal and state governments. A strong emphasis is placed on involving the public in watershed decision-making, partly through the review of reports such as this one and partly through forums that are currently being developed. As the overall program develops, it should result in an efficient and coherent approach to resource protection, restoration, and management throughout the Green River watershed. This reconnaissance report is one of the steps in that direction.

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KING COUNTY DEPARTMENT OF
NATURAL RESOURCES AND PARKS

ENHANCED RECONNAISSANCE OF THE EASTERN TRIBUTARIES OF THE LOWER GREEN RIVER BASIN: DATA, ANALYSES, AND MANAGEMENT RECOMMENDATIONS

KING COUNTY BASIN PLANNING PROGRAM
Surface Water Management Division,
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ENHANCED RECONNAISSANCE OF THE EASTERN TRIBUTARIES OF THE LOWER GREEN RIVER BASIN: DATA, ANALYSES, AND MANAGEMENT RECOMMENDATIONS

EXECUTIVE SUMMARY

This reconnaissance study has two basic goals:

1. To produce a rapid but systematic inventory and analysis of conditions across the stream and drainage system in the study area; and

2. To identify the high-priority management needs and to outline a recommended overall program for surface-water management.

This study focuses on the eastern tributaries of the Lower Green River, a 5.8-square-mile collection of relatively small streams that enter the Green River from the east between the cities of Auburn and Kent. This report is intended to provide basin-level planning for this area; it is also a prototype for how such studies could be accomplished for similar watersheds in the future.

To date, only about one-half of the study area has been affected by development; the study area's current impervious area is characteristic of a low density of suburban development. In the future, however, high-density single-family residences are projected to cover over half of the area, and commercial and multifamily uses will more than double. Over the study area as a whole, the current effective impervious area, 5.5 percent, is anticipated to triple; impervious-area increases to particular stream segments will increase by over six-fold. All available evidence suggests that such increases will entail substantial resource loss and a significant increase in drainage-related problems.

Currently, significant aquatic resources are recognized in lower Olson Creek ("Olson Canyon"), Wetland 46 (high in the Olson Creek system), and the lowermost 0.5 miles of the Lea Hill Tributary 0069. Fish use is substantial in both of these stream segments; habitats are particularly diverse and plentiful in the wetland. Recognized problems are scattered throughout the study area; among the most prominent are flooding of two residential streets and sporadic partial blockage of the Green River Road at Olson Creek, one site of potential future channel migration of the Green River into developed land, and damage to the Olson Creek and Lea Hill resource areas from increasing urban runoff. Water quality data and modeling do not indicate any significant current problems, but the intensity of future land use will likely cause noticeable degradation, particularly by heavy metals associated with automobile traffic, that will likely exceed toxic thresholds repeatedly. Treatment options are technically feasible but financially prohibitive. Predicted future flow increases are also large; given the intensity of proposed future land use, neither planned drainage regulations nor foreseeable capital funding will be sufficient to wholly correct the consequences of those increases.

The recommended management program is a combination of public-agency actions and capital improvement projects. Among the recommended agency actions are an update of the *King County Wetlands Inventory* to include previously unmapped wetlands, a continuation of education and enforcement actions throughout the study area, acquisition of additional parkland in Wetland 46, and specification of the onsite detention standards for new development that are appropriate to each subarea. Capital improvement projects were identified to address the highest priority problems, as were a set of smaller projects and maintenance actions that are particularly cost-effective. These projects include non-erosive conveyance of presently unmanaged road runoff into adjacent tributaries, improving the crossings of the Lea Hill Tributary and Olson Creek under Green River Road, and restoring parts of three wetlands and lower Olson Creek's riparian zone.

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ENHANCED RECONNAISSANCE OF THE EASTERN TRIBUTARIES OF THE LOWER GREEN RIVER BASIN: DATA, ANALYSES, AND MANAGEMENT RECOMMENDATIONS

INTRODUCTION

This reconnaissance study, covering the surface-water drainage system in a part of the Green River basin, has two basic goals:

1. To produce a rapid but systematic inventory and analysis of conditions in the stream and drainage system, covering resources and problems under both current and future land uses;

2. To identify the high-priority management needs in the study area and to outline a recommended program for surface-water management.

Similar goals also have been pursued in other drainage basins of King County by the Surface Water Management (SWM) Division, using a variety of methods. The effort with broadest coverage to date, the six-month 1987 ***Basin Reconnaissance Program***, was a quick listing and field review of known drainage problems throughout most of western King County, together with brief descriptions of possible solutions to those problems. Data collection was emphasized, whereas the recommended solutions were primarily intended to initiate more detailed investigations by appropriate public agencies. In contrast, five **basin plans** published since 1990 have collected and analyzed information on drainage basins in considerable detail and depth, assisted by ongoing citizen and technical advisory committees. These plans are formal policy documents of King County and are adopted as such by the Metropolitan King County Council; not only do they recommend an integrated set of problem solutions and resource enhancements, but also they have needed in some cases to create entirely new programs or policies to implement those actions. This ambitious list of tasks, however, has extracted a severe toll in both the cost and the timeliness of the basin plans themselves.

This Enhanced Reconnaissance represents an intermediate level of effort. Earlier drafts of this document have received widespread external review by potentially affected County divisions, outside agencies, and basin residents, but they were prepared without any ongoing advisory committees or extensive public involvement. The report emphasizes measured or inferred conditions, and it offers a variety of recommended actions that could achieve previously established County-wide goals of surface water management. Yet it neither establishes nor proposes new County policy. The utility of this effort should lie in identifying and ranking surface-water problems, highlighting significant remaining resources, and suggesting ways that public and private actions may improve conditions in the watershed in the face of continued urbanization of the region. The scope and methods of the study presented here were chosen to meet ongoing public commitments for planning coverage across the SWM Service Area, achieving the fundamental goals of those commitments while

acknowledging the limited available resources for future public action.

Organization of the following report is similar to prior basin plans. The section on "Conditions" presents all readily available information on the study area; it is based on field inspection of every major stream channel and wetland, air-photo analysis of land use, recent engineering reports on major private and public development projects, hydrologic modelling of one major drainage system (Olson Creek), and analysis of water quality conditions based on past monitoring data and spreadsheet contaminant models.

The section on "Management Recommendations" highlights the most pressing surface-water needs in the study area. The severity of problems, and thus the priority of solutions, are placed in a County-wide context; only those with a credible likelihood of being addressed receive detailed attention, but all recognized problem sites (Appendix A) are inventoried for future users of this document. In particular, pervasive long-term degradation of the aquatic system by increasing volumes of stormwater and increasing loads of urban-derived pollutants defy any known remediation, given the adopted land use and foreseeable capital funding. Several other issues, particularly those relating to the Green River mainstem, may significantly affect management of the surface-water system in this basin but are beyond the scope of this study to address fully; these are acknowledged separately.

In addition to the narrative of conditions and the outline of management recommendations, a variety of background data, analyses, and descriptions of procedures may prove valuable to future users of this document. This information is included as a set of appendices (B-F) to this document.

CONDITIONS

Basin Overview

Location and Topography. The eastern tributaries of the Lower Green River are a collection of relatively small streams that enter the Green River from the east between the cities of Auburn and Kent. The boundaries of this study area were drawn along the drainage divide with Soos Creek on the east (King County, 1990), on the north generally to *ex*clude the area tributary to Mill Creek except those parts of the Upper Mill Creek watershed that were still in unincorporated King County in early 1994, and on the west and south by the right bank of the Green River between River Miles (RM) 33.8 and 26.5 (Figure 1). The study area covers 5.8 square miles (3730 acres), about half of which was included in the 1987 Lower Green River Basin Reconnaissance Report (King County, 1987) and largely coincident with that report's "South Section."

The study area's topography has two very distinct features. Most of the area lies atop a rolling upland plateau, the "East Hill" of Kent and Auburn that extends for many additional miles to the east beyond the watershed boundary. Topographic relief on this surface is no more than about 100 feet and mainly associated with a few linear hills and valleys that trend to the south-southeast. At the west edge of this plateau, however, the ground surface drops

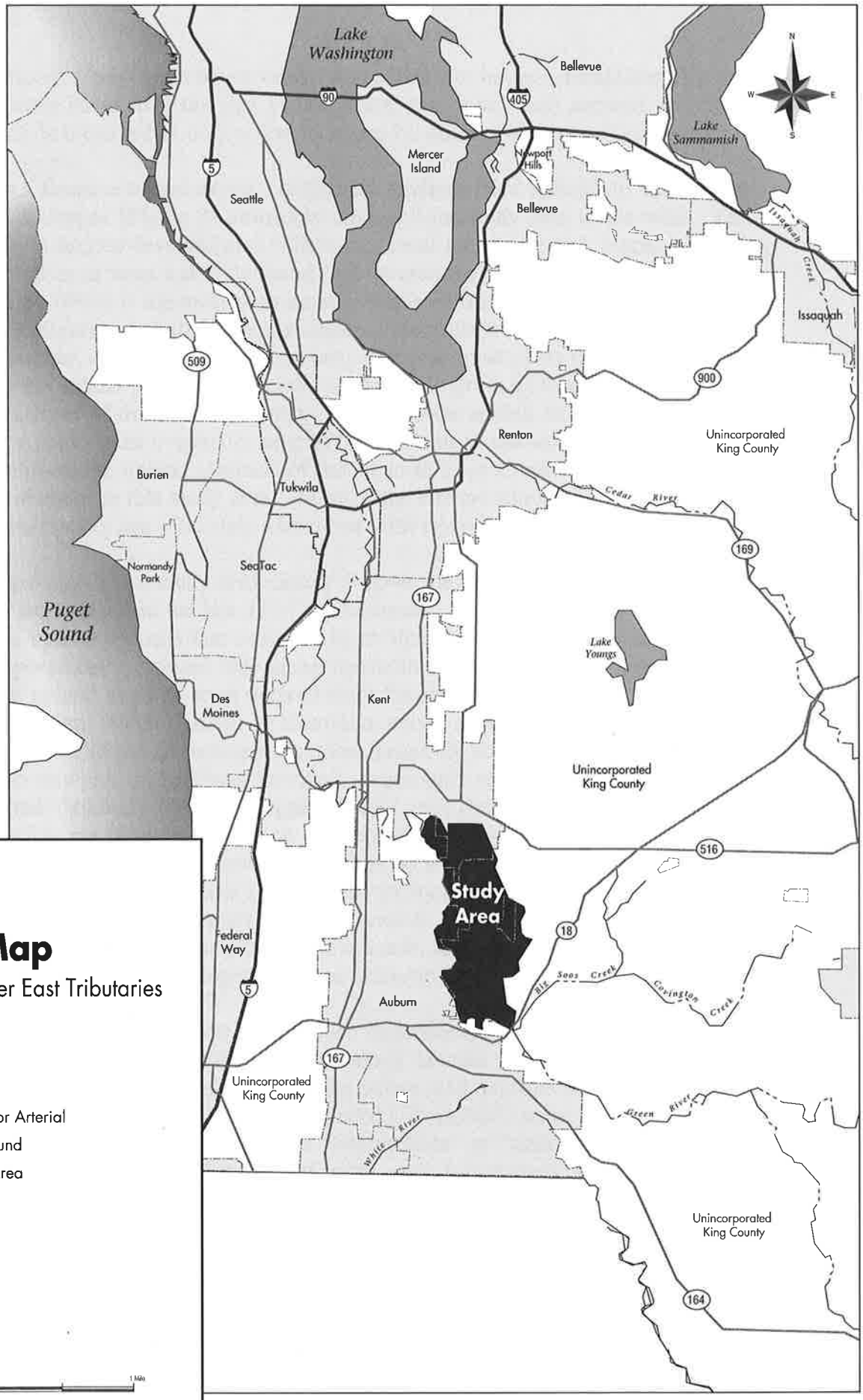

Figure 1

Vicinity Map

Lower Green River East Tributaries

River

Highway/Major Arterial

Lake/Puget Sound

Incorporated Area

0 1/2 1 Mile

abruptly to the floor of the Green River valley, some 300 feet below. Established by lateral erosion of the Green River over the past 14,000 years, this valley wall presents an imposing escarpment which is traversed at only a few locations by either roads or utilities.

Water Features. Because of the strong topographic gradient from uplands to valley floor, all of the major drainages (Figure 2) ultimately must exit the study area to the west. The streams with only a limited drainage area follow this trend for their entire length, extending only a few hundred or at most a few thousand feet up onto the plateau. The Lea Hill Tributary (tributary 0069) is the most prominent example of this pattern, but most of the other numbered tributaries and all of the unnumbered channels follow this course as well. Olson Creek, however, stands in marked contrast. Because most of its three miles of stream channel flow on the upland plateau, the gentler topographic grain of this surface dominates the trend and character of this channel system. Although the stream has a pronounced canyon reach, for it too must eventually drop off the plateau to the valley below, most of the stream is more akin to the upland channels of the adjacent Soos Creek system than to the ravines found elsewhere in this study area. Most of the stream segments that do have significant plateau reaches are intimately associated with riparian wetlands.

Geology. The geology of the study area closely follows the topographic form of the basin. First mapped in some detail in the late 1950's (Mullineaux, 1965), the area is characterized by relatively thin upland deposits that overlie a much thicker (and very complex) sequence of older deposits, sporadically exposed only along the ravines and roads of the Green River valley wall. The upland deposits were derived from the most recent ice-sheet glaciation of the Puget Sound region, which reached its maximum extent about 15,000 years ago (Booth, 1987). The movement of the ice across the region, generally south but more specifically south-southeast in this part of the Puget Lowland, is precisely recorded in the present-day trend of Mill Creek (tributary 0028) and upper Olson Creek (tributaries 0061D and upper 0061). Glacial till is the primary deposit on the upland, found at the ground surface across most of the plateau with only a thin cover of Alderwood soil and, locally, organic muck. Where till is not directly exposed, it is almost certainly located at a shallow depth beneath sand and gravel deposited during the ice sheet's recession. These sandy areas are limited to the southwestern and southeastern corners of the uplands, and at the heads of tributaries 0068 and 0068A. Everett soils are developed on these primarily sandy deposits.

The older, underlying deposits have proven enigmatic to geologists for almost 40 years. By analogy to deposits described in detail along the east wall of the Puyallup River valley (Crandell, 1963), about 15 miles south, the valley-wall deposits here were subdivided into older glacial ("Salmon Springs") and non-glacial ("Puyallup") units. Deposits fitting neither of these established units were dubbed "intermediate" or "undifferentiated" and left for future geological study to decipher. As of today, such future study has not yet occurred; however, the progressive improvement in exposures (mainly from stream-channel erosion due to upstream development) suggests that the sequence of older sediments is much more complex than originally envisioned. Layers of sand, gravel, silt, and clay are finely interbedded; no single layer is thick enough, or extensive enough, to trace unequivocally from one ravine to the next. Groundwater enters these older deposits by slow percolation through the uppermost till, probably at a rate of no more than about 10 inches per year and

only where the ground remains perennially saturated. Vertical movement of groundwater is rapidly interrupted by silty lenses and cemented zones, which tend to divert flow horizontally. As a result, springs and seeps are very common in most of the ravines and along most of the roadcuts of the valley wall. Because most of the deposits are relatively old, they are generally well cemented; thus channel erosion tends to strip away the overlying soil layer but progress only slowly through the underlying geologic deposit. There are, however, several notable exceptions to this condition where the cementation is locally weak or absent altogether. In these locations, channel erosion has proceeded rapidly (see, for example, the discussion of road-drainage outfalls in the Lea Hill subbasin, below).

Land Use. Probably because of the difficulties in access imposed by the Green River and the adjacent valley walls, urban development has proceeded more slowly in the study area than in almost any other part of the adjacent region. Only about one-half of the area has been affected by development to date (Figure 3a); the study area's current effective impervious area[1], 5.5 percent, is characteristic of low-density suburban development (complete land-use data are compiled in Appendix B). In contrast, the watershed area of upper Soosette Creek, adjacent to this area (and even farther east) but easily accessed by State Route 516, already had reached an effective impervious area of 8.5 percent by 1985. Most of the study area is currently in unincorporated King County except for the upper Mill Creek drainage area and some surrounding lands, recently annexed to the City of Kent; a 200-acre parcel near the eastern boundary, which was purchased by and incorporated into the City of Kent in 1987 for a future water-supply reservoir; and the Auburn Regional Golf Course together with some additional City of Auburn parkland.

Based on the study area's location west (*i.e.*, on the urban side) of the Urban Growth Boundary, likely future annexations, and current zoning, a very different future is projected (Figure 3b). High-density single-family residences are expected to cover over half of the area, primarily from the conversion of currently low-density residential areas but also by the loss of over 800 acres of presently undeveloped forest and grassland. In addition, commercial and multifamily uses will more than double in area.

Based on the results of previous basin plans and other studies nationwide, impervious-area percentages provide the most useful summary of urbanization impacts. Over the study area as a whole, the current effective impervious area, 5.5 percent, is anticipated to increase to 18 percent at future build-out. Noteworthy local increases include the watershed area of the Lea Hill Tributary (0069), which has both the highest current level (12%), the greatest increase (21%), and thus the greatest final level (33%). The other particularly significant change will occur in the Olson Creek watershed, which increases from 3 percent (current) to over 19 percent (future), a six-fold change that dwarfs all other proportional changes in the study area.

Urbanization of a watershed degrades both the form and the function of the

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[1]Effective impervious area (EIA) is the impervious area that drains directly into the stream system via overland flow.

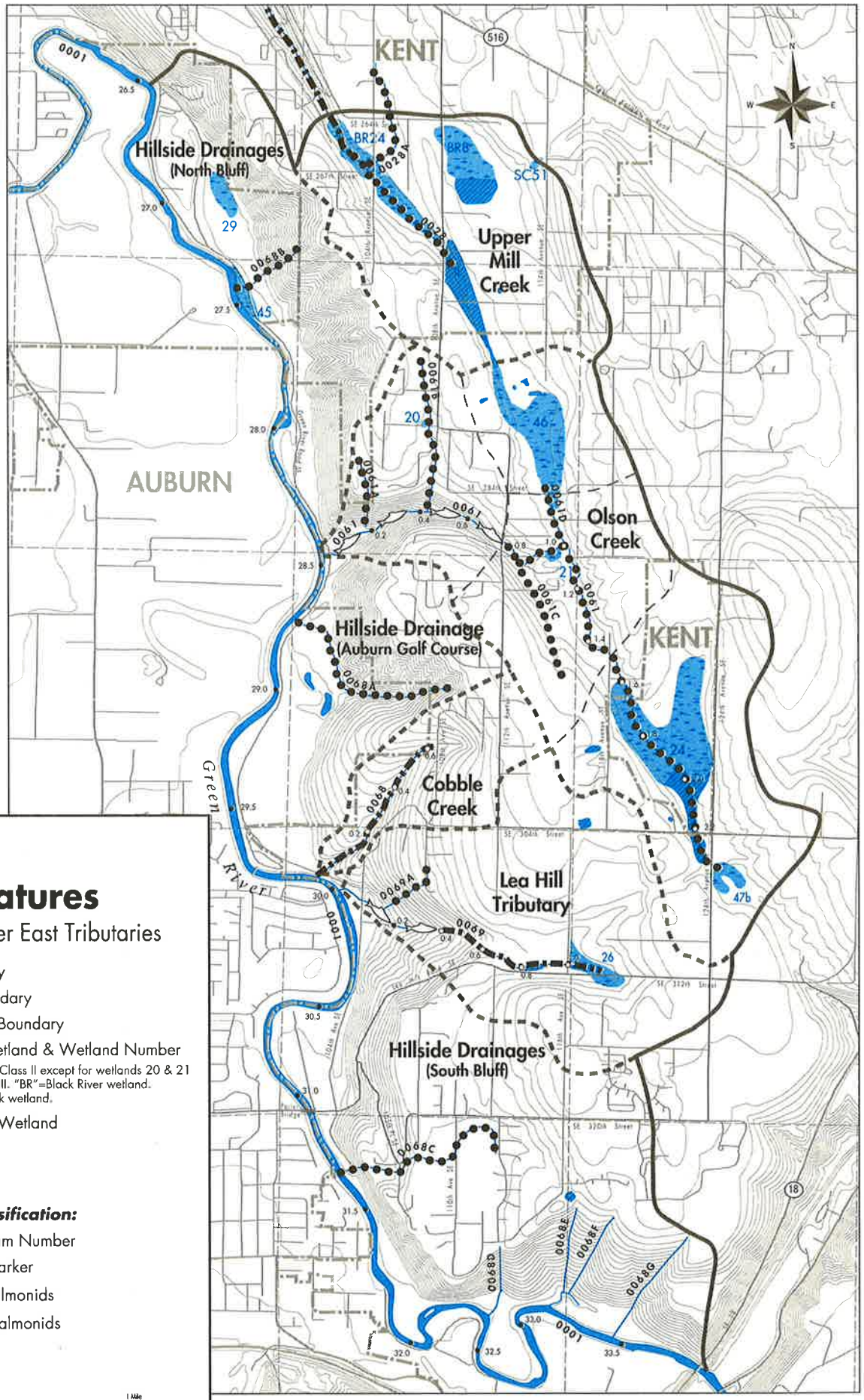

Figure 2

Water Features

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- Subcatchment Boundary
- Inventoried Wetland & Wetland Number
  All wetlands are Class II except for wetlands 20 & 21 which are Class III. "BR"=Black River wetland. "SC"=Soos Creek wetland.
- Uninventoried Wetland
- City Boundary
- Section Line

Stream Classification:

- 0068C Stream & Stream Number
- 30.5 River & mile marker
- Class II w/ salmonids
- Class II w/o salmonids
- Class III
- Unclassified

0 1/2 1 Mile

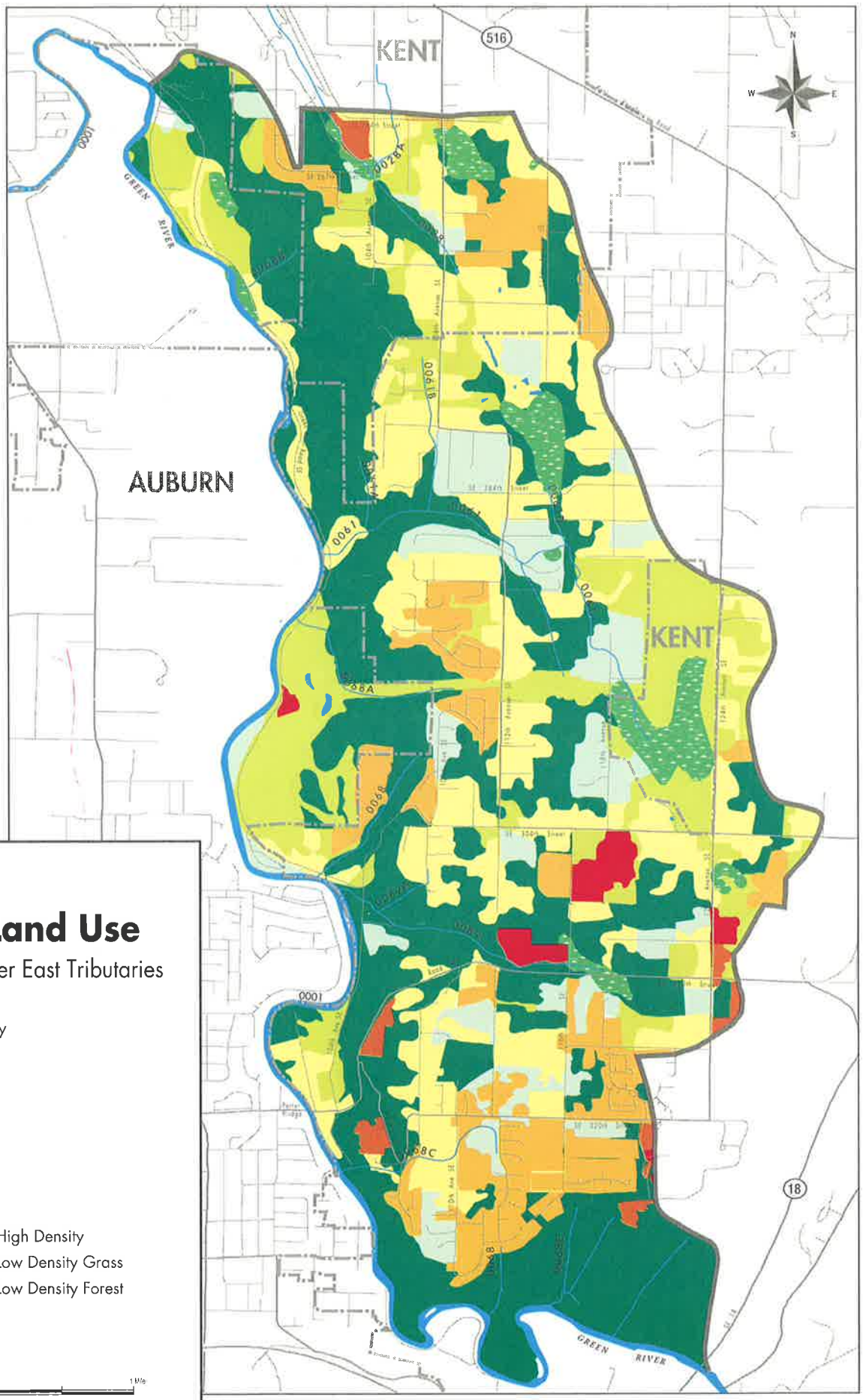

Figure 3a

Existing Land Use

Lower Green River East Tributaries

- Basin Boundary
- Stream
- River/Lake
- City Boundary
- Wetland

- Impervious
- Multifamily
- Single Family High Density
- Single Family Low Density Grass
- Single Family Low Density Forest
- Grass
- Forest

0 1/2 1 Mile

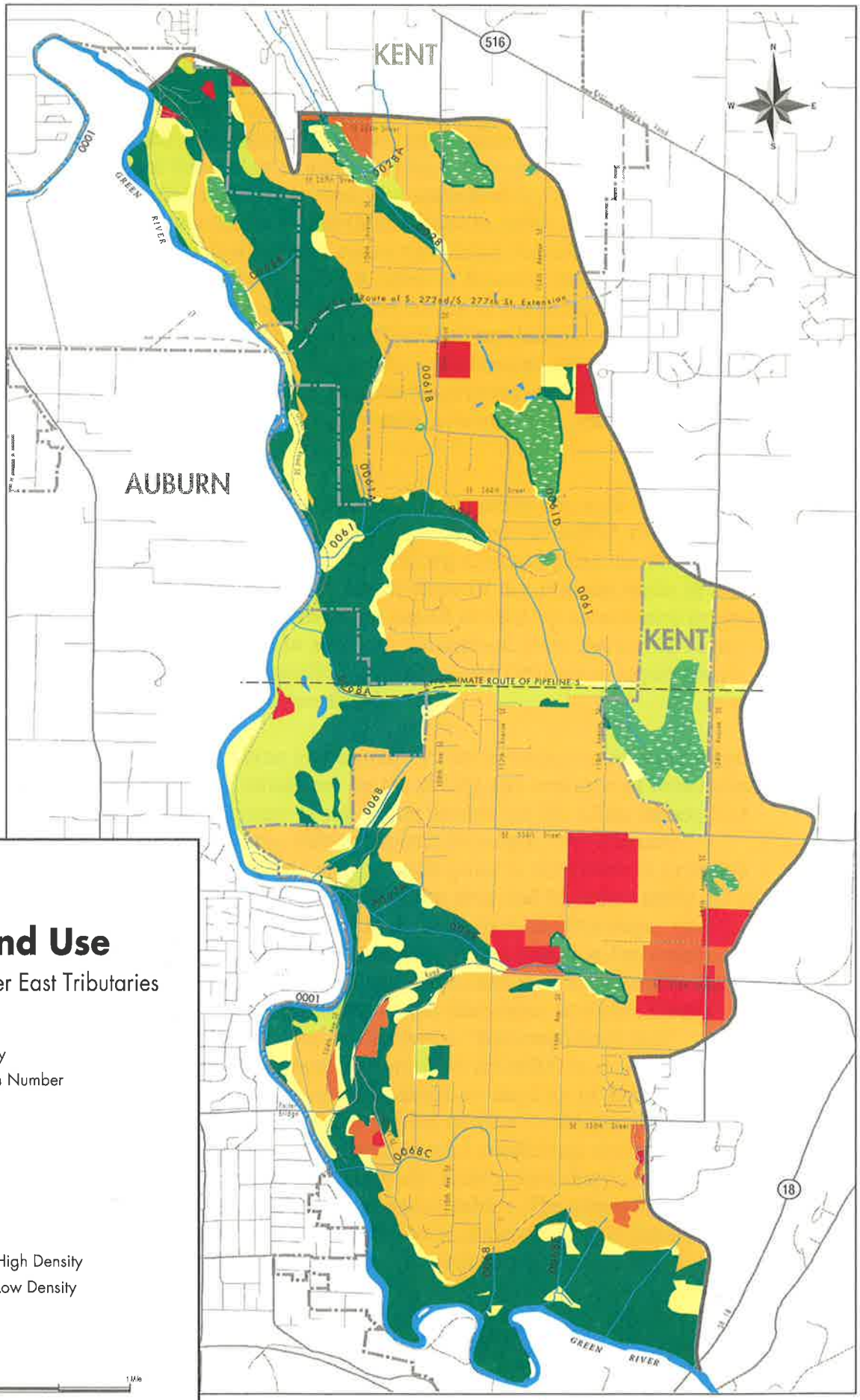

Figure 3b

Future Land Use

Lower Green River East Tributaries

- Wetland
- Basin Boundary
- 0068 Stream/Stream Number
- River/Lake
- City Boundary
- Pipeline

- Impervious
- Multifamily
- Single Family High Density
- Single Family Low Density
- Grass
- Forest

0 1/2 1 Mile

downstream aquatic system, causing changes that can occur rapidly and are very difficult to avoid or correct. A variety of physical and biological data from lowland streams and wetlands in the region, collected and analyzed over the past several years, suggests remarkably clear and consistent thresholds of aquatic-system degradation. In this region, approximately 10 percent effective impervious area in a watershed typically yields demonstrable loss of aquatic-system function (Booth and Reinelt, 1993; Booth and Jackson, 1994). Even lower levels of urban development cause significant degradation in sensitive water bodies and a reduced, but less well quantified, level of function throughout the system as a whole. This threshold is based primarily on observations in watersheds having only minimally effective surface-water mitigation required by older regulations, and so future development should have somewhat fewer consequences. There is no evidence, however, to suggest that impervious-area percentages of the magnitude currently slated for most of the study area's subbasins can be sustained without substantial resource loss and a significant increase in drainage-related problems.

In unincorporated King County, upland parcels close to either the wall of the Green River valley or the lip of Olson Canyon presently are governed by "P-suffix" zoning restrictions in the Soos Creek Community Plan Update (King County, 1991, p. 166-167). In particular, all development within 660 feet of the top-of-slope of the adjacent walls of the Green River valley or Olson Canyon must convey the runoff carried by constructed drainage systems to the base of the slope in a pipe. In addition, the setback from the top of these slopes is 100 feet for new construction, exceeding Sensitive Area Ordinance requirements, unless all reasonable use of a parcel is thus precluded.

Although nearly all of the study area is presently within unincorporated King County, the long-term land use will be strongly influenced by the timing and outcome of annexations. But for the Green River floodplain upstream of the Porter Bridge (at SE 320th Street; RM 31.1), the entire area is presently within the Urban Growth Boundary. As a result, annexation or incorporation of the entire study area at some point in the future is probably inevitable. Auburn's sphere of influence covers most of the area and includes nearly all of the subbasins save Mill Creek (0028) and parts of the northern Hillside Drainages (the "North Bluff"). Auburn's public lands include a recently acquired parcel at the mouth of Olson Creek, the golf course at the mouth of tributary 0068A, and riverfront land in the southern part of the area. The remaining, north part of the study area is within Kent's potential annexation area and is largely included in the recent "Ramstead/East Hill" annexation. Following approval, zoning changes uniformly to RS20000 (*i.e.*, one-half acre lots) for a six-month period while final zones are determined by the City of Kent. This interim zoning increases, at least temporarily, the permitted density in the present GR-2.5-P zone (Growth Reserve, 2.5-acre minimum lot size with special conditions) that covers about half of the annexation area. Because RS20000 is currently Kent's least dense zone, a permanent increase in density in this area probably is unavoidable. The remaining parts of the annexation area are currently a mix of multifamily and high-density single-family residential zoning; those zones have also, temporarily, reverted to low-density single-family lots.

Major Public Projects. Several major construction projects are planned by public agencies

in the study area (Figure 3b). The S 272nd/S 277th Street extension, from the Green River valley floor east up the valley wall about one mile north of the mouth of Olson Creek, affects relatively few stream systems in the study area. Of the numbered tributaries, only Mill Creek (0028) is crossed by the route of this proposed road, at about SE 274th Street. The North Bluff of the basin, however, must be substantially altered in order to accommodate the proposed roadway at a reasonable grade. Over 100-foot-deep cuts will occur in an area of short, steep hillside drainages. Sediment mobilized by the hillside grading will have some opportunity to settle out on the floodplain of the Green River, which here is of only modest width (about 500 feet) but relatively low gradient.

Green River Wetland 24 in the headwaters of Olson Creek, wholly owned and incorporated by the City of Kent since 1987, is the proposed site of a 3200 acre-foot reservoir that will form part of the City of Tacoma's proposed Pipeline 5 water-supply system. Under current plans, the reservoir would cover about 80 acres; berms would isolate it from upstream and downstream surface-water drainage, although minor seepage out the bottom might reemerge at the ground surface farther downstream. Once planned for construction in 1988, the reservoir is still part of the City of Kent's comprehensive water-supply plan but has no firm construction date at this time.

The proposed route of Pipeline 5 also traverses the study area, about one and one-half miles south of the S 272nd/S 277th Street extension. It follows the Bonneville Power Administration's (BPA) easement through the study area, crosses the upper Olson Creek subbasin within Wetland 24, passes through a corner of the watershed area of Cobble Creek (tributary 0068), and then descends to the valley floor of the Green River at the Auburn Regional Golf Course. Its route off the plateau generally follows that of the BPA power lines, in part along the base of the ravine occupied by tributary 0068A.

Other recent and proposed public surface-water projects in the study area include several construction phases of the Kent Springs Water-Transmission Line within several wetlands and the riparian corridor of uppermost Mill Creek, the construction of Upper Mill Creek detention pond at 104th Avenue SE (City of Kent), the piping of tributary 0068A through the golf course (City of Auburn), and planned drainage improvements at 107th Avenue SE along the route of tributary 0068C (King County). The 1987 Basin Reconnaissance Report suggested two possible sites for regional detention, one of three acre-feet in Green River Wetland 26 at the head of the Lea Hill Tributary and another of four acre-feet just downstream of Wetland 24. A third project was subsequently proposed to retrofit an existing small detention pond along 112th Place SE at SE 322nd Place. None of these final three projects presently are funded or planned for construction.

Water Quality

Introduction. The water quality of the tributaries in the study area is intricately linked to the activities occurring on the land surface. Land uses in the study area are examined for their potential contribution to water quality degradation, current pollutant concentrations in stormwater, and the impact of future land-use changes on water quality.

The water quality of the tributary streams, which directly affects their biological function and beneficial uses, is the major focus of this study. Yet the water quality of these tributaries also potentially affects the Green River mainstem. A comprehensive mainstem analysis is beyond the scope of this report; however, some pollutants ultimately may have greater net consequences on the mainstem than on their individual tributaries.

The lower Green River and its tributaries are classified by the Washington State Department of Ecology as "Class A" (excellent). Class A waters can be used for water supply, stock watering, fish and wildlife habitat and recreation. However, the Green River is also on the Washington State Department of Ecology's 1994 list of "troubled waterbodies" for mercury, temperature, dissolved oxygen, and fecal coliform. This listing reflects the systemwide monitoring results that show water quality standards are not being met. The only parameter of concern on this "303(d)" list that was included in the analyses of this study is fecal coliforms due to their localized sources. Temperature and dissolved oxygen were not included here because they are of primary concern in the mainstem, not tributaries. Potential sources of mainstem mercury levels are suspected to be upstream of the study area.

Pollutant Sources and Critical Land Uses. Sources of pollution can be divided into natural and human-caused; these sources can be further classified as either point or diffuse (*i.e.*, "nonpoint") sources of pollution. Nonpoint pollution from human sources is the primary source of pollutants into the lower Green River and its tributaries in the study area. No point sources were identified. The land uses in the study area that are likely to contribute the majority of nonpoint pollution include urban development and roads, land conversion, failing septic systems, localized agricultural practices, and possibly the Auburn Golf Course.

Significant ***urban sources*** in the study area include vehicular traffic, street litter, leaking sanitary sewers, fertilizers, construction activities, metal corrosion, and pesticides. Motor vehicle traffic is a major source and directly responsible for the deposition of substantial amounts of pollutants, including toxic hydrocarbons (gasoline and oil), asbestos (brake and clutch linings), and toxic metals (copper, lead, and zinc) (Novotny and Olem, 1994). Metals are from tire wear, brake linings, exhaust fumes, galvanized flashing and other exterior metal products, and roadway abrasion. In addition to vehicular pollutants, sediment originating from street dust and litter accumulation on impervious areas (and localized yard erosion) can produce a significant sediment load; pet populations can contribute a significant amount of fecal coliforms in urban runoff.

Although ***land conversion*** is temporary, the impact of erosion and siltation from disturbed sites is a significant source of sediment and phosphorus. Almost two-thirds of the study area is currently without tree cover, representing an existing significant impact from past clearing. An additional 560 acres (15 percent of the total area) is anticipated for future conversion. Increases in sediment yield caused by land-use changes have been well documented (Wischmeier and Smith, 1965; Patrick, 1975, Novotny and Olem, 1994). Many studies confirm that the suspended sediment loads of rivers may have increased by a factor of 10 or more as a result of land conversion in a watershed. Sediment yields from developing urban areas can be extremely high, sometimes reaching values in excess of 100,000 tons per square mile per year (Novotny, 1980; Novotny and Chesters, 1981), a dramatic contrast to the anticipated 260 tons per square mile per year (Dunne and Dietrich, 1979) from the Green

River watershed as a whole.

Failing septic systems can be a significant source of pollution in suburban areas, particularly areas with older homes, high water tables, or poor soils. Septic pollution has two pathways: (1) shallow subsurface transport of mobile pollutants (mainly nitrate), occurring primarily during baseflow, and (2) effluent surfacing from failing septic systems. The recent storm water quality data collected by King County (see below) show locally elevated levels in the study area of fecal coliform bacteria, nitrogen, and oil and grease, all of which can be released by failing septic systems.

Although no formal survey has been conducted, the Seattle-King County Department of Public Health (SKCDPH) suspects two major areas of possibly failing septic systems in the study area (Figure 4). One area, Derbyshire, is a collection of older plats approximately bounded by SE 270th Street on the north, SE 277th Street on the south, 116th Avenue SE on the west, and 124th Avenue SE on the east. Although only a small part of the Derbyshire area is inside the study area, the problems here are suspected to be particularly severe. The other problem area, Eastridge, also a collection of older plats, is located west of 112th Avenue SE between SE 281st Street and SE 300th Street. Because many of the septic systems in these areas are old, they were designed under less stringent standards, allowing smaller lots and a thinner depth of soil. Many of them are also at or near the end of their 15- to 30-year life expectancy. Thus, inadequately treated wastewater is potentially entering groundwater and surface waters, a condition that is likely to continue or worsen over time. The Seattle-King County Department of Public Health has expressed a desire that these areas be sewered.

A drive-through survey of the study area revealed only local ***agricultural practices*** and little or no commercial farming. Of those farms observed, many were large pastures with few animals; overgrazing and animal access to streams was not observed. Agricultural practices have the potential to be a significant source of nonpoint pollution, particularly the fecal coliforms found in some of the monitoring data, but they do not appear to be a critical land use in the study area at present.

Unusually high phosphorus concentrations measured at the mouth of tributary 0068A at the Green River confluence suggest that the ***Auburn Regional Golf Course*** is a probable source. This tributary is piped through part of the golf course and so vegetation growth and seasonal decay is not the likely source. The Green River empties into Elliott Bay, which is rapidly flushed, and so eutrophication is not a major problem; other marine-pollution conditions (such as "red tide") are not correlated with nutrient loadings. This condition is therefore of low priority although it is possible that other unmonitored but typically associated pollutants with possibly greater downstream impacts, such as cadmium, pesticides, or herbicides, are also present here.

Measured In-Stream Water Quality of Storm Water and Sediments. As part of the SWM Division's "Stormwatch" program, sample sites were selected in 1993 at the mouth of five tributaries to characterize the wet-weather water quality entering the Green River (Figure 4). Sites were *not* selected to pinpoint specific sources but rather to provide a representation of the quality of water draining the variety of land uses in the tributary subbasins. In

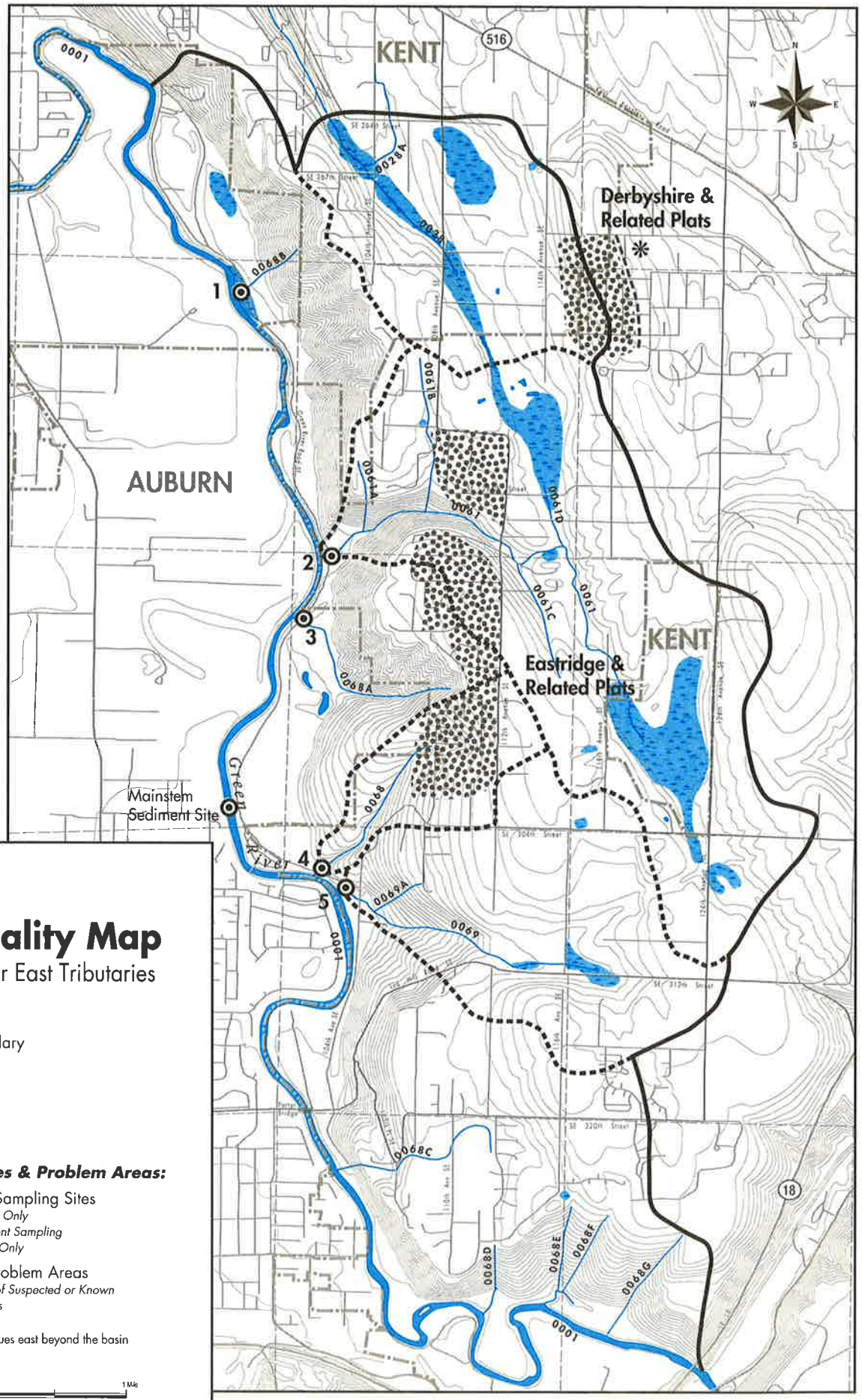

Figure 4

Water Quality Map

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- Stream
- River
- Wetland
- Section Line

Sampling Sites & Problem Areas:

- Water Quality Sampling Sites
  - *1 Water Sampling Only*
  - *2-5 Water & Sediment Sampling*
  - *Mainstem: Sediment Only*
- Septic-System Problem Areas
  - *Approximate Areas of Suspected or Known Septic-System Failures*

✻ Septic-system problem continues east beyond the basin boundary.

0 1/2 1 Mile

addition, stream sediments were collected during the summer of 1993 at some of the same sites within the study area. Stream sediments are less transient than water and act as a storage reservoir, providing a long-term record of pollutants as they pass through the system.

Overall, tributary stream and sediment quality is better than state standards or recommended threshold levels for nearly all measured constituents, revealing some impact by urbanization but at levels well below those of highly developed basins (see below; also see Appendix C for an explanation of threshold levels and complete summary tables and laboratory reports). One sample from tributary 0068A showed high total phosphorus (0.82 mg/L TP), possibly resulting from management practices at the golf course. One sediment sample from lower Olson Creek showed surprisingly high concentrations of non-petroleum oil and grease. Sediment data showed that Olson Creek and Cobble Creek had higher concentrations of total organic carbon, copper, lead, and zinc than the Green River mainstem; the Hillside Drainages and Lea Hill Tributary had lower concentrations of these same pollutants. The following table summarizes these data:

MEASURED POLLUTANT CONCENTRATIONS AND WATER QUALITY CRITERIA

STATION→ POLLUTANT↓	0068B N Bluff	0061 Olson	0068A Aub GC	0068 Cob-ble	0069 Lea Hill	Main-stem	CRITERIA/ THRESHOLDS		
SEDIMENT POLLUTANT CONCENTRATIONS (mg/kg)							Lowest effect[1]	Heavily polluted[2]	Severe effect[1]
TP	*	13	7.4	9.6	6.3	3.2	600	>650	2000
Total oil & grease:	*	2700	310	570	380	<300	1500	>2000	
•petrol.	*	1 %	*	2 %	0 %	*			
•non-petrol.	*	99 %	*	98 %	100%	*			
Total Organic Carbon	*	11	0.94	204	0.43	1.4	1		10
Copper	*	25	14	19	10	18	16	>50	110
Lead	*	<10	<4	<20	<4	<4	31	>60	250
Zinc	*	74	47	73	32	46	120	>200	820
WET-WEATHER IN-STREAM METALS (µg/L) (April 8, 1993 & March 2, 1994)								CRITERIA[3,4] Chronic	Acute
Copper	* <3	<4 <2	<4 <1	<4 <2	<4 <3	*		4-6	5-8
Lead	* <1	<30 <1	<30 <1	<30 <1	<30 <1	*		1	13-23
Zinc	* <5	<5 <5	<5 <6	<5 <5	<5 <6	*		36-52	40-57

STATION→ POLLUTANT↓	0068B N Bluff	0061 Olson	0068A Aub GC	0068 Cob-ble	0069 Lea Hill	Main-stem	CRITERIA/ THRESHOLDS
WET-WEATHER IN-STREAM CONVENTIONALS (mg/L) (April 8, 1993 & March 2, 1994)							THRESHOLD LEVELS
Total Susp. Solids	* 22	5.8 15	11 10	4.8 15	6.2 28	*	50[3]
Total Phosphorus	* 0.19	0.05 0.08	0.12 0.82	0.06 0.07	0.04 0.05	*	0.1[3]
Total oil & grease	* -	- -	- -	- -	- -	*	0.01[5]
Nitrite + Nitrate	* 2.2	1.3 2.8	- 0.21	1 1.9	0.67 1.7	*	1.25[3]
Fecal coliform (CFU/100 ml)	51 65	350 140	710 100	240 100	500 120	*	100[4]

* No data collected
< or - Values less than detection limit (see Appendix C)
Values exceeding criteria/threshold limits
[1] Provincial Sediment Quality Guidelines (1991)
[2] EPA Region V Guidelines for the Pollutional Classification of Harbor Sediments (1977)
[3] See Appendix C for threshold references
[4] WAC 173-201A
[5] USEPA, 1986

Modeling Pollutant Loadings. A simple yet reliable loading model (Horner, 1990) was used to analyze the current and anticipated annual loadings of key water quality parameters. Annual contaminant-yield coefficients from various land uses for total suspended solids (TSS), total phosphorus (TP), zinc (Zn), and fecal coliforms (FC) were applied to each subbasin in the study area. By multiplying these factors by areas of specific land use, an annual pollutant loading was determined. Neither calibration nor monitoring data were used, reducing the ultimate accuracy of the results but allowing the modeling process to be efficiently and rapidly completed, providing an understanding of relative pollutant load increases due to land-use changes.

The model results allow a comparison of relative loadings between subbasins and between current and future water quality conditions. Yield coefficients were compiled from a wide variety of references (Horner, 1990; Reinelt and Horner, 1994; Novotny and Olem, 1994) to simulate pollutant loadings, based primarily on locally derived data where available and chosen for their particular applicability to this study area (see Appendix C for loading coefficients).

In calculating the future pollutant loadings, two basic scenarios were modeled in conjunction with the future land-use map. The first scenario assumed that all new development would take place with no water quality treatment of runoff. The second scenario assumed that all areas of new impervious, commercial, multifamily residential, and single-family high-density residential development would be required to implement those best

management practices (BMP's) as will be required by the pending update of the *King County Surface Water Design Manual* (King County, 1990b) to remove a specified fraction of the pollutants. Following the hydrologic modelling assumptions of past basin plans, 20 percent of the runoff (and associated pollutants) was assumed to bypass the treatment facilities.

The fraction of pollutant removal was taken from proposed requirements in the pending update to the *Design Manual* (which has a menu of alternative BMP's with which to achieve the desired pollutant removal). In areas that must provide any water quality treatment at all, total suspended solids must achieve 80 percent reduction; because certain reaches of the Green River are anticipated to be designated a "sensitive" receiving water under future regulations, zinc must achieve 40 percent reduction. Phosphorus removal would not be required, but 40 percent removal was assumed as a result of the removed total suspended solids (Minton, 1992). Treatment was not assumed to reduce the loading of fecal coliforms.

With unmitigated development, water quality will degrade in all of the subbasins but most dramatically in those with the greatest increase in projected urbanized areas. The Lea Hill and Olson Creek subbasins show the greatest overall increases, particularly in zinc (two- to five-fold increases) and total phosphorus (which roughly doubles). The increase in zinc, in particular, is greatest across the study area as a whole; only the watershed area of tributary 0068A, whose land use is dominated by the (unchanging) Auburn Regional Golf Course, shows less than a two-fold increase. As zinc is an easily detectable pollutant and an indicator of other more toxic and harmful metals, a variety of toxic-related water quality problems can be expected where zinc is present. With maximum build-out the likelihood of such problems becomes evident in a number of subbasins, particularly in Olson Creek. In contrast, total suspended solids and fecal coliforms show less than a two-fold increase in every subbasin. The approximate order in which the subbasins will suffer from future unmitigated water quality degradation, from least to greatest change, is shown by the following list:

Least Change:	Auburn Golf Course
↓	North Hillside Drainages
↓	South Hillside Drainages
↓	Cobble Creek
↓	Upper Mill Creek
↓	Lea Hill Tributary
Greatest Change:	Olson Creek

Although unmitigated development would substantially degrade water quality in most parts of the study area, required treatment substantially limits future water quality changes. For example, parts of the Olson Creek subbasin would have the largest proportional reduction, with future mitigated total suspended solids loadings actually 22 percent *lower* than current conditions. For future developed conditions to yield "cleaner" runoff may seem counterintuitive; but the area of the watershed that will develop with total suspended solids treatment required by the pending *Design Manual* update is enough to improve on the current, untreated condition (as reflected by the recommended loading coefficients, which do

not include instream erosion). However, future zinc loadings still double in four of the subbasins even with mitigation; in Olson Creek, the subbasin of greatest current resource value (see below), the loading is triple that of current conditions.

SUBBASIN	SCENARIO[1]	POLLUTANT LOADINGS[7]							
		TSS[2]		TP[3]		Zn[4]		FC[5]	
		kg/yr	% chg.[6]	kg/yr	% chg.[6]	kg/yr	% chg.[6]	10^{11}/yr	% chg[6]
N Bluff	Current	6501		22		7		3.26	
	Future	7621	+17	32	+45	17	**+143**	3.66	12
	Full Mit.	5850	-10	27	+23	14	**+100**	3.66	
S Bluff	Current	19323		97		46		9.01	
	Future	26685	+38	139	+43	95	**+107**	12.4	38
	Full Mit.	18026	-7	115	+19	77	+67	12.4	
U Mill	Current	10198		53		22		4.94	
	Future	15523	+52	84	+58	63	**+186**	7.23	46
	Full Mit.	8044	-21	64	+21	48	**+118**	7.23	
Aub GC	Current	8491		22		13		4.52	
	Future	9089	+7	26	+21	19	+45	4.75	5
	Full Mit.	7985	-6	23	+5	17	+31	4.75	
Cobble	Current	3911		21		10		1.85	
	Future	5672	+45	30	+46	21	**+119**	2.66	44
	Full Mit.	3608	-7	24	+14	17	+70	2.66	
Lea H	Current	9015		41		23		4.30	
	Future	16450	+82	80	+97	69	**+200**	6.90	61
	Full Mit.	8749	-3	62	+51	52	**+126**	6.90	
Olson	Current	20992		81		29		9.54	
	Future	34079	+62	166	**+104**	125	**+331**	16.32	71
	Full Mit.	16310	-22	117	+44	89	**+207**	16.32	

[1] "Future" assumes no WQ mitigation; only the 100% mitigation ("Full Mit.") is included for comparison (see text).
[2] Assumes 80% removal from treated land area.
[3] Assumes 40% removal from treated land area (by virtue of TSS removal).
[4] Assumes 40% removal from treated land area.
[5] No removal required or assumed.
[6] Listed percent changes are relative to current conditions.
[7] Shaded cells represent a minimum doubling of current loadings.

The approximate order of water quality degradation under fully mitigated future conditions is somewhat different than for the unmitigated future case, although the subbasins with the highest resource value experience substantial degradation under either scenario:

Least Change:	Cobble Creek
↓	North Hillside Drainages
↓	Auburn Golf Course
↓	Upper Mill Creek
↓	Lea Hill Tributary
↓	South Hillside Drainages
Greatest Change:	Olson Creek

In reality, not all of the future development in the study area will fall into the *Design Manual* categories requiring runoff treatment. Past development patterns suggest that about one-half of the new development will be single-family residences constructed on preexisting lots that are exempt from treatment. A third scenario was therefore analyzed in which 50 percent of the development runoff was treated (Appendix C); it would result in future increases for all subbasins in all parameters. The worst, Olson Canyon, would receive total suspended solids loadings 20 percent higher and zinc loadings 268 percent higher than current conditions. At these development levels, both instream flows and pollutant concentrations would increase, with concentrations likely to exceed chronic and acute water quality standards during storms in most subbasins. The frequency and duration of exceedences would depend directly upon the size and duration of the storm and the intensity of the land uses; however, to achieve these loads the concentrations must be significantly higher than under current conditions.

In contrast to nutrients and metals, fecal coliforms are not assumed to be reduced by *Design Manual* regulations so no treatment factor was applied. Future fecal coliform loadings are forecast to increase by as much as two-thirds in the Olson Creek and Lea Hill Tributary subbasins. These future loading calculations for build-out may be high because eventually this area will be sewered by virtue of the study area's location inside the Urban Growth Boundary. However, infrastructure investments (such as sewer systems) will most likely lag behind many of the land-use changes. Thus, before the sewer lines are installed the loadings of fecal coliforms and other contaminants may be even higher due to contributions from failing septic systems on small lots, impairing both baseflow quality as well as stormflow quality.

Summary. Currently, the water quality in the study area is good but shows some degradation from urbanization. Wet-weather in-stream concentrations of phosphorus and lead have been close to the lower limits of detection. As development continues, the concentrations of these parameters will almost certainly increase above those detection limits. Even with best-case mitigation for future development, predicted future zinc loadings (and, by association, those of other toxic metals) are of concern in most of the subbasins but especially in Olson Canyon, Lea Hill, and Upper Mill Creek.

Other pollutants may be of even more immediate concern. The Washington State Department of Ecology believes that the Green River does not meet fecal coliform standards now and has placed the river on its 303(d) list of "troubled waters." In the future, that agency may require a comprehensive management plan under the Federal Clean Water Act to reduce fecal coliform loadings to the river. Although the study area is but a scant fraction of the Green River's watershed as a whole, the identified presence of likely fecal coliform sources here suggest the advisability of some future action here to help correct this more widespread problem.

Subbasin Conditions

1. OLSON CREEK (0061)

Conditions in the Watershed. The Olson Creek subbasin, occupying nearly one-third of the study area, covers 1022 acres and includes over three miles of stream channel and about 70 acres of wetlands. Urban development is currently quite limited here, with only about three percent effective impervious area primarily in the form of scattered low-density single-family residences. Future urban zoning, however, could permit a six-fold increase in future imperviousness. By analogy to other watersheds in the region, this change will almost certainly eliminate the current high-quality aquatic resources in this stream system.

Most of the subbasin is located on the upland plateau between 350 and 500 feet elevation. Glacial till underlies this surface at shallow depths almost everywhere, with only localized patches of recessional outwash likely along the south-southeast-trending valley containing tributary 0061D and upper Olson Creek proper.

Because of its relatively large upland drainage area, Olson Creek has carved the largest of the ravines in the study area down to the Green River valley. Extending from Green River Road SE (elevation 75 feet) nearly one mile up to 112th Avenue SE (elevation 325 feet), Olson Canyon has an average valley slope of less than six percent, making it a once-attractive (but since abandoned) route for the proposed eastward extension of S 272/S 277th Street. The sideslopes of the valley, however, are as steep as almost any in the study area. They expose the same complex sequence of ancient river-deposited sand and gravel layers found throughout the study area, some highly cemented but others quite easily eroded. Significant landsliding has occurred in both recent and prehistoric time, particularly along the north wall of the canyon; landslide debris mantles most of the hillsides and lies thickly along both sides of the valley bottom. Because of these conditions and associated constraints on access, hydrologic modeling of the subbasin did not presume future development to occur within Olson Canyon. The mouth of the canyon was recently purchased by the City of Auburn, and so the policies and actions of that jurisdiction will wholly determine whether these assumed limitations remain applicable in the future.

Beyond the standard provisions of King County's Sensitive Areas Ordinance, future development activities in this subbasin are governed by "P-suffix" restrictions in the Soos Creek Community Plan Update (King County, 1991, p. 166-167). In particular, all development within 660 feet of the top-of-slope of Olson Canyon or the adjacent walls of the Green River valley must convey the runoff carried by constructed drainage systems to the base of the slope in a pipe. In addition, the setback from the top of these slopes is 100 feet for new construction unless all reasonable use of a parcel is thus precluded.

Two large public-works projects are planned for this subbasin. Pipeline 5, the regional water-supply diversion from the upper Green River watershed, is planned to cross the southern part of this subbasin, buried along the Bonneville Power Administration right-of-way. Associated with that pipeline, a water-supply reservoir occupying the depression of Wetland 24 has been proposed by the City of Kent as part of its long-range water-supply

plan. The land for this reservoir was annexed by the City in 1987, although no firm schedule for construction has been established nor permits obtained. The conceptual design suggests that the reservoir would cover 70 to 80 acres, with a maximum 50-foot water depth between elevations 375 and 425 feet and a total capacity of 3200 acre-feet. Some excavation might be required but most of the storage would be achieved with berms, isolating the water-supply system from upstream and downstream surface-water drainage.

Streams and Wetlands. Of all the subbasins in the study area, only Olson Creek has a developed channel network. Two large Class 2 headwater wetlands (Wetland 46 in the north and Wetland 24 in the south) drain towards each other along the same glacial-age valley via tributaries 0061D and upper 0061; a third, Wetland 47b (uninventoried but also of Class 2 rating), drains into Wetland 24 along the same valley axis from farther upstream. Their flows combine at a series of ornamental ponds (RM 1.08), turn westward, and soon drop abruptly through Olson Canyon.

Wetland 46 is centered at about RM 0.4 on tributary 0061D and located generally south of the southern terminus of 114th Avenue SE, north of SE 284th Street and east of 112th Avenue SE. The habitat types in this wetland are predominantly emergent marsh and alder/cottonwood swamp. The King County Wetlands Inventory (King County, 1990) estimates this wetland's size at 17 acres, making it the second largest wetland in the reconnaissance area (Wetland 24 is the largest). The Inventory's boundaries do not include previously unmapped wetland segments near the northwest and south outlets.

Several human alterations have affected this wetland (Ref. #25[2]). Near the northwest outlet, a large area has been excavated and impounded to form two interconnected ornamental open-water ponds. Part of the west half of the wetland and buffer just south of these ponds was recently modified as mitigation for the Kent Springs Water-Supply Transmission Line. A chain-link fence and drainage ditch separate the mitigation site from the east half of the wetland, which remains in a more natural condition, and one of the ponds to the north. The fence also extends along the south boundary of the mitigation area. Just northeast, an asphalt trail in Lone Pine Park has been built in the buffer along the north edge of the wetland. Just south of this, a three-acre area cedar swamp has been extensively graded and partially filled. Dumping of trash and construction debris is an ongoing problem at this location, and it is the subject of recurring citizen complaints. The southern tip of the wetland has been channelized in a grass-lined ditch bordered by residential lawns on both sides of SE 284th Street.

In spite of these impacts, this wetland has several beneficial features. It is the most diversely vegetated wetland in the study area. The eastern half contains an abundance of snags, some of which are greater than 18 inches in diameter and taller than 25 feet in height. At present, a nearly continuous corridor of upland forested and riparian habitats extends from the south end of the wetland to the Green River via Olson Canyon (in contrast, a once-

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[2]Reference Numbers are indexed by the first column of the "Table of Observed Problem Sites" in Appendix A.

equivalent corridor extending from the wetland northwest to the Green River via Mill Creek has become much more fragmented). Because of its size, structural diversity, and crucial headwater location, this wetland has been recognized as a Locally Significant Resource Area (see p. 41 for the formal definition of this term).

Horseshoe-shaped Wetland 47b lies within the "Willow Park" subdivision east of 124th Avenue SE and serves as the development's R/D pond. This six-acre Class 2 wetland consists primarily of scrub-shrub (willow/hardhack) and emergent (reed canarygrass) habitat types; it also contains a stand of large cottonwoods near the houses at its northeast corner. In addition to runoff from Willow Park, this wetland receives surface flows from a sparsely developed upland area to the north and probably also from seasonal groundwater discharge. This wetland has been subjected to an array of impacts (Ref. #24, Appendix A), including placement of an R/D outlet control structure near 124th Avenue SE, construction of R/D pond forebays within its east and south edges, and grading and conversion of an upland area within the "horseshoe" into a manicured grass park. In addition, the high-density development along the east and south edges of the wetland has resulted in steep cuts buttressed by rockeries and houses constructed in the former buffer along the east and south edges. A trail system has also been built alongside and within the wetland. An oil sheen was observed near the outlet. Because the subdivision is not presently (mid-1994) built out, the full extent of its impacts on the wetland have not yet manifested. It remains to be seen whether the small cottonwood swamp at the northeast corner of the wetland can withstand the impacts of increased peak flows and an extended duration of inundation and soil saturation.

Wetland 24 is a Class 2 system lying upstream of RM 1.57 on tributary 0061, north of SE 304th Street and between 124th Avenue SE and 118th Avenue SE. A 157-acre parcel that included the area of this wetland and surrounding lands was annexed to the City of Kent in 1987 for eventual construction of a water-supply reservoir. The King County Wetlands Inventory lists the size of this wetland at 39 acres, but this value does not include uninventoried segments that straddle the inlet near SE 304th Street and the outlet near 118th Avenue SE. Additional surface flows enter the wetland from upland pastures bordering its northeast corner. Almost the entire wetland consists of a heavily grazed wet meadow dominated by pasture grasses and soft rush. In addition, there are small scrub/shrub (hardhack) and deciduous swamp habitats near the northwest corner. Portions of the wetland are cultivated for hay production; drainage into, within, and out of the wetland have been channelized through a system of ditches (Ref. #18, Appendix A).

Very few problems associated with stream channels on the plateau have occurred to date, although resource loss has been locally severe. A number of roads and driveways cross the tributary channels; of them, only two (Crossings #6 and #9) are under-capacity and predicted to fail at less than a 25-year discharge. Fish access to the plateau is blocked upstream of 112th Avenue SE (RM 0.76) by the 80-foot long 36-inch diameter culvert beneath this road. Upstream of this culvert, the aquatic habitat has been extensively degraded from clearing activities, dumping and trash disposal, ornamental manipulation of the stream channel, and historical removal of large woody debris (Ref. #15, Appendix A). This habitat degradation, together with intermittent flows above RM 0.7, probably limit fish use above 112th Avenue SE. This culvert (Crossing #4) was overtopped during the very

high flows of November 24, 1990.

Downstream of 112th Avenue SE (RM 0.76), Olson Creek enters "Olson Canyon" and rapidly takes on a wholly different character. The stream corridor is relatively inaccessible to people and so largely intact; however, some clearing is evident at the top of the ravine and locally encroaches on the steep slopes. Valley-wall landslides are relatively small but common for the first 1000 feet downstream. Channel incision is not dramatic in this reach, probably because channel gradients are still moderate, some woody debris helps roughen and armor the channel, and upstream development is presently minimal. Perennial stream flow is reported by residents to reach nearly up to 112th Avenue SE (*i.e.*, to about RM 0.7), even in very low-flow years.

At RM 0.51, however, incision is dramatically greater. The channel drops steeply through a series of sand and gravel layers and then plunges over a 10-foot-high waterfall supported by a cemented, heterogenous layer of sand, gravel, and silt (Ref. #13, Appendix A). The rate of additional future downcutting through this deposit is likely to be very slow. These falls (RM 0.49) mark the upper limit of anadromous fish. Below the falls, Olson Creek provides habitat for coho salmon (Oncorhynchus kisutch), steelhead/rainbow trout (O. mykiss), and both anadromous and resident forms of cutthroat trout (O. clarki).

At RM 0.48, tributary 0061B enters from the north. This tributary drains a lightly developed upland area of scattered houses and pastures, but its descent off the plateau is so steep that a large gully and 20-foot-high waterfall have been eroded into the north wall of Olson Canyon. Several hundred cubic yards of sediment have been delivered to Olson Creek as a result of this erosion. More recently, however, the rates of gullying have probably slowed as progressively less of the loose soil remains and progressively more of the compact underlying hillslope deposits are exposed. Road drainage discharged from the corner of 109th Avenue SE and SE 284th Street (Outfall #3) joins this channel near the top of the gully, presently via a non-engineered drainage system that is likely to fail in the next large storm. About 100 cubic yards of sediment would be rapidly eroded in such an event; a similar volume has already been washed downslope from this source, together with some slower landsliding that is causing yard subsidence and a potential long-term threat to the house immediately north of the failure.

Below the confluence with tributary 0061B, Olson Canyon widens considerably and a dense riparian corridor emerges. Streamside evidence, such as old-growth conifer stumps flanking the channel edges, suggests that the channel has historically remained in its present confines. A few remnants of old-growth large woody debris (LWD) remain integrated into the matrix of the stream channel. Most of the existing LWD, however, has been recruited from deciduous trees within the riparian zone and so is small and of low quality. The stream channel is characterized by a staircase profile gradient dominated by cobble- to boulder-sized sediments occasionally interlocked with LWD. Larger-sized substrate and LWD-forming debris terraces create a diversity of complex pool and riffle microhabitats. The staircase profile of boulder-cascades through this reach of Olson Canyon currently supports a prolific pacific northwest community of macroinvertebrates. These aquatic insects are mainly represented by caddis (*Trichoptera*), mayfly (*Ephemeroptera*), and stonefly (*Plecoptera*)

species with lesser numbers of other aquatic species present. Benthic invertebrates were abundant in this reach, but noticeably absent above 112th Avenue SE. The thick streamside vegetation also provides habitat for wildlife and terrestrial insects as well as a food source for salmonids and aquatic insects. The aquatic insect community appears relatively healthy throughout the canyon reach. However, a considerable volume of smaller sized sediment, apparently derived from continued urbanization of the upland-plateau region, is migrating onto the canyon reach. This material has infilled some of the interstices between cobbles and boulders; were this condition to worsen, the now-mobile substrate could be cemented and less useful to aquatic insects.

The magnitude of channel erosion in this reach of Olson Creek declines progressively downstream; channel morphology progressively reflects less disturbed conditions. By RM 0.3-0.4, channel incision over the last several decades has been less than one foot, the stream meanders in a belt as least two or three times the average channel width, and in-channel pieces of LWD are relatively abundant and spaced a few tens of feet apart. While temporary accumulations of small in-stream debris may form intermittent fish blockages, such as one currently at about RM 0.4, these would likely be dislodged during large storms.

The character of the channel changes once again as it passes through the farm at its mouth, now park property of the City of Auburn. The corridor vegetation, intact for over one-half mile upstream, is largely lost below RM 0.17 (Ref. #5, Appendix A). In this reach, erosion has been locally rapid and may eventually threaten the adjacent farm house. Here also, Olson Creek lacks a continuum of riparian vegetative cover and in-stream structures (most notably LWD and larger-sized sediment) necessary to form pool:riffle sequences suitable as rearing habitat for juvenile salmonids. At the onset of summer the lack of shade, increasing water temperatures, limited cover within the channel, and low-flow conditions may prompt fish movement out of this reach and into the lush canyon area upstream.

Deposition of the coarse sediment load of the stream is particularly prominent between RM 0.08, adjacent to the access road, and the confluence with the Green River (RM 0.00) where a fan of gravel episodically builds out into the river channel and then is swept away. Historically, temporary barriers to fish passage have resulted from the episodic deposition of sediment in this reach. Particularly given the upstream sediment load, the culvert under the Green River Road (Crossing #2) is both a partial barrier to fish passage and undersized for high flows, most recently overtopped in November 1990.

Olson Creek is recognized as a Locally Significant Resource Area by virtue of its high-quality aquatic habitat and active utilization by at least three anadromous salmonid species: cutthroat trout, steelhead trout, and coho salmon. Site visits in May 1994 revealed hundreds of steelhead fry at the mouth, even more coho fry and juveniles along the stream's lower one-half mile, and some cutthroat adults. These populations are probably wild stocks unique to Olson Creek, mixed together with juveniles from other tributaries and mainstem areas that are attracted by the cold, clean water of Olson Creek.

Although the hillslopes of Olson Canyon are naturally steep and unstable, human activity near their upper edge has further increased that intrinsic instability. On the south

side of the canyon, recent tree clearing on the very steep slopes north of the road end of SE 287th Street has increased the risk of future slope failures, particularly given the concentration and piping of stormwater by the road system near this point (Outfall #4). On the north side of the canyon, a variety of clearing and grading activities spanning many years has, at least locally, destabilized hillside deposits (Ref. #9, Appendix A). Their ultimate contribution to the sediment load of Olson Creek is difficult to quantify, however; the most acute sources of sediment are those within and adjacent to the channel itself, particularly a result of increased flows in tributary 0061B (Ref. #10) and along the mainstem of 0061 at about RM 0.5 (Ref. #13).

Erosion of the north canyon wall itself is also evident. Just east of tributary 0061A, a now-overgrown bulldozer track reaches almost down to the valley bottom, representing a past and potentially future source of sediment to the channel. Tributary 0061A is presently a steep but poorly channelized swale with only slight evidence of recent surface-water flows. It does not actually connect with Olson Creek; the last 200-foot reach of where the channel would be found is entirely obliterated by pasture, suggesting that current flows infiltrate entirely. With future development in its upper watershed, however, the magnitude of future flows will almost certainly result in a newly carved surface-water channel (Ref. #6, Appendix A). Judging from analogous situations elsewhere in the region, channel formation is likely to occur unexpectedly, during a relatively large storm, and with significant damage to any structures or developed land in the path of the runoff, an eventuality of potential relevance to Auburn's park development plans.

Hydrologic Modeling of Olson Creek. A numerical hydrologic model was applied to the Olson Creek subbasin to investigate the effects of future land-use changes (see Appendix D for complete details). HSPF (Hydrologic Simulation Program Fortran; EPA, 1984) was used, applying parameters based on calibrated model runs elsewhere in western Washington. The predicted flows in the study area were not calibrated with actual flows. Therefore, the results are probably more valid where used to compare alternative land uses than as absolute values.

To model the watershed, the land area was separated into four subcatchments (Figure 5). The upper two subcatchments (labeled OC1 and OC2) both contain large wetlands (Wetland 24 and Wetland 46) that add significant storage to the routing of stream flow. Water from these two subcatchments combines and continues on the upland plateau through the middle subcatchment (OC3). Flow then enters Olson Canyon, which is modeled as the lowest subcatchment (OC4). Only tributary 0061 was actually represented in the model; the rest of the streams were included by contributing area (but not by individual stream channel). Thus the utility of this analysis is restricted to the mainstem of tributary 0061.

Critical assumptions affect the results of hydrologic modeling. In this study, potential changes in hydraulic routing were emphasized because of the proposal to convert the area of Wetland 24 into a water-supply reservoir. Under current conditions, Wetland 24 provides substantial detention for subcatchment OC1 (up to 100 acre-feet, depending on water depth). This volume is equivalent to 1.5 to 3.0 inches of natural storage. "Future" model conditions assume the loss of Wetland 24 plus some adjacent pasture acreage, in addition to all

anticipated development-related land-use changes in the watershed. In total, these changes result in significant increases from current to future flows in all downstream subcatchments (up to 139%, depending on the subcatchment and the frequency of flow considered). The following table summarizes the results for the subbasin; more complete information is located in Appendix D. Note that the future modeling did not assume any level of onsite detention for new development. In principle, then, all of these projected future flow increases could be avoided. In practice, the reluctance to provide large and so costly detention facilities and the amount of new development that is not subject to drainage controls (mainly single-family houses on preexisting building lots) render the following figures a pessimistic, but not entirely unreasonable, set of estimates of future conditions.

Subcatchment	Land Use	2-yr Flow	25-yr Flow	100-yr Flow
OC1 (Wetland 24 area)	Forest	9	27	41
	Current	14	31	41
	Future	29	65	89
OC2 (Wetland 46 area)	Forest	3	7	10
	Current	4	8	11
	Future	7	10	11
OC3 (middle mainstem)	Forest	16	52	67
	Current	25	79	100
	Future	60	128	144
OC4 (Olson Canyon)	Forest	23	76	126
	Current	44	121	174
	Future	85	193	251

The only subcatchment that is predicted be relatively unaffected by development is OC2, mainly because of the moderating effect of Wetland 46. Flows in the next subcatchment downstream, OC3, do significantly increase from current to future conditions but even that response is moderated somewhat by channel-storage characteristics, with higher flows utilizing up to 12 acre-feet of in-channel storage. As a result, relative flow increases

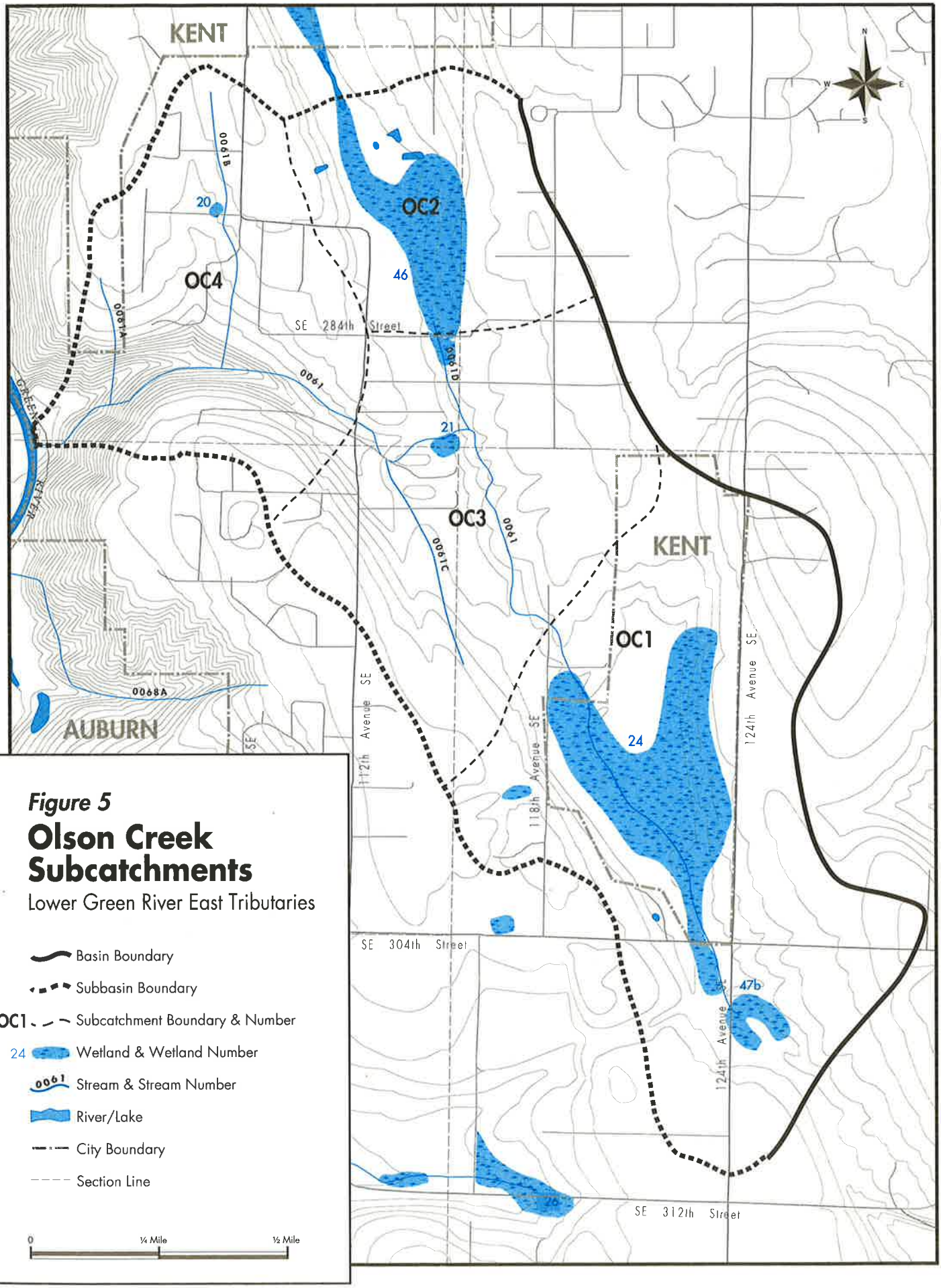

Figure 5

Olson Creek Subcatchments

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- OC1 Subcatchment Boundary & Number
- 24 Wetland & Wetland Number
- 0061 Stream & Stream Number
- River/Lake
- City Boundary
- Section Line

are minimized above about 50 cfs (approximately the 10-year current or 2-year future discharge).

With these model results, the likely future conditions of Olson Creek can be better quantified. Past basin plans have recognized a good correlation between the physical condition of the stream channel and the modeled ratio of the forested 10-year discharge to the current 2-year discharge. Where this ratio is greater than one, the predeveloped 10-year discharge occurs *less than* 5 times as frequently: still allowing for a significant increase, to be sure, but one that appears to maintain relatively stable channel conditions and good-quality habitat for fish. Where this ratio is less than one, large flows occur so frequently that physical destabilization of the channel appears almost inevitable. Under current (1992) land use, this ratio is 1.2, confirming the observations that conditions are locally problematic but the system as a whole still maintains good to very good habitat quality and stability. In the future, however, this ratio drops to 0.6, all but guaranteeing severe instability in the absence of vigorous flow mitigation applied to new development.

The effects of the proposed water-supply reservoir in the area of Wetland 24, independent of the other projected land-use changes, was also modeled (see Appendix D for a full discussion of assumptions and results). Not surprisingly, the changes are greatest at the outlet of subcatchment OC1 (near the downstream end of the wetland) and become progressively less significant as additional tributary area is added. In Olson Canyon (OC4), where any flow increases are likely to have the greatest consequences for channel incision, about three-quarters of the future flow increases shown in the preceding table are caused from projected land-use changes, and about one-quarter result from the loss of in-channel storage from reservoir construction.

Summary of Observed Problem Sites[1]

Site†	Tributary No./RM	Location	Problem Type	Comments
X2	0061 RM 0.01	Green R. Road @ SE 28800	Flooding; Passage	Upstream property purchased by City of Auburn (Parks); culvert overtopped 11/90
lower 0061	0061 RM 0.08-0.17	above Green R. Road	Corridor loss; Erosion	
0061A mouth	0061A @ RM 0.0; 0061 @ RM 0.16	In Auburn parkland	Future erosion	Future channel cutting likely
SE 284th grading	into 0061 between 0061A & B (RB)	SE 284th @ 10700 SE (pvt)	Top-of-slope grading	
03	into 0061B @ RM 0.1 (LB)	SE 284th & 109th SE	Erosion Landslide	
04	into 0061 @ RM 0.4 (LB)	SE 287th @ 10700 SE	Erosion	Runoff now routed to top-of-bank

Site†	Tributary No./RM	Location	Problem Type	Comments
0061 channel	RM 0.5±		Channel incision	Will accelerate with incresed future flows
X4	0061 RM 0.76	112th SE @ SE 28700	Passage; Erosion	Fish blockage; rapid erosion down road embankment
0061 channel	RM 0.8-1.1		Habitat degradation	No feasible solution
X6	0061 RM 1.57	D'way off 118th SE @ SE 29600	D'way flooding	Probably floods at <25-yr event
Wetland 24	0061 RM 1.6-2.2		habitat loss	Cultivation and channelization
X8	0061 RM 2.21	D'way near SE 304th and 124th SE	D'way flooding	Corrected by owner
X9	0061 RM 2.22	D'way near SE 304th and 124th SE	D'way flooding	Probably floods at <25-yr event
Eastridge and associated plats	0061 0061B	west of 112th SE and south of SE 281st	Failing septic systems	Problem recognized by Health Dep't
Wetland 47b	0061 RM 2.4	upstream of 124th SE @ SE 30600	Habitat loss	No feasible solution
Wetland 46	0061D	114th SE @ SE 27800 area	Alterations; Dumping	Aspects of problem have no feasible sol'n

† A complete listing is included in Appendix A.
† "X" = stream crossings by roads; "O" = road-drainage outfalls.

Key Findings

- The Olson Creek subbasin contains two Locally Significant Resource Areas, Olson Canyon and Wetland 46, which have been moderately degraded from land-use activities, particularly corridor encroachment and wetland intrusion. In the future, dramatically increased development in the watershed will likely lead to additional physical impacts and the likelihood of greatly increased flows in Olson Creek; construction of a water-supply reservoir will obliterate Class 2 Wetland 24 altogether.

- The Green River Road crossing of Olson Creek (Crossing #2) has been problematic in the past; the frequency of future culvert blockages and consequent obstruction to fish passage are likely to increase.

- Road drainage from the intersection of SE 284th Street and 109th Avenue SE (Outfall #3) is causing substantial, and largely correctable, erosion into tributary 0061B and downstream into the Locally Significant Resource Area of Olson Canyon.

- The loading of toxic metals is predicted to increase two- to three-fold in the future as a

result of projected land-use changes, even with full water quality treatment applied to future development as required by the *Design Manual*.

2. LEA HILL TRIBUTARY (0069)

Conditions in the Watershed. The Lea Hill subbasin includes 406 acres in the south-central part of the study area. At 12-percent impervious area, primarily a result of multifamily development and two schools, it is currently the most heavily developed of the subbasins. Future high-density single- and multifamily zoning allows a near-tripling of this impervious percentage (to 33 percent), making this the subbasin with both the greatest increase and the greatest final total of any.

Physically, the subbasin consists mainly of a broad upland between about 400 to 450 feet elevation that reaches east along Lea Hill Road SE (SE 312th Street) to the study area's boundary with the Soos Creek watershed. Drainage is westerly along the axis of the subbasin, dropping steeply over a distance of about one-half mile to meet the valley floor at a meander loop of the Green River. It enters the right bank of the Green River at (mainstem) RM 30.15. The geologic materials of the subbasin reflect the topography as a whole: above about 400 feet elevation, the relatively flat uplands are mantled with till, whereas below that elevation the terrain exposes a complex sequence of sand, gravel, silt, and clay on the valley walls. Both current and future development is concentrated on the upland plateau, which constitutes the vast majority of the subbasin's total area.

One natural channel (0069) drains this subbasin. It begins in Wetland 26 on the north side of SE 312th Street just upstream of 116th Avenue SE, crosses 116th Avenue SE, and descends a largely undisturbed ravine. About one-half of the subbasin's total area enters the channel via Wetland 26. Although the wetland may slightly buffer the impacts of existing urban-increased flows, the amount of live storage here, equivalent to less than one-half inch over the contributing watershed as a whole, is inadequate to produce significant hydrologic effects. The original Basin Reconnaissance suggested a regional R/D for the two-acre portion of the wetland south of SE 312th Street (King County Reconnaissance Project 3201); probably a minimum of 10 feet of water-level fluctuation, however, would be necessary to yield any appreciable benefits and would destroy the forested habitat within the wetland.

A second major source of flow is concentrated by 112th Avenue SE from the north basin boundary south into the channel itself. In this vicinity, two very large gullies have been eroded from the road end of 112th Avenue SE (Outfall #10) into tributary 0069. Smaller gullies are also present below Lea Hill Road SE, where runoff from the southwest part of the subbasin has been concentrated by the road drainage network.

One small channel (0069A) joins the Lea Hill Tributary prior to the confluence with the Green River. Its contributing area does not affect flows through the most severely constrained reaches of the Lea Hill Tributary, because it joins with the main channel

downstream of the ravine area. As a result, the associated watershed area for this tributary was excluded from this subbasin's land-use analysis.

As with other subbasins in the study area, future development activities in a few parts of this subbasin are governed by additional "P-suffix" restrictions in the Soos Creek Community Plan Update (King County, 1991, p. 166-167) that regulate drainage conveyance and steep-slope setbacks. South of tributary 0069, the affected area includes most property west of 112th Avenue SE; north of the stream, the affected area lies generally west of 108th Avenue SE.

Streams and Wetlands. Conditions along the wetland and channel system are highly variable. The head of the defined stream system here is Class 2 Wetland 26, which consists almost entirely of forested swamp habitat dominated by Western redcedar and alder, although Sitka spruce, Western hemlock, and Oregon ash are also present. The forest floor is densely vegetated by a variety of shrub and herbaceous species, and covered by a matrix of shallow pools and large and small woody debris. In addition to a modest amount of natural detention, this wetland provides some biofiltration and habitat for birds, small mammals, and amphibians.

Since the original King County Wetlands Inventory was prepared in 1981, approximately 20 percent of the wetland west of 116th Avenue SE was eliminated during construction of the "Auburn Hills Mobile Home Court" (Ref. #41, Appendix A). Other impacts to this wetland include noise and glare from SE 312th Street, buffer removal and habitat fragmentation caused by this arterial road and several driveway crossings, and water quality degradation from untreated road runoff. During a field visit in April 1994, brown scummy water was observed near the road embankment north of SE 312th Street and along driveways that traverse the wetland south of the road. Evidence of adverse impacts from recent hydroperiod changes can be seen in a stand of dead and dying conifers at the northeast corner of the wetland. Future high-density residential development in this subcatchment will lead inevitably to increased water-level fluctuations that will likely kill many of the trees in this wetland, thereby converting forested swamp into more hydrologically tolerant scrub-shrub and emergent plant communities.

In 1987, the Basin Reconnaissance Report noted that the culvert between the two sides of the wetland beneath SE 312th Street (Crossing #16) was clogged, promoting saturation and incipient failure of the road prism. Presently, the culvert remains clogged and the road surface displays a rolling topography typical of construction over compressible organic soils. No severe pavement distress or impending failure is evident, however. At the present downstream outlet of Wetland 26 beneath 116th Avenue SE (RM 1.01), three 28 inch by 20 inch arch culverts (Crossing #15) are largely clogged with trash and debris; minor road flooding is likely at this location.

Also in this area, north-flowing discharge of 116th Avenue SE road-ditch runoff south of Lea Hill Road SE may pose a future public-safety hazard (Outfall #11). Currently, all water infiltrates into the 10-foot-high embankment above Lea Hill Road SE because runoff volumes are not great. However, future development, particularly if single-house

infilling and so exempt from drainage review, could gradually exceed the capacity of the soils to absorb that runoff. Eventually, incision of the embankment and sediment deposition onto Lea Hill Road SE below could occur. Development of the parcel on which the infiltration now occurs could also precipitate this event.

Below SE 116th Street, the channel is confined in a 70-foot-wide forested corridor between the trailer park and SE 312th Street. In this reach there is a significant absence of benthic organisms. Lawns behind several residences in this park are mowed up to the edge of the right bank, exacerbating bank erosion in this reach; foot trails extend across the stream and into an otherwise well-vegetated riparian corridor along the left bank. Trash-dumping appears to be an ongoing problem throughout this area (Ref. #47, Appendix A). Southwest of the mobile home park, numerous semi-mature black cottonwood trees have been felled and bucked into both the steam and a small uninventoried riparian wetland. As a result of canopy removal, this area is undergoing rapid invasion by invasive non-native species such as reed canarygrass, bittersweet nightshade, and blackberries.

At RM 0.78 the channel passes through a 36-inch culvert beneath an old road grade and begins its steep, staircase-like descent in a largely undisturbed forested ravine to the valley floor below. The aquatic zone here is distinguished by relic boulders, large cobbles, and LWD that interlock a stairstep pattern of in-channel features to form a variety of intricate pool and riffle microhabitats. In contrast to the upstream reach, the large-sized sediment throughout the ravine hosts an abundant assortment of aquatic insects, largely caddis, mayfly, and stonefly species. Salmonid spawning habitat, however, is limited to areas of patch-gravels. The riparian zone is well shaded and dense vegetation flourishes alongside the channel edges to provide streamside cover as well as a source of food for aquatic organisms. This zone is represented by a variety of successional deciduous tree and plant species. Stumps from old-growth conifers skirt the hillsides and stream banks throughout the ravine.

In the upper part of this ravine the channel is actively and rapidly incising. A six-foot-high near-vertical knickpoint presently located at RM 0.75 is probably migrating upstream at a rate of several feet per year (Ref. #46, Appendix A). At RM 0.72 the channel meets the first of two right-bank gullies eroded by uncontrolled runoff from the 112th Avenue SE road end (Outfall #10). About 3000 cubic yards of sediment have entered the channel from this erosion, making it the largest single sediment source in this subbasin and dwarfing all non-development-related sources. According to a neighboring property owner and SWM Drainage Investigation complaint files, this erosion began in the November 1990 storm. The headscarp and sideslopes of this gully are still entirely unvegetated and oversteepened; continued gully expansion and sediment release are almost inevitable. The second of the two right-bank gullies originating from the 112th Avenue SE road end is intersected about 400 feet farther downstream (RM 0.64); its volume and magnitude of continued instability are very similar to the first.

For the next 1600 feet downstream of this second gully, to about RM 0.3, channel incision and landsliding are ubiquitous (Ref. #44, Appendix A). In part this is a result of natural processes--clay interbeds result in numerous seeps and springs along the valley sides, resulting in locally saturated conditions and consequent failures involving up to several

hundred cubic yards of sediment. Yet despite the increased sediment load, channel incision is also common, with recent downcutting no more than one decade old averaging one or two feet in this reach. This almost surely reflects the increase in storm discharges as a result of watershed development, which by analogy to similar modelled drainage basins have probably about doubled since development started here. In this reach, the stream provides habitat for coho salmon (Oncorhyncus kisutch) and possibly anadromous and resident forms of cutthroat trout (Oncorhyncus clarki). Juvenile coho salmon were observed as far upstream as RM 0.34, where the stream pours through a bowl formation scoured out of a clay interbed.

Downstream of a 400-foot transition zone, large trees growing at the present channel-bank level suggest that incision ceases by about RM 0.25 as the stream reaches the Green River valley floor. Deposition here is the dominant process; multiple high-flow channels spread out across the alluvial fan that is being constructed of sediment transported out of the ravine. The fan covers the valley floor between this point and the Green River Road (104th Avenue SE, at RM 0.13). Temporary barriers to fish passage may result from channel-spreading throughout this segment; macroinvertebrate populations are confined to pockets of debris masses.

At RM 0.14, tributary 0069A enters the main channel on the right bank. This tributary flows down a generally concave part of the valley wall and so originally drained a very limited area of the adjacent uplands. In now receives a dramatically increased and concentrated volume of runoff as a result of historic diversion of flow by the upland road-drainage system, particularly along 108th Avenue SE south of SE 312th Street. Discharge from a roadside ditch near the road end here (Outfall #13) has carved a 20-foot-high waterfall and associated ravine that has mobilized at least several hundred cubic yards of sediment since its initiation. Most of this sediment has not yet reached the Green River but instead has deposited on the alluvial fan shared by this stream and tributary 0069.

At the Green River Road (104th Avenue SE; RM 0.13) a 50-foot-long 24-inch-diameter concrete pipe (Crossing #14) presently blocks anadromous fish passage of adult coho salmon and may hinder movement of adult cutthroat trout; the movement of coho juveniles remains unaffected. Sand-sized sediment fills about 50 percent of the pipe capacity and the inlet is clogged by small organic debris. It is unclear if these observed conditions affecting fish passage are chronic or temporary. Juvenile coho salmon originating from the mainstem of the Green River would be attracted by the cooler water temperatures and relatively lower flows of tributary 0069. However, the current information is inadequate to know whether the observed upstream population of coho fry originate from the mainstem of the Green River, tributary 0069, or a combination of both.

The potential for road flooding at this location was investigated and is judged a credible but low-priority risk. Using standard culvert-capacity techniques, about 45-50 cubic feet per second (cfs) can pass here if unobstructed by sediment. With the culvert one-half full of sediment, the water capacity is also reduced by a proportional amount. Although no hydrologic analysis of the Lea Hill subbasin has been made, analogy to the model results from Olson Creek suggest that 50 cfs is about the current 25-year discharge. This flow could recur at the 10-year level under full build-out with no onsite R/D. Much of the

present sediment load is probably a result of the erosion associated with Outfall #10 (see above). Assuming this source can be corrected and future onsite R/D can minimize flow increases, the 25-year King County Roads Division standard for culvert passage can probably be achieved, or only slightly missed, for the foreseeable future.

From the Green River Road crossing downstream to the Green River, the Lea Hill Tributary is a sand-bedded stream coursing through layers of fine-sized alluvium in the Green River floodplain. The floodplain has a densely vegetated riparian corridor and is dominated by willows in close proximity to the stream's edge. Periodic incursions of small debris masses, mostly consisting of deciduous material, provide occasional in-stream diversity. These intermittently mobile masses provide hiding areas for juvenile coho salmon in this reach. This section also serves as a transportation zone to more desirable rearing areas upstream.

Based on observed physical and biological conditions in the lowermost 0.5 miles of this tributary, this reach is recognized as a Locally Significant Resource Area (see p. 41). At a relatively high current level of 12-percent effective impervious area in the contributing watershed, this condition is somewhat surprising, and the channel probably does not presently maintain a self-supporting stock of anadromous salmonids. Ready fish access to and from the Green River magnifies the importance of this tributary, however, as does the paucity of major streams entering this part of the Green River valley floor. Yet at projected levels of future urban development, the prognosis for this channel's remnant biological functions is poor.

Summary of Observed Problem Sites

Site	Tributary No./RM	Location	Problem Type	Comments
X14	0069 RM 0.13	Green R. Road @ SE 30800	Culvert blocked (passage)	10-yr road flooding possible if upstream sediment sources (O10) uncorrected
0069 channel	0069 RM 0.3-0.6		Erosion	High sed. load; recent incision 1-2 feet
O10	into 0069 @ RM 0.64 & 0.72 (RB)	112th SE @ SE 31000	Erosion Landslide	New development planned just upstream
0069 channel	0069 RM 0.75		Erosion	Active knickpoint migration upstream
0069 channel	0069 RM 0.78-1.00		Corridor encroachment and habitat loss	
O11	into 0069 @ RM 1.0 (LB)	116th SE @ 31300	Future erosion	Infill development will exacerbate
X15	0069 RM 1.01	116th SE @ SE 31100	Culvert blocked (road flooding)	Private road
Wetland 26	0069 RM 1.0-1.1		Habitat loss	No feasible solution
O13	0069A RM 0.2	108th SE @ SE 30700	Erosion	

Key Findings

- The lowermost 0.5 miles of tributary 0069 has been recognized as a Locally Significant Resource Area, reflecting substantial fish use in this reach. Significant existing problems and very dense future land use, however, render this resource of dubious permanence.

- Fish access to the lower tributary is partly blocked at the Green River Road culvert.

- The largest point sources of eroded sediment into the Green River from the entire study area are located at the 112th SE road end (Outfall #10), with several thousand cubic yards of sediment already mobilized and substantially more readily available for future erosion.

- Resource loss in this subbasin has been severe, with approximately one-third of the original area of Class 2 Wetland 26 being filled during construction of a trailer park and subsequent clearing immediately downstream, which virtually eliminates the stream buffer in this reach.

3. COBBLE CREEK (0068)

Conditions in the Watershed. At 165 acres, Cobble Creek is the smallest of the defined subbasins in the study area. The subbasin includes little of the upland plateau, but because the slope of the Green River valley wall is particularly gentle here, urban development is already 8 percent impervious, second highest in the study area, and projected to reach 20 percent impervious (third highest) in the future.

Drainage is relatively diffuse upstream of 112th Avenue SE, on the upland till surface. SE 299th Place was constructed up the very axis of what was once the upper channel; its road ditches now collect and convey runoff to the entrance of the remaining natural channel downstream of 109th Avenue SE. The ravine here is smaller than in most of the other subbasins; as a result, one major road (106th Avenue SE) has been constructed within the ravine itself, providing access for several dozen lots between the creek and the Auburn Golf Course property.

As with other subbasins in the study area, future development activities in a few parts of this subbasin are governed by additional "P-suffix" restrictions in the Soos Creek Community Plan Update (King County, 1991, p. 166-167) that regulate drainage conveyance and steep-slope setbacks. The boundary of this affected area bisects this subbasin and here includes only property south of Cobble Creek and generally west of 108th Avenue SE.

Streams and Wetlands. Because of the moderate level of existing development in the watershed and relatively common encroachment into the stream corridor, habitat conditions here range from fair to recognizably degraded. At RM 0.11, the channel cross-section has been remeasured on a near-annual basis since 1987 (Appendix E) and shows relative stability but slow widening and deepening. As a whole, the channel displays a trend of relatively recent incision of about a foot or so, most intensely at about RM 0.6, just downstream of 112th Avenue SE. Conversely, the gradient flattens and deposition becomes dominant in the lowermost 400 feet of the channel (RM 0.08 to 0.00).

Neither flooding nor erosion are major hazards in this subbasin, although localized channel erosion has occurred in the upper channel reaches. Two crossings, those under 106th Avenue SE (Crossing #12) and under the Green River Road SE (Crossing #11), have no reports of capacity problems. The former crossing, in particular, is in a zone of the channel where sediment is unlikely to accumulate even if channel incision were to accelerate. The latter crossing, however, may be prone to future blockage because it lies in a zone where any increasing load of sediment eroded from the upper channel will tend to deposit. The capacity of this culvert was evaluated by analogy to the hydrologic model results from Olson Creek, which suggest that overtopping may occur under current conditions at about the 10-year discharge and as frequently as the 2-year discharge if any significant volumes of sediment were ever to accumulate.

Two drainage complaints have been registered in this subbasin since 1990. One, along the now-ditched part of the upper watershed along SE 299th Place, notes erosion from small channels descending the hillside from the southeast (Ref. #29, Appendix A). The

other, even higher in the watershed on the poorly drained uplands along 112th Avenue SE, involves sporadic flooding of yard areas (Ref. #30). Erosion was also noted in 1991 during downstream analysis for the Carrington Bluff subdivision, just downstream of 111th Avenue SE and again below 108th Avenue SE. Field review of this latter site in 1994 indicated that scour was still active, with incision locally several feet deep (Ref. #28). Within a few hundred yards farther downstream, however, gradients flatten and channel stability improves significantly.

Aquatic resources in the subbasin are limited. Wetland areas are restricted to small patches along the channel; any larger upland areas have long since been obliterated by upland development. The bed of Cobble Creek is partly cemented by fine sediment along its entire length. The confluence with the Green River is impassible to fish because the culvert is several feet above the typical water level in the river, but the absence of significant upstream habitat suggests that no corrective action is warranted.

Key Findings

- Existing health and safety problems are not severe in this subbasin; existing aquatic resources are of limited extent and quality.

- Future land-use changes in the subbasin are substantial and will likely accelerate channel incision and sediment transport high in the subbasin. Clogging of the culvert under the Green River Road by that sediment, subsequently deposited, will become progressively more likely over time. If this occurs, overtopping of the roadway could easily become a frequent event that would necessitate culvert replacement.

4. UPPER MILL CREEK (0028)

Conditions in the Watershed. The boundaries of the Upper Mill Creek subbasin were established only partly on the basis of drainage divides, and so the analysis for this area is somewhat incomplete. The northern boundary of the area was chosen to coincide with the northern limit of unincorporated land in this part of King County as of early 1994. This boundary also generally separates those parts of the Mill Creek basin that drain directly into the lower canyon (the "lower" basin, which is *not* included in this report) from those that drain through the Upper Mill Creek Detention Pond, located at SE 267th Street and 104th Avenue SE (the "upper" basin). However, diversion of flows from the lower basin into this pond at high discharges complicate any simple geographic relationship between the upper and lower parts of the Mill Creek watershed. This situation illustrates some of the limitations of any non-watershed-based analysis of surface-water systems.

Of the 433 acres included in this subbasin, single-family residences constitute the bulk of the urban development thus far. Effective impervious area is almost seven percent; future urban zoning would allow this value to increase to 24 percent after development is complete, with the vast majority of the future development in single-family residential subdivisions.

Interestingly, the boundaries of this subbasin are remarkably well-matched by the boundaries of the "Ramstead-East Hill" annexation proposal, recently approved by the King County Boundary Review Board. Virtually the entire subbasin is now part of the City of Kent. Because of the timing of the annexation proposal, our land-use analysis here was based on King County's existing plans and policies. Given the County's residential zoning for this area and the proximity of adjacent industrial and commercial development just inside the previous limits of the City of Kent, this is probably a conservative estimate of the intensity of future development that will actually occur here.

The Upper Mill Creek subbasin lies entirely on the upland plateau of the study area, with its surface underlain by glacial till and showing no more than about 100 feet of topographic relief. Upper Mill Creek occupies an abandoned glacial meltwater channel that extends in total about five miles, from just above the Green River valley floor south-southeast through the headwater wetlands of Olson Creek. In the lower Mill Creek basin, the modern stream has incised a steep ravine over 100 feet deep through the floor of this meltwater channel; upper Mill Creek flows along the largely undisturbed trend of this channel. The boundary between these two channel segments lies just downstream of the Upper Mill Creek Detention Pond at 104th Avenue SE. The types of drainage-related problems that are so common in the lower channel, particularly erosion and sedimentation (Parametrix, 1992) are almost entirely absent in this upper subbasin. Land-use changes here, however, have direct consequences on what has occurred, and will continue to occur, farther downstream. Mill Creek eventually drains into the Green River via the Black River (tributary 0005); for this reason, wetlands in this subbasin are numbered using the "Black River" basin sequence of the King County Wetland Inventory (King County, 1990c).

Streams and Wetlands. The channel of upper Mill Creek has been highly altered throughout almost its entire length (Ref. #2, Appendix A). Originating at an ornamental pond at the Mill Creek-Olson Creek drainage divide, it passes first through an open swale upstream of SE 274th Street, a more fully vegetated but narrow corridor downstream of SE 274th Street, and finally enters the Upper Mill Creek Detention Pond just downstream of 108th Avenue SE, once a large marsh and now subject to about eight feet of water-level fluctuation.

The riparian zone of upper Mill Creek is composed entirely of inventoried and uninventoried wetlands. The poorly channelized swale now in the vicinity of SE 274th Street was a result of excavation and backfilling in the riparian wetland here, in order to place a segment of the Kent Springs Water-Transmission Line at this location. According to local residents, Mill Creek used to flow through this area in a gravel-bedded channel prior to construction activity.

Channel and wetland alterations continue along the riparian corridor. About 1000 feet downstream of SE 274th Street, just southeast of the intersection of SE 271st Street and 108th Avenue SE, Mill Creek has been altered to form a small R/D pond for the subdivision of "Whispering Woods." Immediately downstream of this pond, the terrain flattens and Mill Creek spreads out into Class 2 Wetland 10, composed of alder-cottonwood swamp, scrub-shrub, and emergent habitats. A few hundred feet farther downstream, this relatively

unaltered wetland segment merges with what is now the City of Kent's Upper Mill Creek Regional Detention Pond. The pond consists of a large cattail marsh interspersed with small thickets of willow and hardhack and small patches of open water; stands of mature black cottonwood border the north and south edges of the marsh. An extensive oil sheen was observed near the outlet control structure, which discharges to a ditch along the east side of 104th Avenue SE. The water in the ditch was covered with a thick rust-colored, oily scum during a field visit in late April 1994. Downstream of 104th Avenue SE, a scrub-shrub (willow/hardhack) wetland (Black River Wetland 24) continues along both sides of the stream to the northwestern boundary of the study area. This wetland has been locally fragmented by driveways and filled for parking areas, and its hydroperiod has likely been adversely altered by the massive impoundment directly upstream.

The detention pond also achieves its intended purpose, that of reducing flows in the channel of Mill Creek itself. It has a storage volume of 89 acre-feet (Parametrix, 1992). Although the watershed directly upstream of the pond is only about 400 acres, diversion of high flows from the north tributary (0028A) into the pond approximately doubles the effective drainage area to about 800 acres. This yields a maximum live-storage of about 1.4 watershed inches (*i.e.*, equivalent to a layer of water 1.4 inches deep over the area of the watershed as a whole). This volume is generous by the standards of most detention facilities constructed in the region to date; it is also sufficient to achieve significant flow reductions relative to the undetained runoff from the existing development. Owing to the magnitude of the preexisting development (particularly in the highly commercial watershed of the north tributary), however, flows have undoubtedly increased significantly over their predevelopment values even with the detention pond in place. During the storm of January 1990, 104th Avenue SE was overtopped by stormwater at the pond outlet.

The Parametrix study reports model-simulated flows immediately downstream of the pond at 21, 31, and 45 cfs for the 2, 10, and 100-year discharges, which demonstrate the effectiveness of a pond of this size. For example, (modeled) flows also are available for upper Soosette Creek (subcatchment ST4; King County, 1990a), a watershed lying one mile northeast of the pond with very similar topographic and geologic characteristics to upper Mill Creek. This watershed has nine percent impervious area (probably similar to the impervious-area percentage of the watershed tributary to the Upper Mill Creek pond), lacks any significant detention, and drains an area only 60 percent the size of Upper Mill Creek pond's watershed. Despite the equivalent degree of urban development and the much larger size of the Upper Mill Creek pond's watershed, discharges from these two areas are virtually identical:

	2-Year Flow (cfs)	10-Year Flow (cfs)	100-Year Flow (cfs)
Upper Mill Creek (Parametrix, 1992)	21	31	45
Soosette Creek ST4 (King County, 1990a)	19	31	46

Despite the detention provided by the upper pond, severe problems associated with

high flows are prevalent farther downstream. This condition is largely a consequence of having two-thirds of the flow in lower Mill Creek entering the channel from areas downstream of the Upper Mill Creek subbasin and lacking any equivalent level of detention. Because the Upper Mill Creek subbasin has the greatest amount of yet-undeveloped land draining into the lower ravine, future flow increases are likely to originate more from this headwater source than from the (now-developed) lower watershed. The Parametrix study identified well over $1 million in recommended work at the time of their investigation (1991); it also recommended an interlocal "Critical Basins Agreement" between King County and the City of Kent to limit the consequences of future headwater development. The need to limit those future consequences remains unabated, but the recent annexation should simplify the jurisdictional landscape.

In addition to wetlands directly associated with the channel of Mill Creek, a large wetland (Black River Wetland 8) is located in the eastern part of this subbasin. It is approximately 15 acres in size and lies mainly southeast of the intersection of 108th Avenue SE and SE 264th Street, although a small segment of the northwest corner lies west of the roadway. This Class 2 system consists largely of scrub-shrub (hardhack/willow/cascara) habitat. In addition, a small area of immature cottonwood swamp is located in the northwest tip, two small open-water ponds have been excavated near the southwest corner, and a larger alder/cottonwood swamp forms the south end of the wetland. Development-related impacts to this wetland include fill and minor dumping near residences east of 108th Avenue SE, and extensive alterations in and around the east half of the wetland in the "Tudor Square" subdivision from construction of houses, a cul-de-sac road (110th Avenue SE), an eight-foot wide trail system, an asphalt driveway on fill, and a ballfield with associated drainage channelized in an unbuffered ditch (Ref. #3, Appendix A). A portion the east half of the wetland also has been converted into an R/D pond. Road and yard flooding was extensive in this neighborhood during the January 1990 storm, particularly in the vicinity of the swale leading southeast out of the wetland and now containing 111th Place SE.

Key Findings

- Recent land-use changes place virtually all of the Mill Creek watershed under the jurisdiction of the City of Kent. Analysis of this area's conditions is therefore limited in this report.

- Stream and wetland alteration characterizes virtually all of the riparian zone of upper Mill Creek; alteration has also degraded Black River Wetland 8 in the northeast part of the subbasin.

- The Upper Mill Creek Detention Pond, itself an altered wetland, substantially reduces present flows in the downstream ravine. Future development, however, is likely to overwhelm the moderating influences of this facility unless additional drainage control is provided.

5. HILLSIDE DRAINAGES (0068A-G)

Conditions in the Watershed. Nearly half of the study area drains to the Green River via small channels that reach only a short distance up onto the upland plateau, if at all. These small tributaries are grouped into those of the "North Bluff," reaching the Green River north of Olson Creek (0061); the "Golf Course" tributaries, particularly tributary 0068A which passes through the Auburn Regional Golf Course; and the "South Bluff" tributaries lying south of Lea Hill Road SE. These channels drain a wide variety of land uses, from the nearly undeveloped North Bluff area (1.3-percent effective impervious area) to heavily developed parts of the Green River Community College campus in the southeast corner of the study area. Because much of the land surface of this subbasin slopes steeply, future development will likely proceed less intensively than elsewhere. Sufficient developable land remains above those slopes, however, that future impervious-area percentages are as high as 15 percent in the South Bluff area.

Over six miles of the bluffs along the east side of the Green River valley are included in this subbasin. They display the complex, laterally variable layers of sand, gravel, and clay that typify the geologic deposits in this part of King County. Most of these layers are well cemented by weathering products and the weight of overlying material, and so they are not particularly susceptible to catastrophic stream-channel erosion. In addition, most of the channels receive runoff from only a limited drainage area of several tens of acres and so runoff volumes, even from developed sites, are not terribly high. Where flow from any of the more sizable watersheds has been concentrated, however, the results can be spectacular (such as a 150-foot, two-step waterfall at the downstream end of tributary 0068C).

As with other subbasins in the study area, future development activities in this subbasin are governed by additional "P-suffix" restrictions in the Soos Creek Community Plan Update (1991, p. 166-167) that regulate drainage conveyance and steep-slope setbacks. The North Bluff area and most of the tributary area of 0068A are subject to these conditions, as is the region surrounding the top of the South Bluff.

Streams and Wetlands. Conditions in the various channels of the subbasin differ greatly, reflecting the variety of conditions in their contributing watersheds.

0068A: Although the overall impervious-area percentage contained in this subarea is quite low (4.1 percent), this value reflects inclusion of steep hillslopes and undeveloped valley floor areas, including the Auburn Regional Golf Course, in the calculation. The upland plateau that contributes to this channel, in contrast, is already almost entirely developed in a mix of low- and high-density single-family residences. This represents runoff from land surfaces with an effective impervious-area percentage of perhaps 15 percent draining over the steep slopes here; as a result, channel incision of about one to two feet is ubiquitous. Outfalls from the upland road system have varying effects; thus, for example, release from the junction of 108th Avenue SE and SE 259th Street (Outfall #6) has produced no appreciable channel instability, whereas discharge from the SE 293rd Street road end (Outfall #5) has incised the downstream channel at least two feet deep below its uppermost rip-rapped reach.

The main channel of tributary 0068A reaches the valley floor opposite the clubhouse of the Auburn Regional Golf Course, at the apex of a massive alluvial fan upon which the course is largely located. Given this site of historic (and prehistoric) deposition, severe sedimentation problems would be anticipated here and have been reported for ponds on the golf course (Ref. #33, Appendix A), which up through 1990 were used both for summertime irrigation and as settling basins for the channel's sediment load. Since that time, tributary 0068A has been isolated from the ponds by a berm of silt and sand. The channel's flow is diverted into a pipe, shunted several hundred yards to the north where it reemerges briefly in an ornamental fountain, and is then piped about 2000 feet farther to the Green River (Ref. #31). The channel from Outfall #5, substantially augmented by additional drainage area, joins 0068A at the ornamental fountain. This unnamed tributary channel shows evidence of continued incision; although the lowermost 100 feet have been armored by gabion baskets, failure of the entire pipe system in any subsequent large storm is probably inevitable. Flooding along the southern edge of the golf course also occurs as a result of an old, undersized drainage system for an unnumbered tributary that now receives development-increased flows.

0068B: No problems are reported for this tributary and so it was not field checked upstream of the Green River Road crossing. It is mentioned here because it is one of the sites of long-term "Stormwatch" sampling for water-quality constituents in the study area.

0068C: This channel begins in an old detention pond along 112th Place SE at SE 322nd Place in the subdivision of "Hillcrest Estates." Frequent flooding of the roadway in this area (Ref. #39, Appendix A) has been the subject of a King County study; however, the problem has not been judged significant enough for funding at this time. Downstream of the detention pond, the channel passes through an area of scattered development and then reenters the road drainage system at 107th Avenue SE. To solve a frequent house-flooding problem here, the King County Roads Division is planning to install a larger pipe in this area in 1994 (Ref. #38). At low flow, runoff infiltrates into the ground surface west of 107th Avenue SE and reappears as a spectacular set of springs high on the steep hillside above the Green River. At high flow, water overflows to both the north and to the west, over the lip of the South Bluff and down a 150-foot-high, intermittent waterfall just north of the springs. (The base of the falls can be reached 100 feet south of the road end of 104th Place SE, south of Lea Hill Road SE.)

0068D: The upland road-drainage system has no outfall into this channel; as a result, flow and erosion are minimal. Any sediment transported from the hillside is largely deposited on an alluvial fan just above the floodplain of the Green River. Coho fry were abundant in the lower reaches of this channel (July 1994).

0068E-G: Although road runoff from the east side of 116th Avenue SE is concentrated and discharged into tributary 0068E (Outfall #8), an uninventoried two-acre wetland buffers flows before they reach the head of the steep channel. As a result, erosion in the downstream reach is minimal. In contrast, Outfall #9 exits the southwest-most parking lot of Green River Community College and almost immediately descends the face of the valley wall. Recent incision in this channel (tributary 0068F) is up to several feet deep, reflecting the transport of

at least several hundred cubic yards of sediment to the Green River valley floor. Tributaries 0068E and 0068F join in an abandoned channel on the valley floor, most recently occupied by the Green River in 1973. Tributary 0068G was not visited for this study, but it has virtually no upland or developed drainage area and is not anticipated to show any unusual conditions or significant problems.

Summary of Observed Problems

Site	Tributary No./RM	Location	Problem Type	Comments
O5	into 0068A @ RM 0.2 (RB)	SE 293rd @ 10600 SE	Erosion	
0068A canyon mouth	0068A RM 0.3	upper golf course area	Sedimentation	Problem recognized by golf course
S of 0068A	unnumbered tributary	S edge of golf course	Flooding	Only golf course affected
SE 295th Complaint	above 0068A	10715 SE 295th	Landslide in fill	Above 04 outlet channel
X7	0068C RM 0.2	SE 323rd @ 105th SE	Flooding	Construction planned for 1994
Hillcrest Estates	0068C RM 0.7	112th Place SE @ SE 32100	Flooding	Did not rank high enough for SWM 1994 funding
O9	0068F RM 0.3	SW parking lot, GRCC	Erosion	Very steep channel; difficult access
Eastridge and associated plats	0068A	west of 112th SE	Failing septic systems	Problem recognized by Health Dep't

Key Findings

- A wide variety of topographic and land-use conditions characterize the unnamed tributaries in this subbasin. Future development, and future problems, are most likely in the South Bluff area.

- Plateau flooding is presently a significant problem at two sites (SE 323rd Street at 105th Avenue SE and 112th Place at SE 321st Street). Erosion problems in this subbasin are of moderate extent but limited downstream impact.

6. GREEN RIVER VALLEY FLOOR

Land Use. Although not strictly a "watershed" as the term is used elsewhere in this report, the Green River valley floor is a recognizable physical environment that shares several common attributes along its entire length. In the study area it is accessed from the south at the Porter Bridge, where 8th Avenue NE in Auburn meets Lea Hill Road SE in King County, and from the north along the Green River Road. Only two roads presently reach down to this subbasin from the adjacent uplands to the east, Lea Hill Road SE (constructed down the face of the valley wall) and 304th Way SE (along the valley of tributary 0068). However, future construction of SE 277th Street will improve this access significantly. Existing development in this subbasin is clustered along 102nd Avenue SE, just north of the Porter Bridge, and in widely scattered houses at the base of the North Bluff.

The land is subject to hazards both from the river side, in the form of flooding and channel erosion, and from the upland side, in the form of localized sedimentation from hillslope drainages. Although resolution of the mainstem river processes is beyond the scope of this report, a catalog of local impacts is summarized below.

Zoning in this subbasin is almost entirely residential, presently at densities of one unit per acre (SC zoning) but possibly higher in the future as a result of the study area's location west of the Urban Growth Boundary. Two small areas of higher density single-family residences lie just south of the golf course and just south of the Porter Bridge (RM 31.1). Of these higher density zones, the one south of the bridge lies in an area of moderate channel-migration hazard (see below). All other future land-use changes are unconstrained by hazards associated with the Green River, although some toe-of-slope landslide or drainage concerns may be locally relevant.

Mainstem Resources. Although the scope of this reconnaissance effort was largely limited to the tributaries of the study area, a brief review of the Green River mainstem itself was unavoidable. On this basis, the mainstem Green River is recognized as a Regionally Significant Resource Area upstream of RM 31.8, beyond the scattered houses adjacent to the Porter Bridge, and a Locally Significant Resource Area downstream of that point to the edge of the study area. Although future system-wide analyses of the river will surely develop a more complete framework for evaluating the variety of mainstem resources, we anticipate that these designations will be affirmed.

Despite a moderate level of floodplain development, extensive riparian wetlands and forested uplands remain along the mainstem Green River within the study area, although a majority are not included in the *King County Wetland Inventory*. The wetlands on the valley floor include percolation side channels, wall-base tributaries, and riparian wetlands. The plant communities in these areas typically consist of semi-mature or mature deciduous forests dominated by black cottonwood and other flood-tolerant trees such as red alder and Oregon ash, and understories composed of willow, red-osier dogwood, snowberry, wild rose, and Pacific ninebark. The forests on steep banks and high terraces are characterized by dense stands of big leaf maple, lesser amounts of red alder and Douglas fir, and understories of salmonberry and vine maple.

Of special note are the mainly forested reaches between RM 26.5 (the lower end of the study area) and 29.2, and between 31.8 and 33.8 (the upper end of the study area), which are relatively unaffected by development and also lack flood-control structures. Several parcels of undeveloped King County open-space land and lightly developed City of Auburn parkland lie within these river segments. Most of these areas contain small foot trails and informal access points; as such, they provide outstanding public resources for environmental education and passive recreation.

These riparian forested areas provide shade, natural erosion control, wildlife habitat, nutrients for aquatic biota, and a source of instream large woody debris, which is crucial in forming and maintaining high-quality fish habitat. Abundant juvenile salmonids, numerous waterfowl and passerine birds, and two species of furbearing mammals were sighted during June 1994.

By contrast, the revetted segments between RM 29.2 and 31.8--especially along the left bank in a densely developed part of Auburn--are characterized by intensive vegetation management and invasion by blackberries and other weedy species. Bank armoring in these areas has smoothed and narrowed the river channel, disrupted many of the connections between the river and its historic floodplain, and greatly reduced use of the riparian zone as a corridor for wildlife movement. Several large bank failures are visible along the unrevetted agricultural lands in the lowermost reach of the study area. The main cause of these failures appears to be replacement of mature forest vegetation by tilled fields.

Floodplain Location. No inhabited structures lie in the mapped floodplain of the Green River in this subbasin. The Flood Insurance Rate Maps (Federal Emergency Management Agency, 1989) suggest that this outcome is partly a result of flow limits imposed by Howard Hanson Dam, farther upstream on the Green River at RM 64.5, and partly a result of constructed levees. South of the Porter Bridge, levees are absent yet the dam-modified 100-year flow is still entirely contained within the banks of the Green River channel for about one-half mile upstream of the bridge. Yet farther upstream, high flows do overtop the channel banks and spread out to the base of the South Bluff, but they cover an area without access or other development of any kind. Just downstream of the bridge, the Porter Bridge Levee protects over a dozen houses; beyond that point, floodwaters extend east beyond the channel almost everywhere as far as the elevated embankments of 104th Avenue SE and the Green River Road. Nowhere, however, are these roads overtopped. East of those roads, backwater flooding is predicted but only over parts of the Auburn Regional Golf Course and adjacent undeveloped areas north to the mouth of Olson Creek.

Channel Migration. The Green River has been the subject of a recent study of historic and potential channel migration along most of its length (Perkins, 1993). The south part of the present study area, below the South Bluff, has seen some of the most active and rapid channel shifting in historic time of any along the entire river. Levee construction on the south side (left bank) of the river since 1960 has slowed the rate of channel shifting here in recent time; revegetation of channel bars in response to this stability has further decreased recent migration rates. In contrast, the river farther downstream has been much more stable in historic time, with all past channel locations generally within one hundred feet of their

present location. Extensive levees and revetments constructed in the early 1960's have reinforced this trend of stability even more completely.

These conditions are reflected in the 1993 study's assessment of future channel-migration hazards. Upstream of the Porter Bridge, nearly the entire valley floor is designated "Severe Hazard Area" in recognition of the rapid rate of past channel shifting and the absence of revetments on the right bank of the river; channel migration is judged likely throughout this area over an approximate 50-year period. Three houses are constructed on the right bank of the river along 104th Place SE in this area (Ref. #54, Appendix A), but they occupy a narrow zone that is designated only "Moderate Hazard" (likely migration within about a century). No other structures are located in this reach.

Downstream of the Porter Bridge, the "severe" hazard zone extends only as a narrow strip of land between the Green River Road and the river, from about the Golf Course maintenance yard north to SE 259th Street at the edge of the study area. Almost all of this area is either city or county parkland; no houses or major structures exist here. Even local zones of "moderate" hazard, although not parkland, are devoid of structures.

The relatively low degree of hazard from channel migration in this study area (three houses in the "moderate" zone) reflects the low level of development on the east side of the Green River. Even if all bank protection was eliminated or future maintenance abandoned, only two or three additional houses in the SE 26900 block of Green River Road would be at risk, an equivalent number of houses just north of the Porter Bridge, and the Golf Course club house. In the absence of future maintenance, probably the greatest risk of damage within the study area would be sustained by the Green River Road itself, which traverses a region of significant potential migration hazard almost continuously.

Key Findings

- By virtue of Howard Hanson Dam, levees, and past land-development patterns, flooding is not a significant problem along this reach of the Green River.

- Channel migration of the Green River poses a long-term threat to at most three houses on 104th Place SE, just upstream of the Porter Bridge.

- Fewer than half of the riparian wetlands along the Green River within the study area are identified in the *King County Wetlands Inventory*. Because of this, these systems are particularly vulnerable to damage or wholesale destruction as a result of permitted and unpermitted land-use activities.

MANAGEMENT RECOMMENDATIONS

Problem Significance

Criteria. Because the limited nature of this reconnaissance did not justify the development of an independent and comprehensive set of significance criteria, we have applied the criteria in recently completed basin plans with only minor modifications that reflect conditions particular to this area.

CRITERIA FOR PROBLEM SIGNIFICANCE

	HIGH	MEDIUM	LOW
HEALTH/ SAFETY	•Swift-moving or deep water @ 100-year flow •Potential impoundment failure with downstream flood potential •Contamination to well or aquifer •10-year flooding of residences, commercial or industrial buildings, or arterial roads •Frequent, severe violation of State water-quality standards	•100-year flooding of residences, commercial or industrial buildings, or arterial roads with more than 10% damage •10-year flooding of sole-access roads •Conditions that will likely yield a "High" *future* problem	•100-year flooding of residences, commercial or industrial buildings, or arterial roads with less than 10% damage •10-year ponding of water in areas without structures •Conditions that will likely yield a "Medium" *future* problem •Driveway flooding
AQUATIC RESOUR-CES	•Potential impacts to candidate, threatened, or endangered species •Artificial barriers to large areas of high-quality habitat •10-year damage to Regionally Significant Resource Areas (RSRA's) •Frequent, severe violation of State water-quality standards	•Artificial barriers to small high-quality habitat areas •10-year damage to Locally Significant Resource Areas (LSRA's) •100-year damage to RSRA's •Occasional violation of State water-quality standards •Conditions that will likely yield a "High" *future* problem	•100-year damage to LSRA's •Disproportionate contribution of fine sediment to Green River mainstem •Conditions that will likely yield a "Medium" *future* problem

Two broad categories of problems are recognized by these criteria: ***Health and Safety***, which directly affect the people who live in the basin, and ***Aquatic Resources***, which affect the biological functions and values of the streams in the study area and the Green River. Although the relative significance of one category over the other will be judged differently by different people, this study follows the guidance of past basin plans in recognizing that *both* of these aspects of the surface-water system must be addressed if a basin management program is to succeed.

Two sets of terms in the criteria table require more formal definition. *Significant resource areas* are wetlands or stream reaches that are important to the viability of fish and wildlife populations because of their functions as biological resources. They are grouped as "regionally significant" and "locally significant" resource areas (RSRA's and LSRA's) based not only on their intrinsic value, which is typically related to the size and complexity of the surrounding drainage basin, but also to their present functions, which largely depend on the existing degree of degradation caused by development activity.

Regionally Significant Resource Areas (RSRA's) contribute to the resource base of the entire southern Puget Sound region by virtue of exceptional species and habitat diversity and abundance, when compared to aquatic systems of similar size and structure elsewhere in the region. These areas may also support rare, endangered, or sensitive species. The following criteria are used to recognize RSRA's in the watersheds of King County:

1. Watershed functions are not appreciably altered from predevelopment conditions, as measured by corridor integrity, flow regime, sediment movement, and water quality.

2. The diversity and abundance of aquatic habitat are of consistently high quality and are well dispersed throughout the system.

3. Freshwater and/or marine life, particularly salmonids, approach or exceed the abundance and diversity of equivalent undisturbed systems and make a significant contribution to the regional fishery resource of Puget Sound.

Locally Significant Resource Areas (LSRA's) also contribute to the resource base of the region but at a lower level of both diversity and abundance than RSRA's. Most significantly, they provide wetland and stream habitat that is important for wildlife and salmonids within a particular basin. The following criteria are used to recognize LSRA's in the watersheds of King County:

1. Watershed functions have been altered from clearing and filling, but corridor integrity, flow regime, sediment movement, and water quality generally are adequate for spawning and rearing of salmonids or other wildlife.

2. The diversity and abundance of aquatic and riparian habitats are good but not exceptional; instability and damage are evident but generally confined to localized sites.

3. Freshwater and/or marine life, particularly salmonids, are supported at one or more species and life stages at population levels that are low but sustainable.

On the basis of these definitions, three LSRA's are recognized in the study area: Olson Creek (0061) through Olson Canyon (below 112th Avenue SE, RM 0.0-0.76); lower Lea Hill Tributary (0069) (RM 0.0-0.5); and Wetland 46 in the upper Olson Creek subbasin. Exclusive of the Green River mainstem, there are no RSRA's in the study area.

The problem criteria also recognize the significance of an area's "disproportionate contribution of fine sediment." Defining this term requires some quantification of the likely sediment load of the Green River as it passes the study area. Dunne and Dietrich (1979) estimated the annual sediment load of the Green River below Howard Hanson Dam at about 260 tons per square mile of tributary area. A "disproportionate" sediment contribution from a particular tributary area, therefore, would be one that is greatly in excess of this value. From the study area as a whole (5.8 square miles), for example, we might expect to see about 1500 tons of sediment (about 1000 yd^3) delivered to the Green River annually. Thus discrete, development-induced sediment sources of tens or even a hundred or so cubic yards in volume are probably *not* disproportionate to the Green River as a whole; but sources of several hundred cubic yards would be relevant. At the scale of sediment delivery to individual LSRA's *within* the study area, of course, the level of concern would be proportionally lower.

Results. Based on the full set of significance criteria, no problems are of "High" priority and ten problems are of "Medium" priority (a full listing of problem sites is given in Appendix A). The absence of higher ranked problems reflects the lack of both significant flooding problems and Regionally Significant Resource Areas in the study area.

The ten medium-priority problems (and their Reference Number from Appendix A) are as follows (Figure 6):

1. Flooding of two residences and the intersection of SE 323rd Street and 105th Avenue SE by tributary 0068C (Crossing #13; Reference #38).

2. Frequent flooding of at least one residence and 112th Place SE at SE 321st Street in the subdivision of Hillcrest Estates (Reference #39).

3. Blockage of the culvert under Green River Road by Olson Creek (0061; Crossing #2), causing arterial flooding and blocking fish passage to the upstream LSRA (Reference #4).

4. Damage to the Olson Canyon LSRA as a result of increasing flows and chronic development-related watershed disturbances. Also includes erosion of tributary 0061B and adjacent property from road runoff at 109th Avenue SE and SE 284th Street (Outfall #3; Reference #10).

5. Degradation of Wetland 46 (LSRA) along tributary 0061D from alteration, dumping, and filling (Reference #25).

6. Partial blockage of culvert under Green River Road, limiting fish passage into Lea Hill Tributary (0069) and passage of future 10- to 25-year flows beneath the arterial (Crossing #14; Reference #43).

7. Damage to lower Lea Hill Tributary (0069) LSRA as a result of increasing flows. Also includes gully erosion from the road end of 112th Avenue SE (Outfall

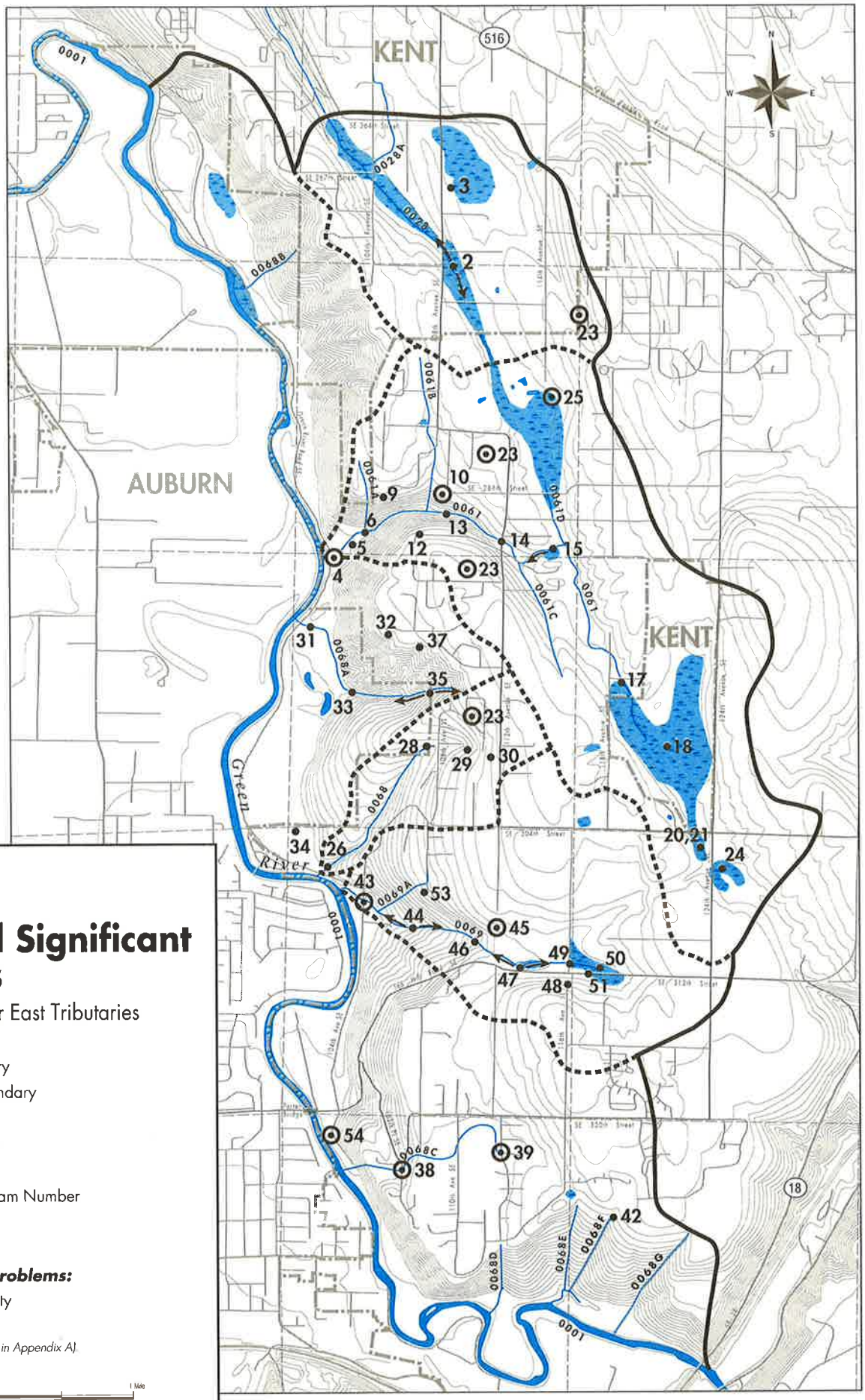

Figure 6

Identified Significant Problems

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- Wetland
- City Boundary
- Section Line
- 0068C Stream & Stream Number
- River/Lake

Identified Problems:

- ⊙ 4 Medium Priority
- • 2 Lower Priority

(Reference numbers in Appendix A)

0 1/2 1 Mile

#10), which is of sufficient volume to be a significant sediment source into the Green River from the study area (Reference #44 and #45).

8. Future threat to three residences from channel migration of the Green River just upstream of the Porter Bridge on 104th Place SE (Reference #54).

9. Future significant water-quality degradation with probable frequent violation of State water-quality standards, particularly for metals (not part of Appendix A).

10. Occasional current and frequent future violations of State water-quality standards, probably from failing septic systems in several older plats (not part of Appendix A).

Recommended Management Program

Overview. Because most of the problems in the study area are of only "low" priority on a County-wide basis, their correction is not terribly likely in the foreseeable future except where low-cost approaches can achieve a disproportionately large improvement. Therefore, extensive solution proposals have not been prepared for a majority of the recognized problem conditions discussed in this report or listed in Appendix A. Instead, the problems simply have been organized and are grouped by the likely vehicle for any eventual solution; within these groups, the problems are arranged in rough priority order. This information, tabulated at the end of this section, provides a ranked list of projects for the eastern tributaries of the Lower Green River basin, to which existing and future public-agency programs will be able to reference.

Even of the "medium-priority" problems, not all warrant extensive analysis here. Two, flooding of SE 323rd Street (Crossing #13) and flooding of 112th Place SE in Hillcrest Estates, both along tributary 0068C, have been analyzed in detail in previous engineering studies. The former is scheduled for correction in 1994 by the King County Roads Division; the latter was judged too low in County-wide significance to qualify for correction under the 1994 SWM CIP program. A third, the channel-migration risk upstream of the Porter Bridge, is a future long-term risk only and is likely to be addressed in a more systematic fashion on a river-wide or County-wide basis. A final problem without extensive analysis here is the predicted water-quality degradation throughout much of the study area (Appendix C), which is likely *despite* anticipated controls on new development and which demonstrates the difficulty in preserving satisfactory water quality in a natural drainage system in the face of intensive urban land use.

Of the remaining medium-priority problems, those relating to Olson Creek are of greatest significance because of the existing value of this LSRA area. Both site-specific actions and watershed-wide efforts would be necessary here for complete protection, because the channel suffers from both localized problems and the overall stress of ever-increasing flows from new development.

Land Use. Because the entire study area presently (June 1994) lies on the "urban" side of the Urban Growth Boundary, proposing low non-urban densities as a strategy to protect existing aquatic resources and to avoid future problems is not viable. Were this option available, the watershed of Olson Creek would be an obvious candidate for such protection, because its current level of urban development is low and (not entirely coincidentally) the value of existing resources is high. The most severe future problem anticipated in this subbasin--the increase in flows and doubling of toxic metal loadings as a result of land-use changes, even with mitigation efforts--will probably eliminate most of the current resource functions recognized here. Equivalent levels of aquatic resources were recognized in parts of the Soos Creek basin and protected with ½-mile-wide low-density corridors (King County, 1990b); an analogous action here would actually achieve full coverage of Olson Creek's tributary area.

Partial relief from the effects of future high-density urban development is provided by one-acre zoning, covering several hundred acres, between Olson Canyon and Wetland 24 to the east. Although this zoning will remain in effect for only as long as the area remains unincorporated, its continuity even after future annexation or incorporation would help moderate the flow increases and water-quality degradation that will otherwise occur.

Water Quality. Where new development is proposed, the degree of water quality control and treatment can significantly reduce the magnitude of downstream impacts. Two management strategies are feasible: source control through implementation of best management practices and water quality treatment through constructed facilities.

Several State and King County ordinances require source control through best management practices (*i.e.*, NPDES, Water Quality Ordinance, Livestock Ordinance) for selected land uses. However, several chronic sources are not required to implement source controls. These sources are existing roadways and single-family residences. Unfortunately, the loadings from each are diffuse, difficult to manage, and directly influenced by the size and lifestyle of the population.

With improved road maintenance techniques and retrofitting road drainage systems as roadways are modified, road drainage quality should improve; however, loadings from roads are directly related to traffic levels. As this study area develops, traffic increases will be responsible for a significant portion of the toxic loadings. Source-control techniques would include having less vehicles on the road or redesigning the vehicles we use to emit fewer toxics. Decreasing traffic through improved public transit may be a more feasible option than implementing the use of copper-free brake linings and other less toxic vehicle materials. Because roadways are such a diffuse source with many discharge points, management is difficult and constructed facilities are expensive.

As proposed in the pending update of the *King County Surface Water Design Manual*, some types of new development will be required to remove a specified fraction of pollutants through constructed facilities; however, single-family residences are exempt. Single-family development can constitute a significant source of pollutants, depending on the lifestyle and practices of the population. Continuous, understandable and targeted

educational programs are critical to address this source.

The likely failing septic systems in several parts of the study area were identififed by, and are under the jurisdiction of, the Seattle-King County Department of Public Health. Accurate field determination of the extent of the problem in these areas should be made; the results of that study should guide the Health Department in deciding whether these areas merit designation and action as "areas of special concern." Although these areas lie within the Urban Growth Boundary, such urban services as sewers (which would also resolve this problem) are not at all certain to be constructed in these areas within any foreseeable length of time.

Onsite Flow Control. Where new development is proposed, the degree of onsite retention or detention (R/D) has a significant influence on the magnitude of downstream impacts. Following the principles of the *King County Surface Water Design Manual*, new development should not allow undetained or inadequately detained runoff to increase downstream flooding, erosion, sedimentation, and aquatic-resource damages.

Achieving this objective can be technically difficult and financially burdensome. Ideally, all runoff from newly constructed impervious surfaces first should be retained onsite to the maximum extent feasible. The runoff that is not infiltrated or otherwise retained should be controlled with one of three **levels** of R/D facility, consistent with the overall intent of avoiding downstream impacts but also recognizing the range of current and future resources and problems in the different tributary subbasins. Following the guidance of existing basin plans and proposed revisions to the *Surface Water Design Manual*, these R/D levels are defined as follows:

LEVEL 0 - NO R/D FACILITIES REQUIRED. In conformance with the **Direct Discharge** provisions of Section 1.2.3 of the 1990 *Surface Water Design Manual*, R/D requirements may be waived where discharge to a "Receiving Water" is possible. The Green River is such a receiving water only up to RM 6, and so no direct discharge is available in the study area. If a subsequent hydrologic analysis of the Green River mainstem shows that flow increases are negligible, however, then the valley floor should be covered under this Level-0 provision.

LEVEL 1 - 2-10 PEAK FLOW R/D. Runoff that must meet a peak-flow reduction standard should be detained in facilities designed using one of the two following methods:

1. Ponds should be designed using the **King County Runoff Time Series** (KCRTS) program (as described and recommended in King County, 1993a) such that post-development 2-year and 10-year discharges should not exceed their pre-development level. A 20-percent volumetric safety factor should be added to ponds sized using KCRTS. The KCRTS program will be included with upcoming revisions to the *Design Manual*.

2. Until KCRTS becomes available, the 7-day Design Storm Method should be used to size ponds that reduce post-development 2-year and 10-year peak discharges to

their respective pre-development levels. A 30-percent volumetric safety factor should be added to ponds using the 7-day Design Storm Method.

Level 1 R/D is designed to prevent new development from causing increases in the magnitude of and frequency of downstream flooding problems. Both design methods achieve the intent of the *Design Manual*, which is to maintain post-development 2-year through 10-year peaks at their pre-development levels under realistic rainfall conditions. Analysis shows that the two alternative design methods result in ponds of very similar size.

In recommending R/D standards to the subbasins here, Level 1 or higher was chosen wherever potential future development was of sufficient magnitude to cause an estimated increase of greater than 10 percent in the magnitude of 2-, 5-, 10-, 25-, and 100-year peak creek flows. This occurs uniformly across the study area. The cost of Level 1 R/D is highly variable but is typically one to several thousand dollars per residential lot.

LEVEL 2 - CHANNEL EROSION PREVENTION R/D STANDARD. Runoff that must avoid increases in the *duration* of erosive or sediment-transporting flows should be detained in facilities designed as follows:

1. Facilities should be designed using the King County Runoff Time Series (KCRTS) program (King County, 1993a) such that post-development flow durations should not exceed pre-development flow durations for all discharges between one-half of the 2-year flow and the 50-year flow. A 20-percent volumetric safety factor should be added to facilities meeting these criteria.

2. Until KCRTS becomes available, facilities should be designed using the SCS-SBUH, 24-hour Storm Method described in the 1990 *Design Manual* such that post-development 2-year, 10-year, and 100-year storm flows do not exceed pre-development storm flows equaling one-half of the 2-year, 2-year, and 10-year flows, respectively. A 30-percent volumetric safety factor should be added to facilities meeting these criteria.

Level 2 R/D is designed to prevent initiation or aggravation of existing channel erosion and instability. It maintains at pre-development levels the aggregate amount of time that post-development flows exceed an erosion-causing threshold. Level 2 R/D may double the size of R/D facilities and so substantially increase costs per lot over Level 1 R/D. Therefore, Level 2 R/D is only recommended where the additional downstream damage or lost value of *not* requiring Level 2 R/D is judged to be substantially greater than the cost of providing it.

ONSITE R/D RECOMMENDATIONS BY SUBBASIN (*FIGURE 7*)

SUBBASIN	TRIB. #	R/D LEVEL	JUSTIFICATION
Olson Creek	0061	2	LSRA; substantial flow increases from projected 6-fold increase in effective impervious area
Lea Hill Tributary	0069	2	LSRA; projected 3-fold increase in effective impervious area to 33 percent
Cobble Creek	0068	1	Low resource value and little opportunity for significant future problems. Green River Road culvert (Crossing #11) may need future upgrade irrespective of R/D standard used
Upper Mill Creek	0028	1/2	Not analyzed for this report in light of annexation; capacity of Upper Mill Creek detention pond may be sufficient to lower onsite R/D requirements (to Level 1) relative to what downstream conditions would otherwise suggest (Level 2)
Hillside Drainages	0068 A-G	1/2	Existing and potential erosion in South Bluff shows potential for disproportionately high sediment input to Green River (Level 2); North Bluff and Golf Course areas sufficiently constrained to minimize future development (Level 1)
Green River Valley Floor	N/A	0/1	Direct discharge (Level 0) not available unless subsequent hydrologic analysis of mainstem show that future flow increases are negligible; were direct discharge permitted, adequate capacity of Green River Road culverts only likely downstream issue (Level 0 or 1)

Other Public-Agency Programs. Several of the identified problems can only be resolved, if at all, through particular public-agency actions that are distinct from either drainage regulations (above) or capital projects (next section). These include:

1. ***Update the King County Wetlands Inventory*** to include previously unmapped wetlands. Although reprinting of the Sensitive Area Folio or Wetlands Inventory Notebooks is very unlikely in the foreseeable future, the computer-based King County information systems maintained at both SWM (Geographic Information System) and DDES (parcel-specific Situs files) could be readily updated. The City of Kent should incorporate this information into its current

permitting information base as well.

2. ***Continue education and/or enforcement actions*** against trash dumping in the northeast part of Wetland 46, clearing in the vicinity of the "Tudor Square" trailer court along the Lea Hill Tributary and Wetland 26, filling and grading along upper tributary 0061B, and top-of-bank clearing and grading on the upper north and south rims of Olson Canyon. Many of these activities pre-date the 1990 adoption of King County's revisions to the Sensitive Areas Ordinance and so legal authority to require correction is limited; but such activities also have been reported subsequent to that time and will undoubtedly continue in the future. Their correction should be a high priority via either grading or water-quality ordinance authority, particularly in the Olson Creek subbasin where the long-term viability of the LSRA's there depend on minimal future disruption.

3. ***Acquire additional parkland*** immediately adjacent to Lone Pine Park at the end of 114th Avenue SE (27800 block). This action would not only expand the park property but also address the chronic grading and dumping problems into Wetland 46 at this site, protect a portion of this LSRA, and provide the public a controlled glimpse into this high-quality wetland system. The 4.75-acre parcel is presently (June 1994) for sale.

   Other parkland purchases, emphasizing stream corridors and high-quality wetlands in the study area, could provide part of the mitigation package to compensate for the loss of Wetland 24, should the City of Kent's water-supply reservoir be constructed.

Capital Projects. The following projects were identified to address medium-priority problems (Figure 8). Within each program category, projects are in recommended priority order; costs are estimated by analogy to similar, recently constructed projects and are included only to give a general idea of the likely magnitude of expense:

SWM CIP's:

LGR1. Tightline of road-end runoff from 112th Avenue SE (Outfall #10) into the Lea Hill Tributary (0069). This problem has been previously recognized in the Neighborhood Drainage Assistance program but was ranked at too low a level by that program's criteria for funding. This problem's broader significance to the downstream LSRA and crossing of the Green River Road (see LGR6, below) should be reassessed within the Division-wide CIP evaluation process.

Estimated cost: $100,000

LGR2. Bypass pipe and R/D retrofit in the plat of Hillcrest Estates. This problem

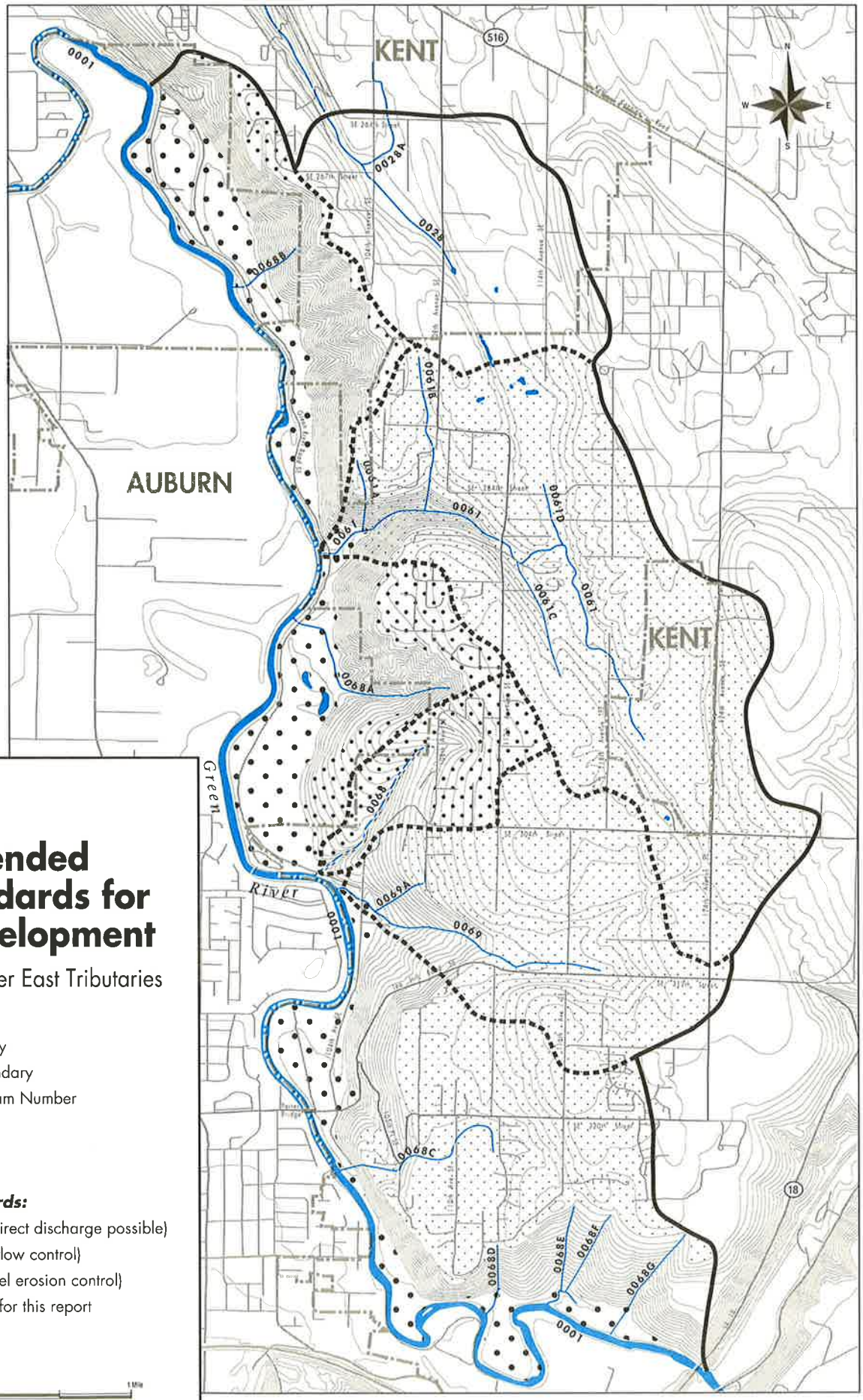

Figure 7

Recommended R/D Standards for New Development

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- 0068C Stream & Stream Number
- River
- City Boundary
- Roads

R/D Standards:

- Level 1 or 0 (direct discharge possible)
- Level 1 (peak flow control)
- Level 2 (channel erosion control)
- Not analyzed for this report

0 1/2 1 Mile

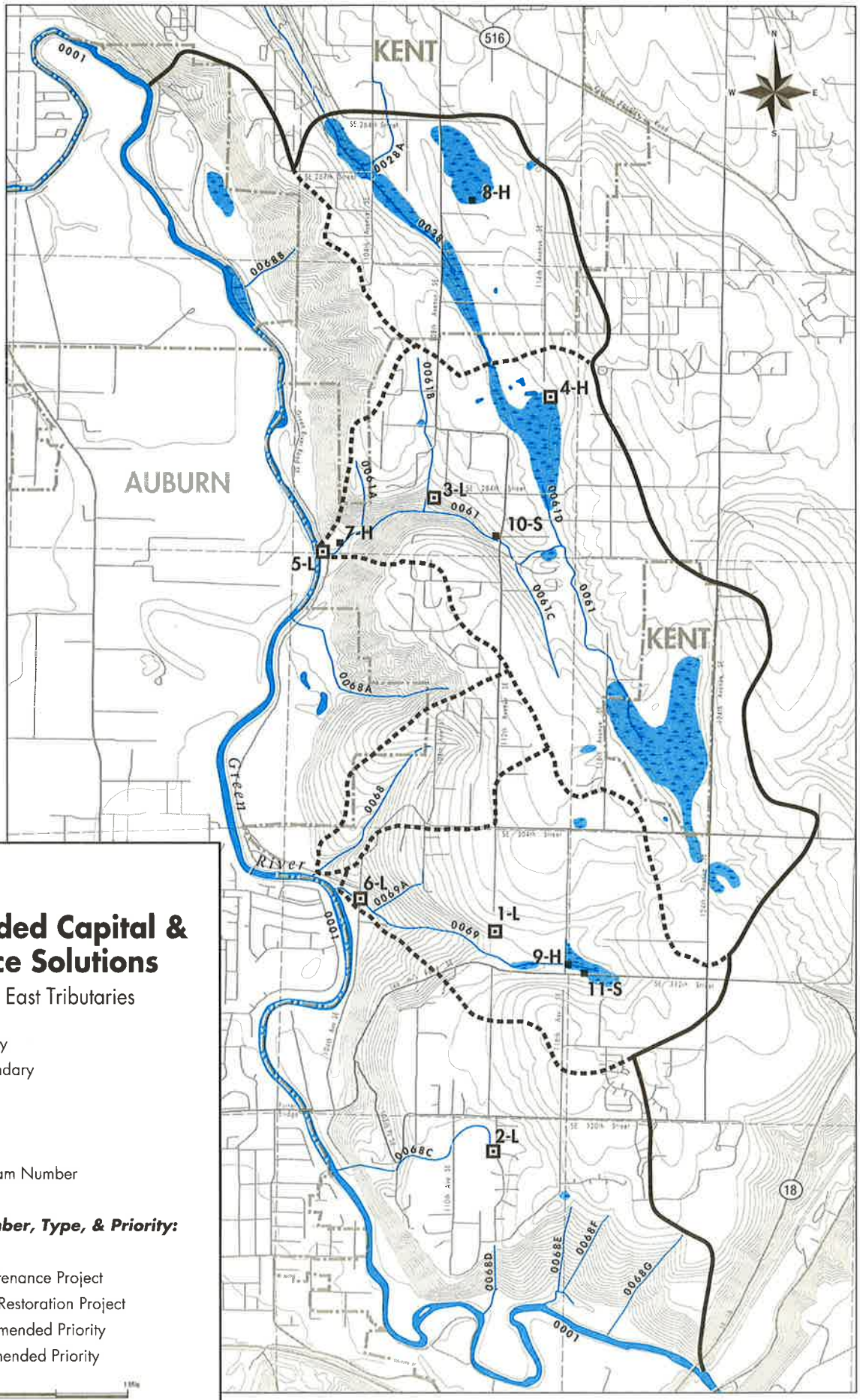

Figure 8
Recommended Capital & Maintenance Solutions

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- Wetland
- City Boundary
- Section Line
- 0068C Stream & Stream Number
- River/Lake

Project Number, Type, & Priority:

- **#-L** Large Project
- **#-S** Small or Maintenance Project
- **#-H** Small Habitat Restoration Project
- Higher Recommended Priority
- Lower Recommended Priority

0 1/2 1 Mile

has been previously recognized and a solution designed through SWM's Drainage Investigations Section (listed cost is based on this study); its significance has ranked at too low a level for 1994 funding.

Estimated cost: $220,000

LGR3. Tightline road runoff at 109th Avenue SE and SE 284th Street (Outfall #3) into tributary 0061B to avoid ongoing erosion into Olson Canyon. This problem has been previously recognized in the Neighborhood Drainage Assistance program but ranked at too low a level by that program's criteria for funding. This problem's broader significance should be reassessed within the Division-wide CIP evaluation process.

Estimated cost: $100,000

SWM Small Habitat Projects (or equivalent program in the City of Kent):

LGR4. Remove the chain-link fence around the Wetland 46 mitigation site to allow wildlife to freely move within the wetland; excavate (and/or plug the outlet end of) the existing ditch to create more open-water habitat; and extensively revegetate the north, south, and west sides of the wetland to create a genuine buffer that limits human intrusion but allows wildlife passage. This problem has not been previously recognized.

Estimated cost: $20,000

KC Roads CIP's:

LGR5. Reduce potential for blockage of the culvert under Green River Road by Olson Creek (0061; Crossing #2). This problem has been previously recognized but no specific action proposed or evaluated; shoulder improvements in this vicinity have been previously proposed by the King County Roads Division.

Estimated cost: $200,000

LGR6. Upsize culvert for the Lea Hill Tributary (0069) under Green River Road (Crossing #14), which presently is limiting passage of both fish and 10-year floods because of a voluminous sediment load. Do not proceed with this project until *after* construction of LGR1 and evaluation of continuing sediment loads. This problem has not been previously recognized.

Estimated cost: $200,000

(The seventh medium-priority problem amenable to capital solution, flooding by tributary 0068C in the vicinity of SE 323rd Street and 105th Avenue SE, is already scheduled for construction in 1994. Of the remaining three medium-priority problem, channel-migration hazard south of the Porter Bridge is best addressed through future Green River watershed-scale regulations; pervasive water-quality degradation does not appear soluble with present technology and given adopted land uses; and water-quality degradation from failing septic systems requires a programmatic response discussed previously.)

In addition to these projects, the following small-habitat and maintenance projects that address low-priority problems appear to be particularly cost-effective and should be considered for near-term action. With one exception, these projects have not previously been recommended:

SWM Small Habitat Projects (or equivalent programs in the cities of Kent and Auburn):

LGR7. Revegetate lower 0.17 miles of Olson Creek riparian zone through parkland (City of Auburn).

LGR8. Revegetate the buffer, underplant with conifers, and post signage around the uninventoried "Tudor Square" wetland, just south of this subdivision (City of Kent).

LGR9. In conjunction with recommended education and/or enforcement actions, post signage and revegetate disturbed areas of Wetland 26 and associated stream segments of the Lea Hill Tributary (0069) behind the "Auburn Hills" trailer court, before the area is completely overtaken by blackberries, reed-canarygrass, and nightshade.

KC Roads Maintenance:

LGR10. Armor the road ditch of 112th Avenue SE into the left bank of Olson Creek to minimize future erosion.

LGR11. Unblock culvert beneath SE 312th Street in Wetland 26 to prevent future road-fill failure (recommended in the 1987 Basin Reconnaissance report).

TABLE OF MANAGEMENT RECOMMENDATIONS

(PROJECTS ARE IN RECOMMENDED RANK ORDER WITHIN EACH GROUP)

Site	Tributary # and RM	Location	Problem Type	Prob. Signf.	Sol'n Type	Comments {Project #}
SWM MAJOR CIP'S						
010	into 0069 @ RM 0.64 & 0.72 (RB)	112th SE @ SE 31000	Erosion Landslide	M	tightline	Additional new development planned just upstream **{LGR1}**
03	into 0061B @ RM 0.1 (LB)	SE 284th & 109th SE	Erosion Landslide	M	extend outfall	**{LGR3}**
Hill-crest Estates	0068C RM 0.7	112th Place SE @ SE 32100	Flooding	M	R/D retrofit & pipe upgrade	Did not rank high enough for SWM 1994 funding **{LGR2}**
013	0069A RM 0.2	108th SE @ SE 30700	Erosion	L	tightline	
04	into 0061 @ RM 0.4 (LB)	SE 287th @ 10700 SE	Erosion	L	tightline	Runoff now routed to top-of-bank
SWM (or cities' equivalent) SMALL HABITAT PROGRAM						
Wetland 46	0061D @ RM 0.4-0.6		Degrada-tion	M	fence removal and reveg.	**{LGR4}**
Olson Corridor	0061 RM 0.08-0.17		Lost buffer	L	revegetation	Auburn parkland **{LGR7}**
Tudor Sq. Wetland	off 0028		Lost buffer	L	revegetation and signage	uninventoried wetland **{LGR8}**
Wetland 26	0069 RM 0.8-1.0	SE 312th Street	Lost buffer	L	revegetation and signage	**{LGR9}**
05	into 0068A @ RM 0.2 (RB)	SE 293rd @ 10600 SE	Erosion	L	instream structure	
09	0068F RM 0.3	SW parking lot, GRCC	Erosion	L	instream structure	Very steep channel; difficult access
KC ROADS (ALL PROGRAMS)						
X13	0068C RM 0.2	SE 323rd @ 105th SE	Flooding	M	tightline	Construction planned for 1994
X4	0061 RM 0.76	112th SE @ SE 28700	Passage Erosion	L	armored channel	Rapid erosion down road embankment **{LGR10}**
X16	0069 RM 1.1	SE 312th @ 11800 SE	Culvert blocked (potential road-fill damage)	L	repair or replace	**{LGR11}**

Site	Tributary # and RM	Location	Problem Type	Prob. Signf.	Sol'n Type	Comments {Project #}
X2	0061 RM 0.01	Green R. Road @ SE 28800	Culvert obstructed during high flows	M	replace culvert	Occurred 1990 **{LGR5}**
X14	0069 RM 0.13	Green R. Road @ SE 30800	Culvert obstructed (passage, road flooding)	M	replace culvert	Project to proceed only *after* construction of LGR1 and evaluation of continuing sediment loads **{LGR6}**
X11	0068 RM 0.01	Green R. Road @ 10300 SE	Future flooding	L		Minimal upstream habitat
011	into 0069 @ RM 1.0 (LB)	116th SE @ 31300	Future erosion	L	tightline	Additional infill development will exacerbate
REGULATIONS/ENFORCEMENT						
X2	0061 RM 0.01	Green R. Road @ SE 28800	Flooding Passage Erosion	M	reg's on upstream development	Upstream property purchased by City of Auburn (Parks)
N. Olson Canyon grading	into 0061 between 0061A & 0061B (RB)	SE 284th @ 10700 SE (pvt)	Top-of-slope grading	L		
Pipe 5 con-struction	0068A RM 0.3-0.7	upper canyon	Down-stream sediment	L		Must be addressed in construction planning & design
Derby-shire, Eastridge, & associated plats	0028 0061 0061B 0068 0068A	See Figure 4	Failing septic systems	M	connect to sewers or increase maintenance	Problem recognized by Health Department
PRIVATE ACTION (not ranked)						
112th SE com-plaint	0068 upper w'shed	30029 112th SE	Yard flooding	L		
East Ridge Manor	0068 RM 0.7	10891 SE 299th Pl.	Erosion	L		
X15	0069 RM 1.01	116th SE @ SE 31100	Culvert blocked (road flooding)	L	maintain or modify inlet	Private road
X8	0061 RM 2.21	D'way near SE 304th and 124th SE	D'way flooding	L		Corrected by owner
X9	0061 RM 2.22	D'way near SE 304th and 124th SE	D'way flooding	L		Probably floods

Site	Tributary # and RM	Location	Problem Type	Prob. Signf.	Sol'n Type	Comments {Project #}
SE 295th com-plaint	above 0068A	10715 SE 295th	Landslide in fill	L	fill stabili-zation	Above 04 outlet channel
0068A canyon mouth	0068A RM 0.3	upper golf course area	Sedimen-tation	L	instream structure; maintenance	Problem recognized by golf course
X6	0061 RM 1.57	D'way off 112th SE @ SE 29600	D'way flooding	L		

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APPENDIX A

TABLE OF OBSERVED PROBLEM SITES

Reference No. and Site	Tributary No./RM	Location	How ID'd	Problem Type	Prob. Signf.	Sol'n Prgm.	Sol'n Type	Comments
UPPER MILL CREEK								
1	Crossing #1	0028	104th SE & SE 26800	Map Field	none			89 acre-foot R/D just upstream
2	0028 channel	upper 0028	upstream of 104th SE	Field	extensive wetland, corridor alteration	L		No feasible solution
3	Black River Wetland 8	east of 0028	108th SE @ SE 26600	Field	Habitat loss	L		No feasible solution
OLSON CREEK								
4	Crossing #2	0061 RM 0.01	Green R. Road @ SE 28800	Map NDA Field	Flooding; Passage	M	KC Roads	reg's on upstream develop-ment; upsize culvert	Upstream property purchased by City of Auburn (Parks); culvert overtopped 11/90
5	lower 0061	0061 RM 0.08-0.17	above Green River Road @ SE 28800	Field	Corridor loss; Erosion	L	SHP (City of Au-burn)	revegeta-tion	
6	0061A mouth	0061A @ RM 0.0 and 0061 @ RM 0.16	In Auburn parkland	Field	Future erosion	L		upland drainage regs.; park design	Future channel-cutting likely
7	Outfall #1	into 0061A (LB)	105th SE @ SE 28300	Map Field	none				No concentrated road runoff
8	Outfall #2	into 0061 between 0061A & B (RB)	SE 284th @ 10700 SE (pvt)	Map Field	none				No concentrated road runoff
9	SE 284th grading	into 0061 between 0061A & B (RB)	SE 284th @ 10700 SE (pvt)	DI	Top-of-slope grading	L	DDES en-force-ment		
10	Outfall #3	into 0061B @ RM 0.1 (LB)	SE 284th & 109th SE	Map NDA Field	Erosion; Landslide	M	NDA	extend outfall	
11	Crossing #3	0061B RM 0.3	SE 281st @ 10700 SE	Map Field	none				
12	Outfall #4	into 0061 @ RM 0.4 (LB)	SE 287th @ 10700 SE	Map Field	Erosion	L		tightline	Runoff now routed to top-of-bank

Reference No. and Site		Tributary No./RM	Location	How ID'd	Problem Type	Prob. Signf.	Sol'n Prgm.	Sol'n Type	Comments
13	0061 channel	RM 0.5±		Field	Channel incision	L			Will accelerate with incresed future flows
14	Crossing #4	0061 RM 0.76	112th SE @ SE 28700	Map Field	Passage; Erosion; Flooding	L	SHP; KC Roads maint.	armored channel	Fish blockage; rapid erosion down road embankment; overtopped 11/90
15	0061 channel	RM 0.8-1.1			Habitat degrada-tion	L			No feasible solution
16	Crossing #5	0061 RM 1.48	118th SE @ SE 29500	Map Field	none				Controls wetland level
17	Crossing #6	0061 RM 1.57	D'way off 118th SE @ SE 29600	Map Field DDES	D'way flooding	L	private action		Probably floods @ ≤25-yr event
18	Wetland 24	0061 RM 1.6-2.2		Field	habitat loss	L			Cultivation and channelization; Class-2 system
19	Crossing #7	0061 RM 2.2	SE 304th @ 12300 SE	Map	none				
20	Crossing #8	0061 RM 2.21	D'way near SE 304th and 124th SE	NDA Map Field	D'way flooding	L	private action		Corrected by owner
21	Crossing #9	0061 RM 2.22	D'way near SE 304th and 124th SE	Map Field	D'way flooding	L	private action		Probably floods @ ≤25-yr event
22	Crossing #10	0061 RM 2.3	124th SE @ SE 30600	Map Field DDES	none				Outlet from "Willow Park" wetland & R/D
23	Derby-shire, East-ridge, & associated plats	0028 0061 0061B 0068 0068A	See Figure 4	Health Dep't	Failing septic systems	M		Sewers; increased mainten-ance	Problem recognized by Health Dept.
24	Wetland 47b	0061 RM 2.4	upstream of 124th SE @ SE 30600	Field	Habitat loss	L			No feasible solution
25	Wetland 46	0061D	114th SE @ SE 27800 area	Field	Alterations; Dumping	M	park pur-chase	Restora-tion	Aspects of problem have no feasible sol'n
					COBBLE CREEK				
26	Crossing #11	0068 RM 0.01	Green R. Road @ 10300 SE	Map Field	Future road flooding	L	KC Roads		Monitoring of future sed. loads necessary to evaluate need

Reference No. and Site		Tributary No./RM	Location	How ID'd	Problem Type	Prob. Signf.	Sol'n Prgm.	Sol'n Type	Comments
27	Crossing #12	0068 RM 0.36	106th SE @ SE 30300	Map Field	none				
28	0068 channel	RM 0.6±	downstream of 108th SE	Field DDES	Erosion	L			Incision 1-3 feet over several hundred yards
29	East Ridge Manor	0068 RM 0.7	10891 SE 299th Pl.	NDA	Erosion	L	NDA tech. assist.		
30	112th SE Complaint	0068 upper w'shed	30029 112th SE	NDA	Yard flooding	L	NDA tech. assist.		

HILLSIDE DRAINAGES

31	Auburn Golf Course	0068A RM 0.0-0.3		Field	Habitat loss from piped channel	L			No feasible solution
32	Outfall #5	into 0068A @ RM 0.2 (RB)	SE 293rd @ 10600 SE	Map Field	Erosion	L	SWM SHP	instream structure	
33	0068A canyon mouth	0068A RM 0.3	upper golf course area	Field	Sedimen-tation	L	private action	instream structure; mainten-ance	Problem recognized by golf course
34	S of 0068A	unnumbered tributary	S edge of golf course	DDES	Flooding	L			Only golf course affected
35	Pipe 5 con-struction	0068A RM 0.3-0.7	upper canyon	Report Field	Down-stream sediment	L			Must be addressed in construction planning & design
36	Outfall #6	into 0068A @ RM 0.5 (RB)	SE 259th @ 108th SE	Map Field	none				
37	SE 295th Complaint	above 0068A	10715 SE 295th	NDA	Landslide in fill	L	private action	fill stabili-zation	Above 06 outlet channel
38	Crossing #13	0068C RM 0.2	SE 323rd @ 105th SE	NDA Roads Map Field	Flooding	M	KC Roads	tightline	Construction planned for 1994
39	Hillcrest Estates	0068C RM 0.7	112th Place SE @ SE 32100	SWM DI study	Flooding	M	KC Roads, SWM CIP	R/D retrofit & pipe upgrade	Did not rank high enough for SWM 1994 funding
40	Outfall #7	west of 0068D	111th Place SE @ 110th SE	Map Field	none				Drainage is tightlined

Reference No. and Site		Tributary No./RM	Location	How ID'd	Problem Type	Prob. Signf.	Sol'n Prgm.	Sol'n Type	Comments
41	Outfall #8	0068E RM 0.3	116th SE @ SE 326th Place	Map Field	none				Wetland buffers flows
42	Outfall #9	0068F RM 0.3	SW parking lot, GRCC	Map Field	Erosion	L	SWM SHP	instream structure	Very steep channel; difficult access
				LEA HILL TRIBUTARY					
43	Crossing #14	0069 RM 0.13	Green R. Road @ SE 30800	Map Field	Culvert blocked (passage)	M	SWM Small CIP		10-yr road flooding if main sed. source site (Outfall #10) uncorrected
44	0069 channel	RM 0.3-0.6		Field	Erosion	L			High sed. load; recent incision 1-2 feet
45	Outfall #10	into 0069 @ RM 0.64 & 0.72 (RB)	112th SE @ SE 31000	NDA Map Field	Erosion; Landslide	M	SWM CIP	tightline	Additional new development planned just upstream
46	0069 channel	RM 0.75		Field	Erosion	L			Active knickpoint migration upstream
47	0069 channel	RM 0.78-1.00		Field	Corridor encroach-ment and habitat loss	L	SWM SHP	signs and revegeta-tion	
48	Outfall #11	into 0069 @ RM 1.0 (LB)	116th SE @ 31300	Map Field	Future erosion	L	KC Roads Small CIP	tightline	Additional infill development will exacerbate
49	Crossing #15	0069 RM 1.01	116th SE @ SE 31100	Field	Culvert blocked (road flooding)	L	private action	maintain or modify inlet	Private road
50	Wetland 26	0069 RM 1.0-1.1		Field	Habitat loss				No feasible solution
51	Crossing #16	0069 RM 1.1	SE 312th @ 11800 SE	Recon Map Field	Culvert blocked (road-fill damage)	L	KC Roads maint.	repair or replace	No acute problem
52	Outfall #12	into lower 0069A (RB)	107th SE @ SE 30500	Map Field	none				No concentrated road runoff
53	Outfall #13	0069A RM 0.2	108th SE @ SE 30700	Map Field	Erosion	L	SWM CIP	tightline	

Reference No. and Site	Tributary No./RM	Location	How ID'd	Problem Type	Prob. Signf.	Sol'n Prgm.	Sol'n Type	Comments
GREEN RIVER VALLEY FLOOR								
54	Porter Bridge area	Green River upstream of Porter Bridge	104th Pl SE @ SE 32100	King County (1993a)	Channel migration	M			Potential 100-yr hazard to 3 houses

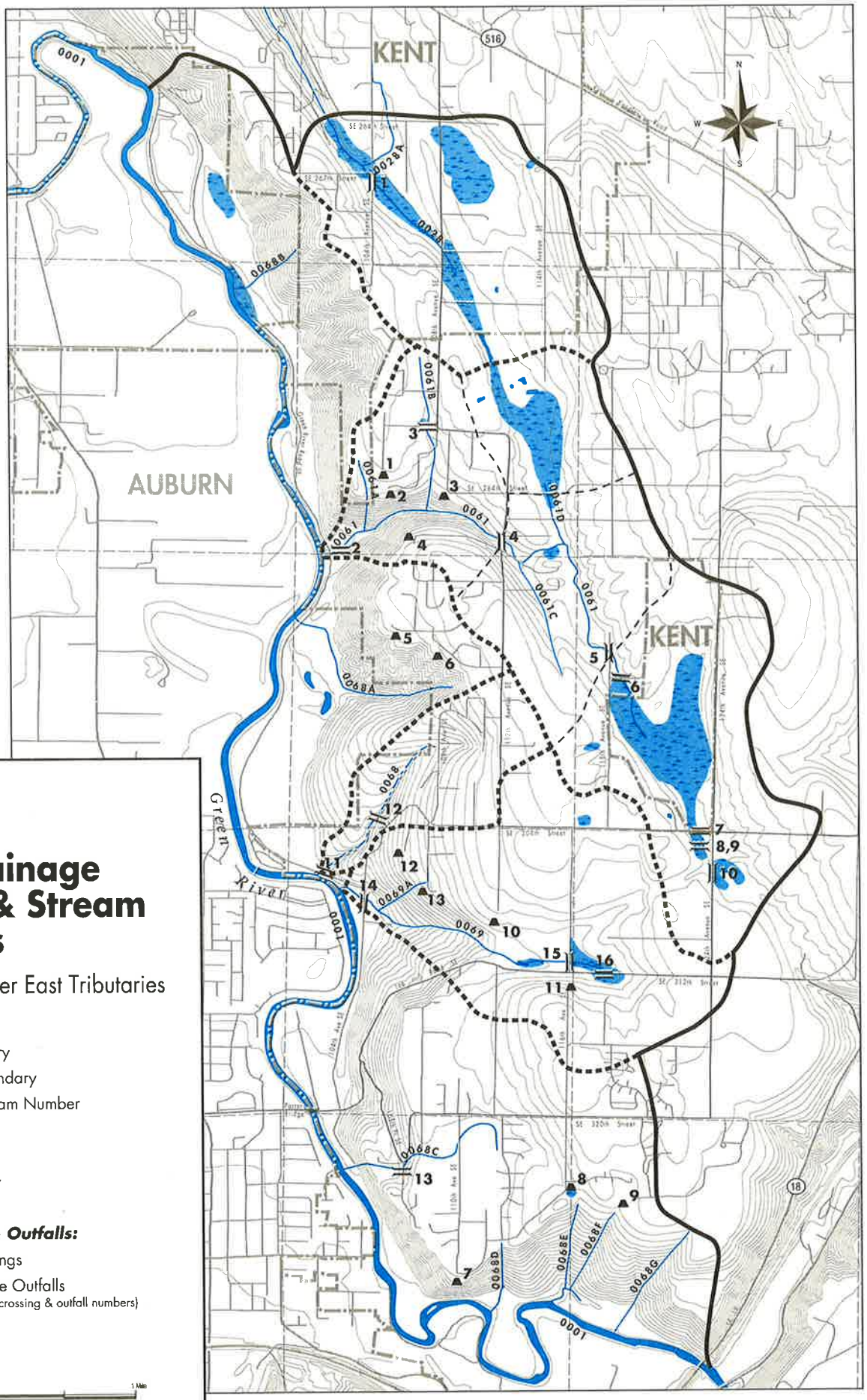


Figure A1

Road-Drainage Outfalls & Stream Crossings

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- 0068C Stream & Stream Number
- River
- Wetland
- City Boundary
- Section Line

Crossings & Outfalls:

- Stream Crossings
- 12 Road-Drainage Outfalls (Numbers refer to crossing & outfall numbers)

0 1/2 1 Mile

APPENDIX B
CURRENT AND FUTURE LAND USE
(see also Figures 3a and 3b)

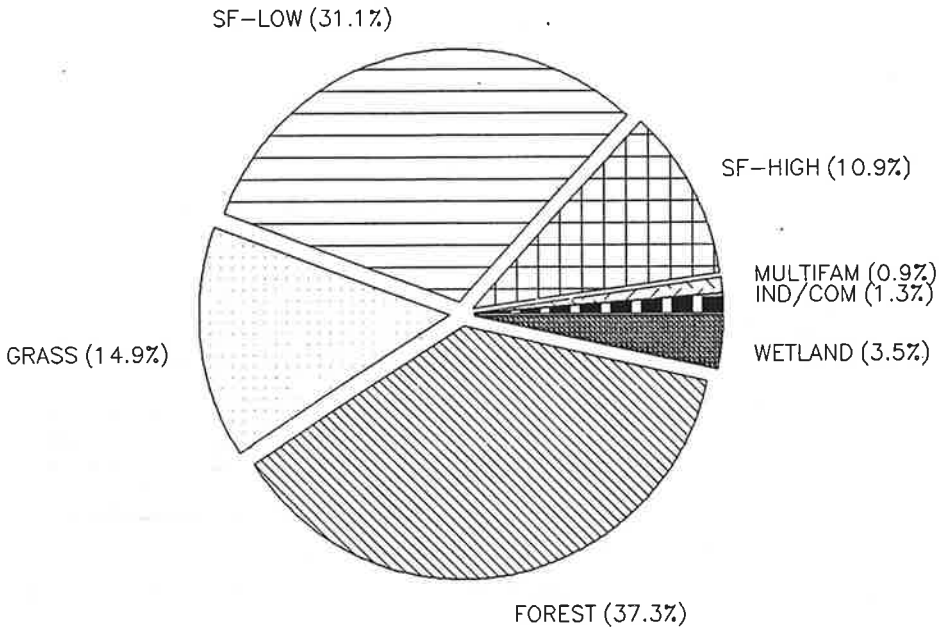
CURRENT (1992) LAND USE
(compiled from aerial photography)

	N BLUFF	U MILL	GOLF	COBBLE	S BLUFF	LEA HILL	OLSON	TOTAL
Industrial/ Commercial	0	0	2.9	0	1.3	36.8	6.2	47.2
Multifamily	0	8.4	0	0	22.1	2	2.5	35
Single-Family (high density)	12.1	73.7	38.9	44.8	172.9	43.5	22.3	408.2
Single-Family (low density)	57.7	179.4	51.3	54.7	238.3	110.5	469.2	1161.1
Grass	59.7	50	137.5	11	31.3	34.2	230.9	554.6
Forest	268.8	100.4	118.6	54.5	480	167.7	202.5	1392.5
Wetland	10.5	21.8	0	0	0.7	11.3	88.1	132.4
TOTAL ACRES	408.8	433.7	349.2	165.0	946.6	406.0	1021.7	3731
TOTAL EFFECTIVE IMPERVIOUS PERCENT	1.3%	6.8%	4.1%	8.1%	6.8%	11.7%	3.0%	5.5%

FUTURE LAND USE

	N BLUFF	U MILL	GOLF	COBBLE	S BLUFF	LEA HILL	OLSON	TOTAL
Industrial/ Commercial	4.2	9.1	2.9	0	2.2	70	21.9	110.3
Multifamily	0	9.1	0	0	23.8	30	12.6	75.5
Single-Family (high density)	76.6	357.7	82.7	127	514.8	241	694.1	2093.9
Single-Family (low density)	35.2	9.3	21.5	12.1	60.6	10.2	34.1	183
Grass	35.4	4.1	124.2	8	11.5	0	115	298.2
Forest	244.9	17.9	117.8	17.9	332.8	43	55.3	829.6
Wetland	10.5	26.1	0	0	0	12	88.3	136.9
TOTAL ACRES	406.8	433.3	349.1	165.0	945.7	406.2	1021.3	3727
TOTAL EFFECTIVE IMPERVIOUS PERCENT	5.9%	23.5%	6.9%	19.5%	15.3%	33.1%	19.5%	17.7%

CURRENT LAND USE



FUTURE LAND USE

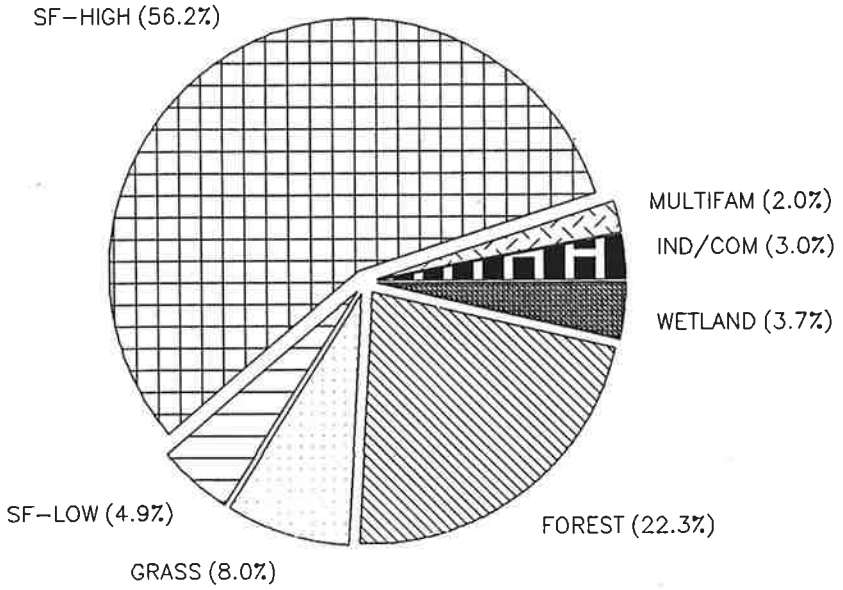


Figure B1

APPENDIX C
WATER QUALITY

IN-STREAM WATER QUALITY

Sampling Strategy

Grab samples were collected at the mouths of five tributaries during two large storm events, large enough to saturate the ground and cause runoff (>0.5 inches of rainfall) and were preceded by at least three dry days to allow pollutant accumulation on the land surface.

Sample sites were selected to characterize wet weather water quality from a variety of representative land uses in the basin, not to pinpoint specific sources of contamination. Since sampling nonpoint source runoff directly from its sources is very difficult or impossible, in-stream grab samples were taken to characterize the first flush or, due to logistics, at least the rising limb of the hydrograph to catch the more concentrated runoff. Samples were analyzed for pH, total suspended solids (TSS), hardness, total phosphorus (TP), nitrate and nitrite nitrogen (NO3 + NO2-N), fecal coliform, oil and grease, and metals (total copper, lead and zinc). Table C-1 shows the parameters, their definition, significance and likely sources in the study area.

Table C-1: Water Quality Parameter, Definitions, Significance, and Possible Sources

Parameter	Definition	Significance	Possible Sources in the Lower Green Basin East Tributaries
Carbon, Total Organic (TOC)	Concentration of carbon associated with organic material	Indicative of total organic matter; useful for determining adsorptive capacity of metals to suspended matter.	Vegetation, soils, animal wastes, oils and greases
Coliforms, Fecal (FC)	Pathogen indicator organisms present in gut/feces of warm-blooded animals (bacteria)	>50 colonies/100mL indicate water unsuitable for human consumption; >100 colonies/100mL indicate water unsuitable for swimming	Failing septic tanks, wild and domestic animals, hobby farms
Nitrite (NO^2) and Nitrate (NO^3)	Oxidized forms of nitrogen (mostly NO^3 is present); essential micronutrient	Bioavailable form of nitrogen; can be a limiting nutrient for biological productivity; toxic to humans in drinking water at >10 mg/L	Failing septic tanks, animal waste, farm and lawn fertilizers, automobile exhaust and other combustion processes
Oil and Grease, Total (O/G)	Any material recovered as a substance soluble in trichlorotrifluoroethane	High concentrations are indicative of large anthropogenic organic compounds	Petroleum products, oil from automobile engines, oils of animal or vegetable origin
Phosphorus, Total (TP)	Total concentration of all forms of phosphorus; essential nutrient	Indicative of lake trophic state or health; excessive phosphorus may result in abundant nuisance aquatic plant growth	Fertilizers, human and animal waste, phosphate detergents, decomposing organic matter, gasoline, soils

Solids, Total Suspended (TSS)	Suspended particulate matter > 0.45 μm	Indicative of stream clarity and suspended bedload; interferes with recreational uses and aesthetic enjoyment of water; detrimental effects to aquatic life and habitat	Runoff and erosion from construction sites, overgrazed pastures, cropland, and lawns; bank and bed scouring; recent landslides
Zinc (Zn)	Inorganic heavy metal; micronutrient at low levels	Acute and chronic toxicity to aquatic life	Pipe corrosion protection, tires, metal corrosion, roof gutters, petroleum products, soils
Lead (Pb)	Inorganic heavy metal	Acute and chronic toxicity to aquatic life	Leaded gasoline, automobile batteries, paint, lead pipes, soils
Copper (Cu)	Inorganic heavy metal; micronutrient at low levels	Acute and chronic toxicity to aquatic life	Vehicle brake linings, metal corrosion, paint, wood preservatives, petroleum products, soils

Wet-Weather Conventionals

Table C-2 presents measured instream averages and ranges of conventional pollutant concentrations for this basin. Typical in-stream ranges and threshold values corresponding to these pollutants are indicated in Table C-3. The local data are from stormwater runoff collected from developments in King and Snohomish Counties (King County, 1993b). The typical ranges are from the National Urban Runoff Program representing the best general characterization of urban runoff-pooled data from many sites and developed land uses except for open land. Washington state criteria do not exist for TSS, TP, oil and grease or nitrate/nitrite; however, thresholds were developed from literature or recommended by the U. S. Environmental Protection Agency (EPA). It should be noted that these thresholds were developed for base flow conditions (average, longer time) and therefore do not directly relate to storm events (intermittent, intense but shorter time) but provide a guideline beyond which aquatic species health may be compromised.

Table C-2: Concentrations of wet weather in-stream conventionals

Conventionals (all units are in mg/L except for Fecal Coliform, in CFU/100mL)		April 8, 1993	March 2, 1994	Average**
North Valley (Trib. 0068B)	Total Suspended Solids	*	22	
	Total Phosphorous	*	0.19	*
	Total Oil and Grease	*	(3)	*
	Nitrite + Nitrate Nitrogen	*	2.2	*
	Fecal Coliform	51	65	58
Olson Canyon (Trib. 0061)	Total Suspended Solids	5.8	15	10
	Total Phosphorous	0.049	0.083	0.066
	Total Oil and Grease	<2	(2)	2
	Nitrite + Nitrate Nitrogen	1.3	2.8	2.1
	Fecal Coliform	350	140	245
Hillside Drainages (Trib. 0068A)	Total Suspended Solids	11	10	11
	Total Phosphorous	0.12	0.82	0.47
	Total Oil and Grease	<2	(3)	1.5
	Nitrite + Nitrate Nitrogen	<0.05	0.21	0.13
	Fecal Coliform	710	100	405
Cobble Creek	Total Suspended Solids	4.8	15	9.9

(Trib. 0068)	Total Phosphorous	0.062	0.071	0.067
	Total Oil and Grease	<2	<0.005	1
	Nitrite + Nitrate Nitrogen	1	1.9	1.5
	Fecal Coliform	240	100	170
Lea Hill (Trib. 0069)	Total Suspended Solids	6.2	28	17
	Total Phosphorous	0.04	0.047	0.044
	Total Oil and Grease	<2	(2)	2
	Nitrite + Nitrate Nitrogen	0.67	1.7	1.2
	Fecal Coliform	500	120	310

* No Data Collected.
** Values reported as <MDL are assumed equal to MDL for computation of averages.
< Values less than Method Detection Limits (MDL). MDL value listed.
( ) Values less than or equal to Reported Detection Limit (RDL).

Table C-3: Typical Urban In-Stream Wet-Weather Concentrations and Recommended Threshold Values for Surface Water Quality

Parameter	King and Snohomish Stormwater Data			NURP-National averages (2)	Threshold
	Low Range(1)	Moderate Range (1)	High Range (1)		
TSS (mg/l)	5-30	30-100	100-1500	141-244	50 mg/l (3)
TP (mg/l)	0.02-0.1	0.10-0.5	0.5->5	0.3-0.5	0.1 mg/l (3)
NO2 + NO3	0.10-0.30	0.30-0.50	0.50-1.0	0.76-0.96	1.25 mg/l (4)
Zn (mg/l)	0.05-0.10	0.10-0.25	0.25-1.0	---	chronic .032-.056 (5)
TPH (mg/l)	0.4-<2	2-6	10->30	-----	none established

(1) King County, 1993b
(2) EPA, 1983
(3) King County (1993c)
(4) King County (1990d)
(5) WAC 173-201A for Class A streams based on hardness

Some of the sampling results fall below Reported Detection Limits (RDL) and/or Method Detection Limits (MDL). RDL's are the limit at which the laboratory determines that the results are accurately reported. Although measured values are reported below the RDL, i.e. as low as the Method Detection Limit, this data should be used with caution and may not be as reliable as that above the RDL. Tables reporting values below MDL's (e.g. "<2") indicate concentrations of usually negligible amounts. Copies of the complete sampling reports are included in this appendix.

The results indicate that TSS is below the threshold and less than that found in urban basins. The concentrations are more typical of basins with a low level of disturbance. Typically TSS is much higher in more developed urban basins which lack the filtering influence of vegetation buffers in riparian zones. The phosphorus concentrations exceed the threshold at North Valley (Site #1) and Hillside Drainages (Site #3). The threshold of 0.1 mg/l TP is recommended to prevent nuisance plant growth in streams (EPA, 1986). The TP concentration of 0.82 mg/l TP collected in 1994 near the golf course is eight times the threshold (0.1 mg/l TP) and could be a result of fertilizer use on the golf course or other

upstream sources. In any case, the concentration exceeds typical urban runoff by almost twice.

Oil and grease were within acceptable ranges and do not represent a concern. Nitrate-nitrite levels were above the threshold during at least one storm at tributaries 0068B, 0061 and 0068A yet are not of extreme concern. Research has shown that concentrations above 1.25 mg/l could impact some species of salmon, however the duration of exposure in the laboratory tests was 96 hours to cause death of half the test population. Typically storm concentrations are higher than baseflow and do not have a long enough duration to cause mortality unless the concentrations are much higher than measured in the tributaries. Nitrogen values greater than 1 mg/l are greater than clean unimpacted streams, suggesting possible waste input such as septic system malfunction or animal wastes. Given the locations of potential septic failures described earlier, some portion of the nitrogen measured in Olson Canyon (tributary 0061), Cobble Creek (0068), and tributary 0068A may be due to improperly working septic systems. Further field work is necessary to verify this. Fecal coliform levels exceed the criteria for drinking water and recreational contact. The concentrations are high but typical of developed areas. Concentrations of storm water often are 10 to 100 times the 100 mg/L threshold.

Overall, the stream quality is at or below threshold levels and is of relatively good quality, revealing some impact by urbanization but at levels below highly developed basins. The exception is the one sample from Hillside Drainages (tributary 0068A) which includes drainage from the golf course (0.82 mg/l TP) which may be due to management practices of the course. Further investigation is necessary to verify this.

Metals

In general, the metals concentrations do not exceed the chronic or acute criteria and are indicative of relatively "clean" water for a developing basin. Specifically, all in-stream sampling for the April 1993 storm event indicate levels of copper, lead and zinc below method detection limits (see Table C-4). For the March 1994, storm event all metal concentrations are below RDL's. For the data reported (i.e. below the RDL but above the MDL), acute criteria is never exceeded. In addition, for this same data, all copper and zinc levels are below chronic criteria. Lead exceeded the chronic criteria by less than 0.001 at Cobble Creek and Lea Hill (Tribs 0068 and 0069) and is below chronic criteria at the remaining sites. Both acute and chronic criteria are calculated from hardness based on equations described in Washington State regulations (WAC 173-201A 040).

Table C-4: Concentrations of Wet Weather In-Stream Metals Compared to Washington State Water Quality Criteria[1]

Total Metals		April 8, 1993 mg/L	March 2, 1994 mg/L	Hardness mg/L	Acute Criteria**	Chronic Criteria**
North Valley (Trib. 0068B)	Copper	*	(0.003)	49	0.008	0.006
	Lead	*	<0.001	49	0.023	0.001
	Zinc	*	<0.005	49	0.057	0.052
Olson Canyon (Trib. 0061)	Copper	<0.004	(0.002)	32	0.005	0.004
	Lead	<0.03	<0.001	32	0.013	0.001
	Zinc	<0.005	<0.005	32	0.040	0.036
Hillside Drainages (Trib. 0068A)	Copper	<0.004	(0.001)	37	0.006	0.004
	Lead	<0.03	<0.001	37	0.016	0.001
	Zinc	<0.005	(0.006)	37	0.045	0.041
Cobble Creek (Trib. 0068)	Copper	<0.004	(0.002)	45	0.007	0.005
	Lead	<0.03	(0.001)	45	0.020	0.001
	Zinc	<0.005	(0.005)	45	0.053	0.048
Lea Hill (Trib. 0069)	Copper	<0.004	(0.003)	48	0.008	0.005
	Lead	<0.03	(0.001)	48	0.022	0.001
	Zinc	<0.005	(0.006)	48	0.056	0.051

* No Data Collected
** Acute and Chromic Criteria are based on sampled total hardness values.
< Values less than Method Detection Limits (MDL).
( ) Values less than or equal to Reported Detection Limit (RDL).
[1] WAC 173-201A-040

Sediments

Stream sediment was sampled during the summer of 1993 at selected sites within the basin. Results of stream sediments, sampled between September 1, 1993 and August 26, 1993, are listed in Table C-5. Sediment sampling sites correspond to in-stream storm water monitoring site. The mainstem site is at the John Reddington Bridge downstream of Cobble Creek.

Washington does not have freshwater sediment criteria for comparison purposes. Instead, the Department of Ecology (DOE) recommends using criteria developed by the Ontario Ministry of the Environment. These guidelines establish a "lowest level" and "severe level" of effects on aquatic life The "lowest effect level" indicates a level of contamination that can be tolerated by most benthic organisms. Concentrations at the "severe effect level" could result in pronounced disturbance of sediment dwelling organisms, and could be detrimental to the majority of benthic species (Ontario Ministry of the Environment, 1991). Additionally, DOE recommends comparing sediment quality to guidelines developed by EPA Region V for classification of harbor sediments (used as dredging disposal criteria) for those parameters not included in the Ontario criteria.

With the exception of Olson Canyon, all other sites are near or below the "lowest effects criteria" in regard to the pollutants listed. Overall, the sediments are fairly clean but do exhibit the impact of urbanization. Sediments collected at the mouth of Olson Canyon contained concentrations of total organic carbon above the "lowest effect criteria" and total

oil and grease concentrations above the EPA "heavily polluted concentration." The source of oil and grease is predominately non-petroleum based substances (99% non-petroleum vs. 1% petroleum). This ratio was similar to the other sites but the overall concentration was higher at Olson Canyon's mouth. Sources of non-petroleum based oil and greases include human wastes and animal wastes, and natural oils found in vegetation and soils. Given the elevated levels of both total organic carbon and oil and grease found in the sediments of Olson Canyon, possible sources high in organic matter could either be failing septic systems or a dead decomposing animal. Further investigation would be required to define the source(s) specifically.

Sediment from Olson Canyon and Cobble Creek showed higher concentrations of total organic carbon, copper, lead, and zinc, than the Green River mainstem. For a river of its size and complexity of land uses, these sediment concentrations for the Green River Mainstem are fairly clean but do exhibit some impacts of urbanization as seen in the elevated copper and total organic carbon concentrations.

Table C-5: Sediment Pollutant Concentrations Compared to Quality Guidelines

	Stream Sampling Sites (and stream classification)					Guidelines		
	0068B (trib)	0068A (trib)	0068 (trib)	0069 (trib)	GR (main)	Heavily Polluted Conc.**	Lowest Effect***	Severe Effect***
Total Phosphorous, mg/kg	13	7.4	9.6	6.3	3.2	>650	600	2000
Total Oil and Grease, mg/kg	2700	310	570	380	(300)	>2000	1500	
% non-polar (petro)	1%	*	2%	0%	*			
% polar (non-petro)	99%	*	98%	100%	*			
Total Organic Carbon (%)	11	.94	2.4	.43	1.4		1	10
Copper , Total mg/kg	25	14	19	10	18	>50	16	110
Lead, Total mg/kg	(10)	<4	(20)	<4	<4	>60	31	250
Zinc, Total mg/kg	74	47	73	32	46	>200	120	820

( ) Values less than or equal to Reported Detection Limit (RDL).
< Values less than Method Detection Limits (MDL).
* No Data Collected
** EPA Region V Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments (1977)
***Ontario Provincial Sediment Quality Guidelines (1991)

MODELING POLLUTANT LOADINGS

Methods

In the unit loading model based on Horner (1990), areas of specific land use are multiplied by pollutant yield coefficients to compute annual pollutant loads. The formula is:

*Pollutant Loading (kg/yr) = Yield Coefficient (kg/ha-yr) * Area (ha)*

Areas of specific land uses were calculated from maps of current and future conditions. The current land use map was constructed from 1989 aerial photos and updated

with 1992 photos. Future land use was predicted by assuming maximum build out based on existing regional and community plans, zoning, lot patterns and rights of way, existing land cover, proposed development, and property ownership.

Table C-6 lists the yield coefficients which are based on the best available data to simulate pollutant loadings in the study area.

Table C-6: Pollutant Yield Coefficients

Land Use	Total Suspended Solids kg/ha-yr	Total Phosphorus kg/ha-yr	Zinc kg/ha-yr	Fecal Coliform #/ha-yr
Forest	26	0.095	0.020	1.2+E9
Grass	80	0.010	0.060	4.8+E9
Low Density Single Family - Forest (Current Land Use)	40	0.140	0.080	1.4+E9
Low Density Single Family - Grass (Current Land Use)	60	0.457	0.080	2.8+E9
Single Family Low Density (Future Land Use)	50	0.298	0.080	2.1+E9
Single Family High Density	97	0.540	0.400	4.5+E9
Multi-Family	133	0.588	0.630	6.3+E9
Commercial	242	0.688	1.000	1.7+E9
Impervious	133	0.588	0.630	6.3+E9
Wetland	0	0.000	0.000	0

The impervious land-use category consists of predominately parking lots associated with schools but also includes large roof tops, tennis courts, and a water tank. Pollutant loadings from wetlands vary widely. Given that the wetlands remain essentially unchanged between current and future conditions, the pollutant loading was assumed to be zero.

The future single-family low-density category was assumed to be an equal combination of the current low-density grass and current low-density forest conditions. Therefore the loading coefficients for the future low-density land use were an average of the two current low-density land-use categories.

In calculating the future pollutant loadings three scenarios were modeled using the future land use maps. The first assumed that all new development would take place with no water quality treatment of runoff. The second scenario assumed that all new impervious, commercial, multi-family residential, and single-family high-density residential areas would be required to implement best management practices (BMPs) to remove a portion of the pollutants. The third scenario assumed that only half of those same newly developed areas would be required to implement BMPs. This last assumption was based on the 1987-1992

King County Annual Growth Report. To account for the portion of the runoff likely to bypass treatment, 20% of the pollutants were assumed to escape. In areas that must provide water quality treatment, the pending update to the *Surface Water Design Manual* proposes 80% total suspended solids (TSS) removal. For zinc, the proposed requirement is 40% removal if the area drains to a sensitive stream reach. The Green River in this area was assumed to be a sensitive stream reach. There would be no phosphorus removal requirement in this area, but 40% of the phosphorus was assumed to be associated with the removed TSS (Minton, 1992).

Results

The following five tables summarize the modeling effort. Table C-7 shows current and future division of land use by subbasin. Table C-8 shows estimated current and future loadings and a percent change for each pollutant. Figure C-1 compares the percent increases from current to future unmitigated conditions by subbasin. Annual pollutant loadings for the three future scenarios are shown in Table C-9. Tables C-10 and C-11 provide more detailed information. For a discussion of the results, refer to the main report.

Figure C1

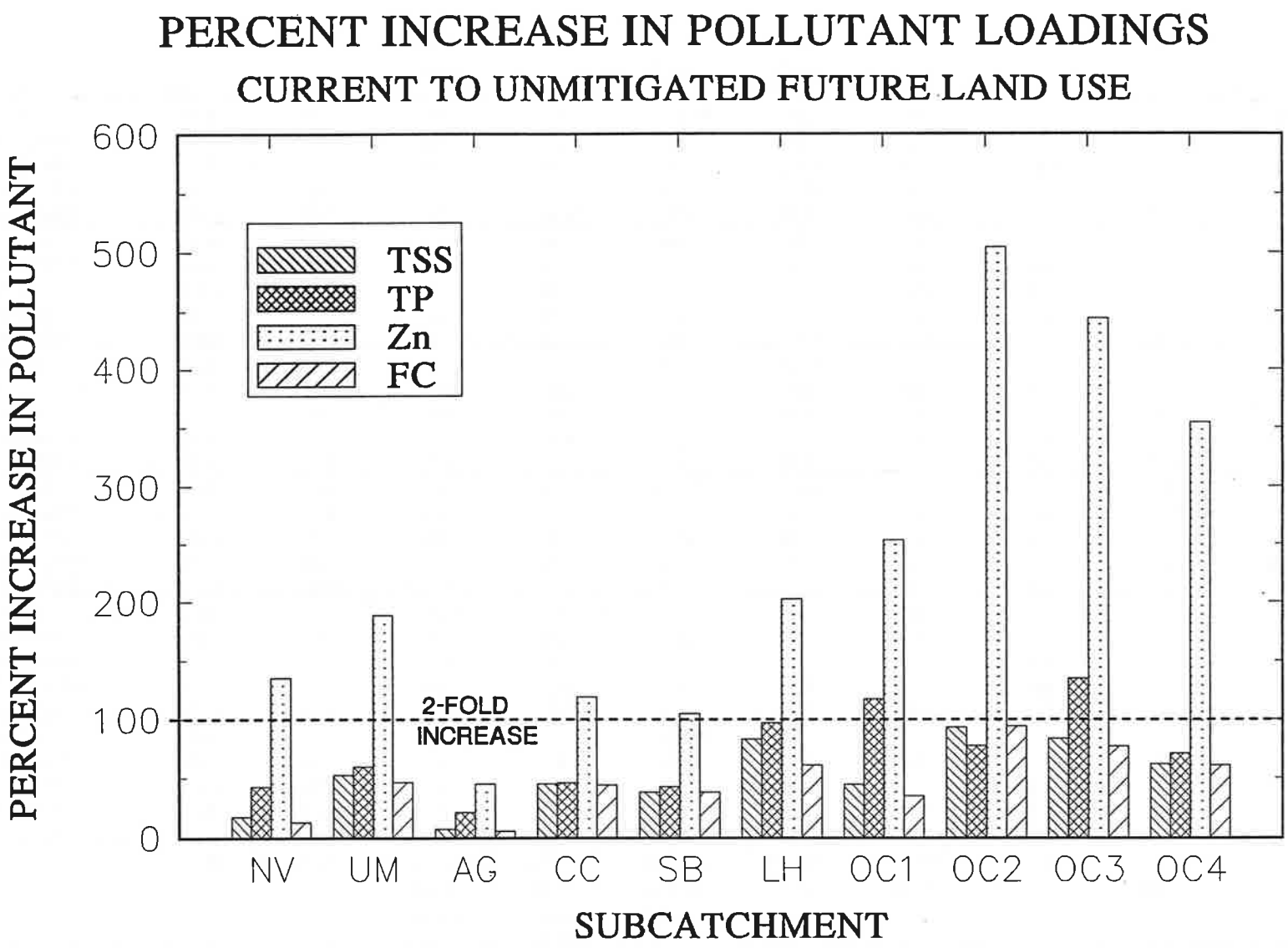

PERCENT INCREASE IN POLLUTANT LOADINGS
CURRENT TO UNMITIGATED FUTURE LAND USE
PERCENT INCREASE IN POLLUTANT
600
500
400
300
200
100
0
TSS
TP
Zn
FC
2-FOLD
INCREASE
NV
UM
AG
CC
SB
LH
OC1
OC2
OC3
OC4
SUBCATCHMENT

Table C-7: Current and Future Land Use by Subbasin

Subbasin		Forest	Grass	Low Density Forest (Current)	Low Density Grass (Current)	Low Density (Future)	High Density	Multi-Family	Commercial	Imper-vious	Wetland	Total Acres
NV	Current Land Use (acres)	266.8	59.7	12.6	45.1	0.0	12.1	0.0	0.0	0.0	10.5	406.8
	% Total Area of Subbasin	66%	15%	3%	11%	0%	3%	0%	0%	0%	3%	
	Future Land Use (acres)	244.9	34.4	0.0	0.0	35.2	76.7	0.0	0.0	4.2	10.5	406.0
	% Total Area of Subbasin	60%	8%	0%	0%	9%	19%	0%	0%	1%	3%	
	% Change in Area (b)	-8%	-42%	---	---	-39% (a)	536%	---	---	---	0%	
UM	Current Land Use (acres)	100.4	50.0	17.9	161.5	0.0	73.6	8.4	0.0	0.0	21.8	433.5
	% Total Area of Subbasin	23%	12%	4%	37%	0%	17%	2%	0%	0%	5%	
	Future Land Use (acres)	17.9	4.2	0.0	0.0	9.3	357.8	9.1	0.0	9.1	26.1	433.5
	% Total Area of Subbasin	4%	1%	0%	0%	2%	83%	2%	0%	2%	6%	
	% Change in Area (b)	-82%	-92%	---	---	-95% (a)	386%	9%	---	---	20%	
AG	Current Land Use (acres)	118.6	137.5	14.7	36.6	0.0	38.8	0.0	0.0	2.9	0.0	349.0
	% Total Area of Subbasin	34%	39%	4%	10%	0%	11%	0%	0%	1%	0%	
	Future Land Use (acres)	117.7	124.2	0.0	0.0	21.5	82.7	0.0	0.0	2.9	0.0	349.0
	% Total Area of Subbasin	34%	36%	0%	0%	6%	24%	0%	0%	1%	0%	
	% Change in Area (b)	-1%	-10%	---	---	-58% (a)	113%	---	---	0%	---	
CC	Current Land Use (acres)	54.5	11.0	12.0	42.7	0.0	44.8	0.0	0.0	0.0	0.0	165.1
	% Total Area of Subbasin	33%	7%	7%	26%	0%	27%	0%	0%	0%	0%	
	Future Land Use (acres)	17.9	8.0	0.0	0.0	12.1	127.0	0.0	0.0	0.0	0.0	165.1
	% Total Area of Subbasin	11%	5%	0%	0%	7%	77%	0%	0%	0%	0%	
	% Change in Area (b)	-67%	-27%	---	---	-78% (a)	183%	---	---	---	---	
SB	Current Land Use (acres)	479.8	31.3	68.0	169.5	0.0	173.9	14.1	0.0	9.2	0.7	946.5
	% Total Area of Subbasin	51%	3%	7%	18%	0%	18%	1%	0%	1%	0%	
	Future Land Use (acres)	332.8	11.5	0.0	0.0	60.6	514.8	15.9	0.0	10.2	0.0	945.7
	% Total Area of Subbasin	35%	1%	0%	0%	6%	54%	2%	0%	1%	0%	
	% Change in Area (b)	-31%	-63%	---	---	-74% (a)	196%	13%	---	11%	---	
LH	Current Land Use (acres)	167.7	34.2	38.3	72.5	0.0	43.5	15.1	0.0	23.7	11.3	406.3
	% Total Area of Subbasin	41%	8%	9%	18%	0%	11%	4%	0%	6%	3%	
	Future Land Use (acres)	43.0	0.0	0.0	0.0	9.0	241.0	43.1	19.9	38.9	11.3	406.3
	% Total Area of Subbasin	11%	0%	0%	0%	2%	59%	11%	5%	10%	3%	
	% Change in Area (b)	-74%	---	---	---	-92% (a)	454%	186%	---	64%	0%	

Table C-7 Current and Future Land Use by Subbasin (continued)

Subbasin		Forest	Grass	Low Density Forest (Current)	Low Density Grass (Current)	Low Density (Future)	High Density	Multi-Family	Commercial	Imper-vious	Wetland	Total Acres
OC1	Current Land Use (acres)	46.9	156.7	44.6	88.0	0.0	14.4	2.5	0.0	6.2	58.0	417.3
	% Total Area of Subbasin	11%	38%	11%	21%	0%	3%	1%	0%	1%	14%	
	Future Land Use (acres)	1.0	96.1	0.0	0.0	8.1	229.1	12.6	0.1	12.1	58.0	417.0
	% Total Area of Subbasin	0%	23%	0%	0%	2%	55%	3%	0%	3%	14%	
	% Change in Area (b)	-98%	-39%	---	---	-94% (a)	1493%	409%	---	95%	0%	
OC2	Current Land Use (acres)	33.1	4.8	16.7	55.2	0.0	0.0	0.0	0.0	0.0	28.3	138.1
	% Total Area of Subbasin	24%	3%	12%	40%	0%	0%	0%	0%	0%	20%	
	Future Land Use (acres)	7.4	0.2	0.0	0.0	6.9	88.1	0.0	0.0	7.2	28.3	138.1
	% Total Area of Subbasin	5%	0%	0%	0%	5%	64%	0%	0%	5%	20%	
	% Change in Area (b)	-78%	-96%	---	---	-90% (a)	---	---	---	---	0%	
OC3	Current Land Use (acres)	65.4	50.5	50.7	79.5	0.0	6.2	0.0	0.0	0.0	1.5	253.7
	% Total Area of Subbasin	26%	20%	20%	31%	0%	2%	0%	0%	0%	1%	
	Future Land Use (acres)	1.5	18.7	0.0	0.0	0.7	231.2	0.0	0.0	0.0	1.5	253.7
	% Total Area of Subbasin	1%	7%	0%	0%	0%	91%	0%	0%	0%	1%	
	% Change in Area (b)	-98%	-63%	---	---	-99% (a)	3631%	---	---	---	0%	
OC4	Current Land Use (acres)	57.2	18.9	48.0	86.4	0.0	1.7	0.0	0.0	0.0	0.3	212.6
	% Total Area of Subbasin	27%	9%	23%	41%	0%	1%	0%	0%	0%	0%	
	Future Land Use (acres)	45.4	0.0	0.0	0.0	18.4	145.8	0.0	0.0	2.6	0.5	212.6
	% Total Area of Subbasin	21%	0%	0%	0%	9%	69%	0%	0%	1%	0%	
	% Change in Area (b)	-21%	---	---	---	-86% (a)	8297%	---	---	---	57%	

Note: Percentages were calculated via spreadsheet before rounding took place, therefore reported percentages may not correspond exactly to the ares presented in this table
(a) Percent change from single family low density grass and forest (current land use) to single family low density (future land use).
(b) Percent change in area from current to future

Table C-8: Estimated Current and Future Pollutant Loadings by Subbasin

Subbasin		Pollutant Loadings			
		TSS (kg/yr)	TP (kg/yr)	Total Zn (kg/y	FCs (#/yr)
North Valley (NV)	Current	6,501	22	7	3.26E+11
	Future	7,621	32	17	3.66E+11
	% Change	17%	42%	135%	12%
Upper Mill (UM)	Current	10,198	53	22	4.94E+11
	Future	15,523	84	63	7.23E+11
	% Change	52%	59%	188%	46%
Auburn Golf Course (AG)	Current	8,491	22	13	4.52E+11
	Future	9,089	26	19	4.75E+11
	% Change	7%	21%	45%	5%
Cobble Creek (CC)	Current	3,911	21	10	1.85E+11
	Future	5,672	30	21	2.66E+11
	% Change	45%	46%	119%	44%
South Bluff (SB)	Current	19,323	97	46	9.01E+11
	Future	26,685	139	95	1.24E+12
	% Change	38%	43%	104%	38%
Lea Hill (LH)	Current	9,015	41	23	4.30E+11
	Future	16,450	80	69	6.90E+11
	% Change	82%	97%	202%	61%
Upper Olson Canyon (OC1)	Current	9,437	26	13	5.00E+11
	Future	13,599	57	46	6.74E+11
	% Change	44%	117%	253%	35%
North Olson Canyon (OC2)	Current	2,106	12	3	9.74E+10
	Future	4,066	22	16	1.89E+11
	% Change	93%	77%	504%	94%
Middle Olson Canyon (OC3)	Current	5,303	22	7	2.60E+11
	Future	9,710	51	38	4.59E+11
	% Change	83%	135%	444%	77%
Lower Olson Canyon (OC4)	Current	4,146	21	6	1.93E+11
	Future	6,704	36	25	3.10E+11
	% Change	62%	71%	354%	61%

Table C-9: Estimated Annual Future Loadings by Subbasin

Subbasin	Percent of new I, C, MF, & SH [1] develop't req'd to reduce pollutant loadings	Pollutant Loadings[2]			
		TSS [3] (kg/yr)	TP [4] (kg/year)	Total ZN [5] (kg/yr)	FC [6] (#/yr)
NV	0%	7,621	32	17	3.66E+11
	50%	6,736	29	16	3.66E+11
	100%	5,850	27	14	3.66E+11
UM	0%	15,523	84	63	7.23E+11
	50%	11,784	74	55	7.23E+11
	100%	8,044	64	48	7.23E+11
AG	0%	9,089	26	19	4.75E+11
	50%	8,537	25	18	4.75E+11
	100%	7,985	23	17	4.75E+11
CC	0%	5,672	30	21	2.66E+11
	50%	4,640	27	19	2.66E+11
	100%	3,608	24	17	2.66E+11
SB	0%	26,685	139	95	1.24E+12
	50%	22,355	127	86	1.24E+12
	100%	18,026	115	77	1.24E+12
LH	0%	16,450	80	69	6.90E+11
	50%	12,599	71	60	6.90E+11
	100%	8,749	62	52	6.90E+11
OC1	0%	13,599	57	46	6.74E+11
	50%	10,625	49	40	6.74E+11
	100%	7,651	41	34	6.74E+11
OC2	0%	4,066	22	16	1.89E+11
	50%	2,835	19	14	1.89E+11
	100%	1,604	15	11	1.89E+11
OC3	0%	9,710	51	38	4.59E+11
	50%	6,883	43	32	4.59E+11
	100%	4,057	35	26	4.59E+11
OC4	0%	6,704	36	25	3.10E+11
	50%	4,850	31	21	3.10E+11
	100%	2,996	26	18	3.10E+11

Notes and assumptions:

[1] I=impervious. C=commercial, MF=multi-family, SH=single-family high-density residential.

[2] Where treatment is required, 20% of flow and pollutants escape treatment.

[3] Where treatment is required, 80% removal of the captured TSS.

[4] Where treatment is required, 80% TSS removal also removes 40% of the remaining TP.

[5] Where treatment is required, 40% removal of the remaining zinc since the whole basin drains to a "sensitive" reach, the Green River.

[6] No removal required

Table C-10: Percentage of Land Use by Total Subbasin Area

Subbasin	Rural Classification (<= Low Density Single Family Residences) Current Land Use	Rural Classification (<= Low Density Single Family Residences) Future Land Use	Urban Classification (>= High Density Single Family Residences) Current Land Use	Urban Classification (>= High Density Single Family Residences) Future Land Use	% Change From Rural to Urban Classification
NV	94%	77%	6%	23%	17%
UM	76%	7%	24%	93%	69%
AG	88%	75%	12%	25%	13%
CC	73%	23%	27%	77%	50%
SB	79%	43%	21%	57%	36%
LH	76%	13%	24%	87%	63%
OC1	81%	25%	19%	75%	56%
OC2	80%	10%	20%	90%	70%
OC3	97%	8%	3%	92%	89%
OC4	99%	30%	1%	70%	69%

Table C-11: Change in estimated annual future pollutant loadings by subbasin

Loadings with Mitigation

	Percent of new I, C, MF, & SH [1] develop't req'd to reduce pollutant loadings	Change in pollutant loadings from the unmitigated future scenario			
		TSS [3]	TP [4]	ZN [5]	FC [6]
NV	50% 100%	-12% -23%	-8% -15%	-11% -21%	0% 0%
UM	50% 100%	-24% -48%	-12% -24%	-12% -25%	0% 0%
AG	50% 100%	-6% -12%	-6% -12%	-6% -12%	0% 0%
CC	50% 100%	-18% -36%	-10% -19%	-10% -20%	0% 0%
SB	50% 100%	-16% -32%	-9% -17%	-9% -19%	0% 0%
LH	50% 100%	-23% -47%	-12% -23%	-12% -24%	0% 0%
OC1	50% 100%	-22% -44%	-14% -28%	-14% -27%	0% 0%
OC2	50% 100%	-30% -61%	-15% -30%	-16% -31%	0% 0%
OC3	50% 100%	-29% -58%	-16% -31%	-15% -31%	0% 0%
OC4	50% 100%	-28% -55%	-14% -28%	-15% -30%	0% 0%

Notes and assumptions:

[1] I=impervious. C=commercial, MF=multi-family, SH=single-family high-density residential.
[2] With treatment, 20% of flow and pollutants escape treatment
[3] With treatment, 80% removal of the captured TSS.
[4] With treatment, 80% TSS removal also removes 40% captured TP.
[5] With treatment, 40% removal of the captured zinc since the whole basin drains to a stream protection area, the Green River.
[6] No removal required

METRO Environmental Lab Analytical Report

PROJECT: B40179

		Locator:	GREEN1			Locator:	GREEN2			Locator:	GREEN3			Locator:	GREEN4			Locator:	GREEN5		
		Sampled:	Apr 08, 93			Sampled:	Apr 08, 93			Sampled:	Apr 08, 93			Sampled:	Apr 08, 93			Sampled:	Apr 08, 93		
		Lab ID:	L762-1			Lab ID:	L762-2			Lab ID:	L762-3			Lab ID:	L762-4			Lab ID:	L762-5		
		Matrix:	STORM WTR			Matrix:	STORM WTR			Matrix:	STORM WTR			Matrix:	STORM WTR			Matrix:	STORM WTR		
		% Solids:				% Solids:				% Solids:				% Solids:				% Solids:			
Parameters		Qualifier	Value	MDL	RDL	Qualifier	Value	MDL	RDL	Qualifier	Value	MDL	RDL	Qualifier	Value	MDL	RDL	Qualifier	Value	MDL	RDL
CONVENTIONALS			- Wet Weight Basis				- Wet Weight Basis				- Wet Weight Basis				- Wet Weight Basis				- Wet Weight Basis		
M.Code=SM209C, ed16																					
Total Suspended Solids	mg/L		6.4	1	2		5.8	1	2		11	1	2		4.8	1	2		6.2	1	2
M.Code=SM2130-B																					
Turbidity	NTU		1.7	0.5	1		4.4	0.5	1		5.1	0.5	1		4.2	0.5	1		4.3	0.5	1
M.Code=SM4500-P-B,E																					
Total Phosphorus	mg/L		0.021	0.005	0.01		0.049	0.005	0.01		0.12	0.005	0.01		0.062	0.005	0.01		0.04	0.005	0.01
M.Code=SM5520-B																					
Oil and Grease, Total	mg/L		14	2	5	<MDL		2	5	<MDL		2	5	<MDL		2	5	<MDL		2	5
M.Code=(No Method Code)																					
Nitrite + Nitrate Nitrogen	mg/L		0.31	0.05	0.1		1.3	0.05	0.1	<MDL		0.05	0.1		1	0.05	0.1		0.67	0.05	0.1
Ortho Phosphorus	mg/L		0.011	0.005	0.01	<RDL	0.009	0.005	0.01	<RDL	0.008	0.005	0.01	<RDL	0.008	0.005	0.01	<RDL	0.009	0.005	0.01

METRO Environmental Lab Analytical Report

FECAL COLIFORM

	Qual	Wet Wght CFU/100g	Wet MDL CFU/100g	M.Code
Locator: GREEN1 Sampled: Apr 08, 93 Lab ID: L762-1 Matrix: LG STORM WTR		51		SM-9222 D ed.17
Locator: GREEN2 Sampled: Apr 08, 93 Lab ID: L762-2 Matrix: LG STORM WTR		350		SM-9222 D ed.17
Locator: GREEN3 Sampled: Apr 08, 93 Lab ID: L762-3 Matrix: LG STORM WTR		710		SM-9222 D ed.17
Locator: GREEN4 Sampled: Apr 08, 93 Lab ID: L762-4 Matrix: LG STORM WTR		240		SM-9222 D ed.17
Locator: GREEN5 Sampled: Apr 08, 93 Lab ID: L762-5 Matrix: LG STORM WTR		500		SM-9222 D ed.17
Locator: GREEN6 Sampled: Apr 08, 93 Lab ID: L762-6 Matrix: LG STORM WTR		150		SM-9222 D ed.17
Locator: GREEN7 Sampled: Apr 08, 93 Lab ID: L762-7 Matrix: LG STORM WTR		70		SM-9222 D ed.17
Locator: GREEN8 Sampled: Apr 08, 93 Lab ID: L762-8 Matrix: LG STORM WTR		45		SM-9222 D ed.17
Locator: GREEN9 Sampled: Apr 08, 93 Lab ID: L762-9 Matrix: LG STORM WTR		62		SM-9222 D ed.17
Locator: GREEN10 Sampled: Apr 08, 93 Lab ID: L762-10 Matrix: LG STORM WTR		42		SM-9222 D ed.17

METRO Environmental Lab Analytical Report

PROJECT: B40179

Locator:	GREEN1	GREEN2	GREEN3	GREEN4	GREEN5
Sampled:	Apr 08, 93	Apr 08, 93	Apr 08, 93	Apr 08, 93	Apr 08, 93
Lab ID:	L762-1	L762-2	L762-3	L762-4	L762-5
Matrix:	STORM WTR	STORM WTR	STORM WTR	STORM WTR	STORM WTR
% Solids:					

Parameters	Qualifier	Value (mg/L)	MDL (mg/L)	RDL (mg/L)	Qualifier	Value (mg/L)	MDL (mg/L)	RDL (mg/L)	Qualifier	Value (mg/L)	MDL (mg/L)	RDL (mg/L)	Qualifier	Value (mg/L)	MDL (mg/L)	RDL (mg/L)	Qualifier	Value (mg/L)	MDL (mg/L)	RDL (mg/L)
METALS		- Wet Weight Basis				- Wet Weight Basis				- Wet Weight Basis				- Wet Weight Basis				- Wet Weight Basis		
M.Code=METRO 16-02-001																				
Aluminum	<RDL	0.2	0.1	0.5	<RDL	0.5	0.1	0.5	<RDL	0.2	0.1	0.5	<RDL	0.3	0.1	0.5	<RDL	0.3	0.1	0.5
Arsenic	<MDL		0.05	0.25	<MDL		0.05	0.25	<MDL		0.05	0.25	<MDL		0.05	0.25	<MDL		0.05	0.25
Barium	<RDL	0.003	0.001	0.005		0.013	0.001	0.005		0.0051	0.001	0.005		0.007	0.001	0.005		0.008	0.001	0.005
Beryllium	<MDL		0.001	0.005	<MDL		0.001	0.005	<MDL		0.001	0.005	<MDL		0.001	0.005	<MDL		0.001	0.005
Cadmium	<MDL		0.003	0.015	<MDL		0.003	0.015	<MDL		0.003	0.015	<MDL		0.003	0.015	<MDL		0.003	0.015
Calcium		6	0.05	0.25		9.3	0.05	0.25		11	0.05	0.25		13	0.05	0.25		12	0.05	0.25
Chromium	<MDL		0.005	0.025	<MDL		0.005	0.025	<MDL		0.005	0.025	<MDL		0.005	0.025	<MDL		0.005	0.025
Copper	<MDL		0.004	0.02	<MDL		0.004	0.02	<MDL		0.004	0.02	<MDL		0.004	0.02	<MDL		0.004	0.02
Iron	<RDL	0.2	0.05	0.25		0.27	0.05	0.25		0.44	0.05	0.25		0.31	0.05	0.25	<RDL	0.2	0.05	0.25
Lead	<MDL		0.03	0.15	<MDL		0.03	0.15	<MDL		0.03	0.15	<MDL		0.03	0.15	<MDL		0.03	0.15
Magnesium		1.5	0.03	0.15		2.9	0.03	0.15		3.5	0.03	0.15		5	0.03	0.15		4.5	0.03	0.15
Manganese		0.014	0.002	0.01	<RDL	0.01	0.002	0.01		0.02	0.002	0.01		0.017	0.002	0.01		0.015	0.002	0.01
Molybdenum	<MDL		0.02	0.1	<MDL		0.02	0.1	<MDL		0.02	0.1	<MDL		0.02	0.1	<MDL		0.02	0.1
Nickel	<MDL		0.02	0.1	<MDL		0.02	0.1	<MDL		0.02	0.1	<MDL		0.02	0.1	<MDL		0.02	0.1
Potassium	<MDL		2	10	<RDL	2	2	10	<RDL	2	2	10	<MDL		2	10	<MDL		2	10
Selenium	<MDL		0.05	0.25	<MDL		0.05	0.25	<MDL		0.05	0.25	<MDL		0.05	0.25	<MDL		0.05	0.25
Silver	<MDL		0.004	0.02	<MDL		0.004	0.02	<MDL		0.004	0.02	<MDL		0.004	0.02	<MDL		0.004	0.02
Sodium		3.1	0.5	2.5		5.3	0.5	2.5		9.4	0.5	2.5		6.2	0.5	2.5		5.1	0.5	2.5
Zinc	<MDL		0.005	0.025	<MDL		0.005	0.025	<MDL		0.005	0.025	<MDL		0.005	0.025	<MDL		0.005	0.025
M.Code=METRO 16-03-001																				
Copper, Total, GFAA	<MDL		0.001	0.004	<RDL	0.002	0.001	0.004	<RDL	0.002	0.001	0.004	<RDL	0.002	0.001	0.004	<RDL	0.002	0.001	0.004
Lead, Total, GFAA	<MDL		0.001	0.004	<MDL		0.001	0.004	<MDL		0.001	0.004	<MDL		0.001	0.004	<MDL		0.001	0.004
M.Code=SM 2340B ED18																				
Total Hardness		21	0.2	1.3		35	0.2	1.3		42	0.2	1.3		53	0.2	1.3		48	0.2	1.3

METRO Environmental Lab Analytical Report

PROJECT: B40179

Locator:	GREEN1	GREEN2	GREEN3
Sampled:	Mar 02, 94	Mar 02, 94	Mar 02, 94
Lab ID:	L3135-1	L3135-2	L3135-3
Matrix:	STORM WTR	STORM WTR	STORM WTR
% Solids:			

Parameters	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units
			- Wet Weight Basis					- Wet Weight Basis					- Wet Weight Basis		
COMBINED LABS															
M.Code=METRO 16-02-001															
Aluminum, Total, ICP	1.1		0.1	0.5	mg/L	1.1		0.1	0.5	mg/L	0.5	<RDL	0.1	0.5	mg/L
Arsenic, Total, ICP		<MDL	0.05	0.25	mg/L		<MDL	0.05	0.25	mg/L		<MDL	0.05	0.25	mg/L
Barium, Total, ICP	0.0074		0.001	0.005	mg/L	0.017		0.001	0.005	mg/L	0.019		0.001	0.005	mg/L
Beryllium, Total, ICP		<MDL	0.001	0.005	mg/L		<MDL	0.001	0.005	mg/L		<MDL	0.001	0.005	mg/L
Cadmium, Total, ICP		<MDL	0.003	0.015	mg/L		<MDL	0.003	0.015	mg/L		<MDL	0.003	0.015	mg/L
Calcium, Total, ICP	12		0.05	0.25	mg/L	8.4		0.05	0.25	mg/L	9.2		0.05	0.25	mg/L
Chromium, Total, ICP		<MDL	0.005	0.025	mg/L		<MDL	0.005	0.025	mg/L		<MDL	0.005	0.025	mg/L
Iron, Total, ICP	1.3		0.05	0.25	mg/L	0.82		0.05	0.25	mg/L	0.58		0.05	0.25	mg/L
Magnesium, Total, ICP	4.8		0.03	0.15	mg/L	2.8		0.03	0.15	mg/L	3.4		0.03	0.15	mg/L
Manganese, Total, ICP	0.045		0.002	0.01	mg/L	0.047		0.002	0.01	mg/L	0.028		0.002	0.01	mg/L
Molybdenum, Total, ICP		<MDL	0.02	0.1	mg/L		<MDL	0.02	0.1	mg/L		<MDL	0.02	0.1	mg/L
Nickel, Total, ICP		<MDL	0.02	0.1	mg/L		<MDL	0.02	0.1	mg/L	0.02	<RDL	0.02	0.1	mg/L
Potassium, Total, ICP		<MDL	2	10	mg/L	2	<RDL	2	10	mg/L	2	<RDL	2	10	mg/L
Selenium, Total, ICP		<MDL	0.05	0.25	mg/L		<MDL	0.05	0.25	mg/L		<MDL	0.05	0.25	mg/L
Silver, Total, ICP		<MDL	0.004	0.02	mg/L		<MDL	0.004	0.02	mg/L		<MDL	0.004	0.02	mg/L
Sodium, Total, ICP	5.3		0.5	2.5	mg/L	4.9		0.5	2.5	mg/L	11		0.5	2.5	mg/L
Thallium, Total, ICP		<MDL	0.2	1	mg/L		<MDL	0.2	1	mg/L		<MDL	0.2	1	mg/L
Zinc, Total, ICP		<MDL	0.005	0.025	mg/L		<MDL	0.005	0.025	mg/L	0.006	<RDL	0.005	0.025	mg/L
M.Code=METRO 16-02-002															
Aluminum, Dissolved, ICP															
Arsenic, Dissolved, ICP															
Barium, Dissolved, ICP															
Beryllium, Dissolved, ICP															
Cadmium, Dissolved, ICP															
Calcium, Dissolved, ICP															
Chromium, Dissolved, ICP															
Iron, Dissolved, ICP															
Magnesium, Dissolved, ICP															
Manganese, Dissolved, ICP															
Molybdenum, Dissolved, ICP															
Nickel, Dissolved, ICP															
Potassium, Dissolved, ICP															
Selenium, Dissolved, ICP															
Silver, Dissolved, ICP															
Sodium, Dissolved, ICP															

METRO Environmental Lab Analytical Report

PROJECT: B40179

Locator:	GREEN1					Locator:	GREEN2					Locator:	GREEN3				
Sampled:	Mar 02, 94					Sampled:	Mar 02, 94					Sampled:	Mar 02, 94				
Lab ID:	L3135-1					Lab ID:	L3135-2					Lab ID:	L3135-3				
Matrix:	STORM WTR					Matrix:	STORM WTR					Matrix:	STORM WTR				
% Solids:						% Solids:						% Solids:					
Parameters	Value	Qual	MDL	RDL	Units	Value	Qual	MDL	RDL	Units		Value	Qual	MDL	RDL	Units
	- Wet Weight Basis					- Wet Weight Basis						- Wet Weight Basis				
Thallium, Dissolved, ICP																
Zinc, Dissolved, ICP																
M.Code=METRO 16-03-001																
Copper, Total, GFAA	0.003	<RDL	0.001	0.003	mg/L	0.002	<RDL	0.001	0.003	mg/L		0.001	<RDL	0.001	0.003	mg/L
Lead, Total, GFAA		<MDL	0.001	0.003	mg/L		<MDL	0.001	0.003	mg/L			<MDL	0.001	0.003	mg/L
M.Code=METRO 16-03-002																
Copper, Dissolved, GFAA																
Lead, Dissolved, GFAA																
M.Code=SM 2340B ED18																
Total Hardness	49		0.2	1.3	mg/L	32		0.2	1.3	mg/L		37		0.2	1.3	mg/L
M.Code=SM-9222 D ed.17																
Fecal Coliform	65				CFU/100ml	140				CFU/100ml		100				CFU/100ml
M.Code=SM2130-B																
Turbidity	12		0.5	1	NTU	8		0.5	1	NTU		7		0.5	1	NTU
M.Code=SM2540-D																
Total Suspended Solids	22		0.5	1	mg/L	15		0.5	1	mg/L		10		0.5	1	mg/L
M.Code=SM4500-NO3-F																
Nitrite + Nitrate Nitrogen	2.2		0.05	0.1	mg/L	2.8		0.05	0.1	mg/L		0.21		0.05	0.1	mg/L
M.Code=SM4500-P-B,E																
Total Phosphorus	0.19		0.005	0.01	mg/L	0.083		0.005	0.01	mg/L		0.82		0.005	0.01	mg/L
M.Code=SM4500-P-F																
Ortho Phosphorus	0.092		0.002	0.005	mg/L	0.029		0.002	0.005	mg/L		0.038		0.002	0.005	mg/L
M.Code=SM5520-B																
Oil And Grease, Total	3	<RDL	2	5	mg/L	2	<RDL	2	5	mg/L		3	<RDL	2	5	mg/L

METRO Environmental Lab Analytical Report

PROJECT: B40179

	GREEN4	GREEN5	GREEN6	GREEN7
Locator:	GREEN4	GREEN5	GREEN6	GREEN7
Sampled:	Mar 02, 94	Mar 02, 94	Mar 02, 94	Mar 02, 94
Lab ID:	L3135-4	L3135-5	L3135-6	L3135-7
Matrix:	STORM WTR	STORM WTR	STORM WTR	FILTER WTR
% Solids:				

Parameters	GREEN4 Value	Qual	MDL	RDL	Units	GREEN5 Value	Qual	MDL	RDL	Units	GREEN6 Value	Qual	MDL	RDL	Units	GREEN7 Value	Qual	MDL	RDL	Units
			- Wet Weight Basis					- Wet Weight Basis					- Wet Weight Basis					- Wet Weight Basis		
COMBINED LABS																				
M.Code=METRO 16-02-001																				
Aluminum, Total, ICP	1.1		0.1	0.5	mg/L	1.7		0.1	0.5	mg/L	0.3	<RDL	0.1	0.5	mg/L					
Arsenic, Total, ICP		<MDL	0.05	0.25	mg/L		<MDL	0.05	0.25	mg/L		<MDL	0.05	0.25	mg/L					
Barium, Total, ICP	0.0096		0.001	0.005	mg/L	0.018		0.001	0.005	mg/L	0.0072		0.001	0.005	mg/L					
Beryllium, Total, ICP		<MDL	0.001	0.005	mg/L		<MDL	0.001	0.005	mg/L		<MDL	0.001	0.005	mg/L					
Cadmium, Total, ICP		<MDL	0.003	0.015	mg/L		<MDL	0.003	0.015	mg/L		<MDL	0.003	0.015	mg/L					
Calcium, Total, ICP	11		0.05	0.25	mg/L	12		0.05	0.25	mg/L	7.5		0.05	0.25	mg/L					
Chromium, Total, ICP		<MDL	0.005	0.025	mg/L		<MDL	0.005	0.025	mg/L		<MDL	0.005	0.025	mg/L					
Iron, Total, ICP	0.94		0.05	0.25	mg/L	1.6		0.05	0.25	mg/L	0.44		0.05	0.25	mg/L					
Magnesium, Total, ICP	4.4		0.03	0.15	mg/L	4.4		0.03	0.15	mg/L	3.5		0.03	0.15	mg/L					
Manganese, Total, ICP	0.054		0.002	0.01	mg/L	0.047		0.002	0.01	mg/L	0.025		0.002	0.01	mg/L					
Molybdenum, Total, ICP		<MDL	0.02	0.1	mg/L		<MDL	0.02	0.1	mg/L		<MDL	0.02	0.1	mg/L					
Nickel, Total, ICP		<MDL	0.02	0.1	mg/L		<MDL	0.02	0.1	mg/L		<MDL	0.02	0.1	mg/L					
Potassium, Total, ICP		<MDL	2	10	mg/L		<MDL	2	10	mg/L		<MDL	2	10	mg/L					
Selenium, Total, ICP		<MDL	0.05	0.25	mg/L		<MDL	0.05	0.25	mg/L		<MDL	0.05	0.25	mg/L					
Silver, Total, ICP		<MDL	0.004	0.02	mg/L		<MDL	0.004	0.02	mg/L		<MDL	0.004	0.02	mg/L					
Sodium, Total, ICP	5.8		0.5	2.5	mg/L	5		0.5	2.5	mg/L	3.8		0.5	2.5	mg/L					
Thallium, Total, ICP		<MDL	0.2	1	mg/L		<MDL	0.2	1	mg/L		<MDL	0.2	1	mg/L					
Zinc, Total, ICP	0.005	<RDL	0.005	0.025	mg/L	0.006	<RDL	0.005	0.025	mg/L	0.008	<RDL	0.005	0.025	mg/L					
M.Code=METRO 16-02-002																				
Aluminum, Dissolved, ICP																	<MDL	0.1	0.5	mg/L
Arsenic, Dissolved, ICP																	<MDL	0.05	0.25	mg/L
Barium, Dissolved, ICP																0.001	<RDL	0.001	0.005	mg/L
Beryllium, Dissolved, ICP																	<MDL	0.001	0.005	mg/L
Cadmium, Dissolved, ICP																	<MDL	0.003	0.015	mg/L
Calcium, Dissolved, ICP																5		0.05	0.25	mg/L
Chromium, Dissolved, ICP																	<MDL	0.005	0.025	mg/L
Iron, Dissolved, ICP																	<MDL	0.05	0.25	mg/L
Magnesium, Dissolved, ICP																1.1		0.03	0.15	mg/L
Manganese, Dissolved, ICP																0.004	<RDL	0.002	0.01	mg/L
Molybdenum, Dissolved, ICP																	<MDL	0.02	0.1	mg/L
Nickel, Dissolved, ICP																	<MDL	0.02	0.1	mg/L
Potassium, Dissolved, ICP																	<MDL	2	10	mg/L
Selenium, Dissolved, ICP																	<MDL	0.05	0.25	mg/L
Silver, Dissolved, ICP																	<MDL	0.004	0.02	mg/L
Sodium, Dissolved, ICP																2.7		0.5	2.5	mg/L

METRO Environmental Lab Analytical Report

PROJECT: B40179

	GREEN4	GREEN5	GREEN6	GREEN7
Locator:	GREEN4	GREEN5	GREEN6	GREEN7
Sampled:	Mar 02, 94	Mar 02, 94	Mar 02, 94	Mar 02, 94
Lab ID:	L3135-4	L3135-5	L3135-6	L3135-7
Matrix:	STORM WTR	STORM WTR	STORM WTR	FILTER WTR
% Solids:				

Parameters	GREEN4 Value	Qual	MDL	RDL	Units	GREEN5 Value	Qual	MDL	RDL	Units	GREEN6 Value	Qual	MDL	RDL	Units	GREEN7 Value	Qual	MDL	RDL	Units
		- Wet Weight Basis					- Wet Weight Basis					- Wet Weight Basis					- Wet Weight Basis			
Thallium, Dissolved, ICP																	<MDL	0.2	1	mg/L
Zinc, Dissolved, ICP																	<MDL	0.005	0.025	mg/L
M.Code=METRO 16-03-001																				
Copper, Total, GFAA	0.002	<RDL	0.001	0.003	mg/L	0.003	<RDL	0.001	0.003	mg/L	0.002	<RDL	0.001	0.003	mg/L					
Lead, Total, GFAA	0.001	<RDL	0.001	0.003	mg/L	0.001	<RDL	0.001	0.003	mg/L		<MDL	0.001	0.003	mg/L					
M.Code=METRO 16-03-002																				
Copper, Dissolved, GFAA																	<MDL	0.001	0.003	mg/L
Lead, Dissolved, GFAA																	<MDL	0.001	0.003	mg/L
M.Code=SM 2340B ED18																				
Total Hardness	45		0.2	1.3	mg/L	48		0.2	1.3	mg/L	33		0.2	1.3	mg/L					
M.Code=SM-9222 D ed.17																				
Fecal Coliform	100				CFU/100ml	120				CFU/100ml	20				CFU/100ml					
M.Code=SM2130-B																				
Turbidity	8		0.5	1	NTU	17		0.5	1	NTU	4.2		0.5	1	NTU					
M.Code=SM2540-D																				
Total Suspended Solids	15		0.5	1	mg/L	28		0.5	1	mg/L	4		0.5	1	mg/L					
M.Code=SM4500-NO3-F																				
Nitrite + Nitrate Nitrogen	1.9		0.05	0.1	mg/L	1.7		0.05	0.1	mg/L	0.95		0.05	0.1	mg/L					
M.Code=SM4500-P-B,E																				
Total Phosphorus	0.071		0.005	0.01	mg/L	0.047		0.005	0.01	mg/L	0.039		0.005	0.01	mg/L					
M.Code=SM4500-P-F																				
Ortho Phosphorus	0.049		0.002	0.005	mg/L	0.035		0.002	0.005	mg/L	0.018		0.002	0.005	mg/L					
M.Code=SM5520-B																				
Oil And Grease, Total		<MDL	2	5	mg/L	2	<RDL	2	5	mg/L		<MDL	2	5	mg/L					

METRO Environmental Lab Analytical Report

PROJECT: B40179

		Locator: G2				Locator: G3				Locator: G4				Locator: G5				Locator: G6			
		Sampled: Aug 17, 93				Sampled: Aug 17, 93				Sampled: Aug 17, 93				Sampled: Aug 17, 93				Sampled: Aug 17, 93			
		Lab ID: L1764-1				Lab ID: L1764-2				Lab ID: L1764-3				Lab ID: L1764-4				Lab ID: L1764-5			
		Matrix: FRSHWTRSED				Matrix: FRSHWTRSED				Matrix: FRSHWTRSED				Matrix: FRSHWTRSED				Matrix: FRSHWTRSED			
		% Solids: 31				% Solids: 70				% Solids: 49				% Solids: 76				% Solids: 28			
Parameters		Qualifier	Value (ug/Kg)	MDL (ug/Kg)	RDL (ug/Kg)	Qualifier	Value (ug/Kg)	MDL (ug/Kg)	RDL (ug/Kg)	Qualifier	Value (ug/Kg)	MDL (ug/Kg)	RDL (ug/Kg)	Qualifier	Value (ug/Kg)	MDL (ug/Kg)	RDL (ug/Kg)	Qualifier	Value (ug/Kg)	MDL (ug/Kg)	RDL (ug/Kg)
CONVENTIONALS			- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis		
M.Code=SM4500-P-B,E																					
Total Phosphorus	mg/Kg		13	0.02	0.032		7.4	0.007	0.014		9.6	0.01	0.02		6.3	0.007	0.013		16	0.02	0.036
M.Code=SM5310-B																					
Total Organic Carbon	mg/Kg		110000	2	3.2		9400	0.7	1.4		24000	1	2		4300	0.7	1.3		54000	2	3.6
M.Code=SM5520-B,F																					
Oil and Grease, Total	mg/Kg		2700	6.5	16		310	3	7.1		570	4.1	10		380	2.6	6.6		2800	7	18
Oil, Petro (Non-Polar)	mg/Kg		31	6.5	16					<RDL	9.8	4.1	10	<MDL		2.6	6.6		570	7.1	18
Oil, Polar (Non-Petro)	mg/Kg		2600	6.5	16						550	4.1	10		380	2.6	6.6		2200	7.1	18

METRO Environmental Lab Analytical Report

PROJECT: B40179

		Locator: G18				Locator: GA1				Locator: GBS				Locator: GJR			
		Sampled: Sep 01, 93				Sampled: Aug 26, 93				Sampled: Aug 17, 93				Sampled: Aug 26, 93			
		Lab ID: L1764-11				Lab ID: L1764-12				Lab ID: L1764-13				Lab ID: L1764-14			
		Matrix: FRSHWTRSED				Matrix: FRSHWTRSED				Matrix: FRSHWTRSED				Matrix: FRSHWTRSED			
		% Solids: 50				% Solids: 66				% Solids: 41				% Solids: 76			
Parameters		Qualifier	Value (ug/Kg)	MDL (ug/Kg)	RDL (ug/Kg)	Qualifier	Value (ug/Kg)	MDL (ug/Kg)	RDL (ug/Kg)	Qualifier	Value (ug/Kg)	MDL (ug/Kg)	RDL (ug/Kg)	Qualifier	Value (ug/Kg)	MDL (ug/Kg)	RDL (ug/Kg)
CONVENTIONALS			- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis		
M.Code=SM4500-P-B,E																	
Total Phosphorus	mg/Kg		48	0.01	0.02		15	0.008	0.015		12	0.01	0.024		3.2	0.007	0.013
M.Code=SM5310-B																	
Total Organic Carbon	mg/Kg		42000	1	2		18000	0.8	1.5		24000	1	2.4		14000	0.7	1.3
M.Code=SM5520-B,F																	
Oil and Grease, Total	mg/Kg		2800	400	1000		3800	300	760		1600	5	12	<RDL	300	300	660
Oil, Petro (Non-Polar)	mg/Kg		2200	400	1000		2400	300	760		660	4.9	12	<MDL		260	660
Oil, Polar (Non-Petro)	mg/Kg	<RDL	660	400	1000		1200	300	760		900	4.9	12	<MDL		260	660

METRO Environmental Lab Analytical Report

PROJECT: B40179

Locator:	G2	G3	G4	G5	G6
Sampled:	Aug 17, 93	Aug 17, 93	Aug 17, 93	Aug 17, 93	Aug 17, 93
Lab ID:	L1764-1	L1764-2	L1764-3	L1764-4	L1764-5
Matrix:	FRSHWTRSED	FRSHWTRSED	FRSHWTRSED	FRSHWTRSED	FRSHWTRSED
% Solids:	31	70	49	76	28

Parameters	Qualifier	Value (mg/Kg)	MDL (mg/Kg)	RDL (mg/Kg)	Qualifier	Value (mg/Kg)	MDL (mg/Kg)	RDL (mg/Kg)	Qualifier	Value (mg/Kg)	MDL (mg/Kg)	RDL (mg/Kg)	Qualifier	Value (mg/Kg)	MDL (mg/Kg)	RDL (mg/Kg)	Qualifier	Value (mg/Kg)	MDL (mg/Kg)	RDL (mg/Kg)
		- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis		
METALS																				
M.Code=METRO 16-01-004																				
Mercury, Total, CVAA																				
M.Code=METRO 16-02-004																				
Aluminum, Total, ICP		16000	30	150		13000	10	70		15000	20	98		10000	10	62		27000	40	180
Arsenic, Total, ICP	<MDL		20	77	<MDL		7	36	<MDL		10	49	<MDL		7	32	<MDL		20	89
Barium, Total, ICP		100	0.3	1.5		69	0.1	0.7		84	0.2	0.98		47	0.1	0.62		160	0.4	1.8
Beryllium, Total, ICP	<RDL	0.6	0.3	1.5	<RDL	0.4	0.1	0.7	<RDL	0.6	0.2	0.98	<RDL	0.4	0.1	0.62	<RDL	1	0.4	1.8
Cadmium, Total, ICP	<MDL		1	4.5	<MDL		0.4	2.1	<MDL		0.6	2.9	<MDL		0.4	1.8	<MDL		1	5.4
Calcium, Total, ICP		6800	20	77		5600	7	36		6900	10	49		4200	7	32		7500	20	89
Chromium, Total, ICP		23	2	7.7		17	0.7	3.6		20	1	4.9		26	0.7	3.2		31	2	8.9
Copper, Total, ICP		25	1	6.1		14	0.6	2.9		19	0.8	3.9		10	0.5	2.5		39	1	7.1
Iron, Total, ICP		17000	20	77		20000	7	36		18000	10	49		14000	7	32		28000	20	89
Lead, Total, ICP	<RDL	10	10	45	<MDL		4	21	<RDL	20	6	29	<MDL		4	18	<RDL	40	10	54
Magnesium, Total, ICP		4200	10	45		4900	4	21		3900	6	29		5000	4	18		6400	10	54
Manganese, Total, ICP		450	0.6	3		310	0.3	1.4		880	0.4	2		320	0.3	1.2		610	0.7	3.5
Molybdenum, Total, ICP	<MDL		6	30	<MDL		3	14	<MDL		4	20	<MDL		3	12	<MDL		7	35
Nickel, Total, ICP	<RDL	20	6	30		14	3	14	<RDL	20	4	20		29	3	12	<RDL	30	7	35
Potassium, Total, ICP	<RDL	600	600	3000	<RDL	700	300	1400	<RDL	800	400	2000	<RDL	700	300	1200	<RDL	1000	700	3500
Selenium, Total, ICP	<MDL		20	77	<MDL		7	36	<MDL		10	49	<MDL		7	32	<MDL		20	89
Silver, Total, ICP	<MDL		1	6.1	<MDL		0.6	2.9	<MDL		0.8	3.9	<MDL		0.5	2.5	<MDL		1	7.1
Sodium, Total, ICP	<RDL	300	200	770		430	70	360		570	100	490	<RDL	100	70	320	<RDL	700	200	890
Thallium, Total, ICP	<MDL		60	300	<MDL		30	140	<MDL		40	200	<MDL		30	120	<MDL		70	350
Zinc, Total, ICP		74	2	7.7		47	0.7	3.6		73	1	4.9		32	0.7	3.2		170	2	8.9

METRO Environmental Lab Analytical Report

PROJECT: B40179

Locator:	G18				GA1				GBS				GJR				GU1		
Sampled:	Sep 01, 93				Aug 26, 93				Aug 17, 93				Aug 26, 93				Aug 26, 93		
Lab ID:	L1764-11				L1764-12				L1764-13				L1764-14				L1764-15		
Matrix:	FRSHWTRSED				FRSHWTRSED				FRSHWTRSED				FRSHWTRSED				FRSHWTRSED		
% Solids:	50				66				41				76				49		
Parameters	Qualifier	Value (mg/Kg)	MDL (mg/Kg)	RDL (mg/Kg)	Qualifier	Value (mg/Kg)	MDL (mg/Kg)	RDL (mg/Kg)	Qualifier	Value (mg/Kg)	MDL (mg/Kg)	RDL (mg/Kg)	Qualifier	Value (mg/Kg)	MDL (mg/Kg)	RDL (mg/Kg)	Qualifier	Value (mg/Kg)	MDL (mg/Kg)	RDL (mg/Kg)
		- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis				- Dry Weight Basis		
METALS																				
M.Code=METRO 16-01-004																				
Mercury, Total, CVAA																	<RDL	0.2	0.04	0.41
M.Code=METRO 16-02-004																				
Aluminum, Total, ICP		12000	20	94		9100	20	73		16000	20	110		13000	10	66		6500	20	100
Arsenic, Total, ICP	<MDL		10	46	<MDL		8	36	<MDL		10	59	<MDL		7	33	<RDL	10	10	51
Barium, Total, ICP		84	0.2	0.94		47	0.2	0.73		100	0.2	1.1		61	0.1	0.66		98	0.2	1
Beryllium, Total, ICP	<RDL	0.4	0.2	0.94	<RDL	0.2	0.2	0.73	<RDL	0.5	0.2	1.1	<RDL	0.3	0.1	0.66	<RDL	0.6	0.2	1
Cadmium, Total, ICP	<RDL	2	0.6	2.8		2.6	0.5	2.1	<MDL		0.7	3.4	<MDL		0.4	2	<MDL		0.6	3.1
Calcium, Total, ICP		10000	10	46		3600	8	36		6800	10	59		5700	7	33		5500	10	51
Chromium, Total, ICP		30	1	4.6		23	0.8	3.6		49	1	5.9		22	0.7	3.3		16	1	5.1
Copper, Total, ICP		58	0.8	3.8		38	0.6	2.9		20	1	4.6		18	0.5	2.6		14	0.8	4.1
Iron, Total, ICP		24000	10	46		20000	8	36		23000	10	59		22000	7	33		22000	10	51
Lead, Total, ICP		120	6	28		110	5	21	<RDL	7	7	34	<MDL		4	20	<MDL		6	31
Magnesium, Total, ICP		4600	6	28		3900	5	21		7100	7	34		5300	4	20		3700	6	31
Manganese, Total, ICP		480	0.4	1.9		290	0.3	1.5		710	0.5	2.3		530	0.3	1.3		1000	0.4	2
Molybdenum, Total, ICP	<MDL		4	19	<MDL		3	15	<MDL		5	23	<MDL		3	13	<MDL		4	20
Nickel, Total, ICP										44	5	23								
Potassium, Total, ICP	<RDL	800	400	1900	<RDL	500	300	1500	<RDL	700	500	2300	<RDL	700	300	1300	<RDL	1000	400	2000
Selenium, Total, ICP	<MDL		10	46	<MDL		8	36	<MDL		10	59	<MDL		7	33	<MDL		10	51
Silver, Total, ICP	<MDL		0.8	3.8	<MDL		0.6	2.9	<MDL		1	4.6	<MDL		0.5	2.6	<MDL		0.8	4.1
Sodium, Total, ICP	<RDL	400	100	460	<RDL	300	80	360	<RDL	200	100	590		300	70	330	<RDL	200	100	510
Thallium, Total, ICP	<MDL		40	190	<MDL		30	150	<MDL		50	230	<MDL		30	130	<MDL		40	200
Zinc, Total, ICP		340	1	4.6		300	0.8	3.6		66	1	5.9		46	0.7	3.3		120	1	5.1

APPENDIX D
OLSON CREEK HYDROLOGIC MODELING WITH HSPF

INTRODUCTION

Olson Creek was the only one of seven subbasins to have a hydrologic analysis done with HSPF. HSPF (Hydrological Simulation Program-FORTRAN) is a continuous event model with the ability to model most aspects of hydrology within a basin or several basins. With the use of several parameters, it is possible to calibrate a simulation of runoff to observed and/or recorded data. However, to expedite this analysis, it was necessary to use regional parameters (Dinicola, 1990) and forgo calibration for this model (See Table D-1 through Table D-3). This appendix explains the analysis methods for four different scenarios: forest, current, future with reservoir, and future without reservoir. These four scenarios enable a comparison between different stages of development. Moreover, the City of Kent's proposed Pipeline 5 reservoir project necessitated the use of two future scenarios to estimate not only the potential impact of future development, but what the replacement of Wetland 24 with a water-supply reservoir might do.

Description

Olson Creek (tributary 0061) is located in the eastern Lower Green River basin. It is the largest of the tributaries in this Basin. The watershed of Olson Creek was divided into four catchments; OC1, OC2, OC3, and OC4. OC1 and OC2 are both part of the upper watershed feeding down into OC3 and then OC4 (outlet to Green River). The catchment boundaries are delineated to differentiate between storage area (wetlands), flat channel reaches, and steep channel reaches. Hence, OC1 and OC2 have large wetlands (Wetland 24 and Wetland 46). Subcatchment OC3 receives from both OC1 and OC2 and is relative flat in slope, while OC4's routing is very steep (see Figure D-1).

Regional parameters are a set of parameters that were calibrated for HSPF using flow data from a number of basins in King and Snohomish counties. These parameters provide a good estimate of runoff where no basin-specific data are available. Furthermore, these regional parameters provide a good starting point for calibrating basins. These parameters have a quasi-physical basis and simulate hydrologic response for a variety of soil and cover combinations called "land types."

The total surface area belonging to each land type in each catchment was based on zoning, topographic, soils maps, surficial geology maps, aerial photos, and field reconnaissance. A summary of these land types is shown in Table D-4. The model computes hydrologic response of each land type within a subbasin on a per-unit-area basis and apportions the amount of surface runoff, interflow, and groundwater entering the drainage element of each catchment consistent with the computed land-type area totals. Consequently, the model represents the hydrologic effect of spatial distribution of land types to the extent that land-type composition varies among catchments of a subbasin. However, it ignores the effects of the landscape position of land types within individual catchments.

There are three primary determinants of the hydrologic response of a system: soils, land cover, and slopes:

Soils: For hydrologic modeling purposes, all soils were classified as either till, outwash, or wetland. 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 re-emerging at the base of hill slopes. 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.

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.

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 baseflow to streams in the summer months and attenuate storm flows via temporary storage and slow release in the winter.

Olson Creek subbasin is practically all till soils (see Figure D-2). Wetland soils are commonly called "hydric soils" by the Soil Conservation Service (SCS), as mapped on Figure D-1. There are differences between what is mapped as wetland (Figure D-1) and hydric soils (Figure D-2). The assumption here is that wetlands are mapped more accurately than hydric soils mapped in the geology map. Therefore, wetland soils were determined by wetland delineation and not by geology. Conversely, soils mapped as hydric soils but not wetland were modeled as till. The three soils types described before are actually an aggregation of many soils types that behave similar enough for our modeling efforts. For example, there are several type of soils that are considered till soils (see Table D-5).

Land Cover: Five land cover classes were considered in analyzing the Olson Creek hydrology: forest, grass, pasture, impervious, and wetland (saturated/hydric). The percentages of each catchment belonging to these five classes were determined from land-use assumptions and their typical coverage per range of densities (see Table D-6). These five land coverages are broken down into different soils and slopes, yielding eleven pervious land types ("PERLNDS") and one impervious land type ("IMPLND") as previously shown in Table D-4.

Forested areas generate the least amount of surface runoff. Forest cover is most significant in regions of glacial till where tree root systems open pores in low-permeability soil, 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.

Pasture areas are a hybrid between forest and grass. This type of land cover is used least the frequently because our areas of study typically do not entail large amounts of pasture. What most people refer to as pasture is actually considered grass (i.e. grazing grasslands). Pasture as defined for hydrologic modeling is land coverage with substantial vegetation growth (i.e. very tall grass and shrubs). The idea behind pasture is to represent an infiltration capacity near forested conditions with smaller amounts of soil column storage and evapotranspiration as typified by grass. As a result, pasture has the potential to behave like grass and forest depending on the intensity and duration of weather (i.e. precipitation).

Grassed areas produce more surface runoff than forested and pasture areas. When forest vegetation is removed to create grassed 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. Impervious areas consist of roads, rooftops, sidewalks, parking lots, driveways, and other constructed surfaces. They produce the most surface runoff 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.

Saturated areas such as stream channels, lakes, and wetlands also affect the runoff characteristics from a given area. These features store flows and release them slowly, thus reducing the flow peak. The degree to which these flows are reduced depends upon the roughness, slope volume, and shape of the drainage element. Of these, volume has the most effect on reducing peaks. Thus, wetlands and lakes by virtue of their larger storage volume are typically more effective than channels at reducing flow peaks.

Slopes: 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 (0-6%), moderate (6-15%), and steep (>15%). Steeper slopes have faster responses than moderate slopes. This allows the thin surface soil in steeper sloping areas to drain faster than soils in moderately sloping areas (see Figure D-3).

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.

Land Use

Land use is a function of assumed density and the typical usage of the densities. For our purposes we have delineated land use into ten categories: Commercial, Multifamily, Single Family-High, Single Family-Medium, Single Family-Low with Grass Cover, Single Family-Low with Forest Cover, Grass, Pasture, Forest, and Wetland. In turn these classified densities are proportioned with the various land types. There is one subtle difference between the assumed low density in current conditions and future land use. Future land use assumes only one kind of low density use, and not the two as recognized

under current conditions (namely low density-grass and low density-forest). Consequently, future land use has nine delineations: Commercial, Multifamily, Single Family-High, Single Family-Medium, Single Family-Low, Grass, Pasture, Forest, and wetland. Within Olson Creek, there was no measured or assumed "Medium Density" to exist in either current or future land uses.

Currently, Olson Creek is mostly low density single-family residential, grass, and forest covered. Three percent (31 of 977 acres) of the subbasin has densities greater than 1 dwelling units per acre (Medium Density) and seventy-four percent (23 of 31 acres) of this is concentrated in catchment OC1. In a broader range, fifty-one percent (500 acres) of Olson Creek is developed. However, 94 percent (469 acres) of this is low density-grass and low density-forest (see Table D-7). In a distilled version (based on modeling assumptions), 36 percent (356 acres) is forest, 40 percent (389 acres) is grass, 5 percent (45 acres) is wetland, 16 percent (157 acres) is pasture, and 3 percent (31 acres) is effectively impervious (see Figure D-4).

Based on current zoning, ~~potential~~ likely future annexations, and provisions of the Growth Management Act that pertain to urban areas ~~and other considerations, potential future~~ development is very high for Olson Creek. Currently, the basin is roughly 3 percent developed. Potential future development could exceed 80 percent (763 acres), with 22 percent (200 acres) effective impervious area (EIA). The following two tables are Land use assumed for modeling current and future conditions (see Figure D-5).

In addition to this future land use, a second future scenario was run assuming that a water-supply reservoir is not constructed in Wetland 24. As a result, the impacts of the reservoir (and the consequent loss of the wetland storage to the surface-water drainage system) can be compared and analyzed. Likewise, the forested conditions scenario is simply the application of running the model and assuming no development existed (see Table D-9). This is done to provide a baseline condition. By applying Tables D-1 through D-3 on Tables D-4 through D-6, the results can then be used for the HSPF model. Tables D-7 through D-9 are a summary of this process.

MODELING

Precipitation Input

The HSPF model was run for a period of record starting October 1, 1948 through May 30, 1992 at one-hour time steps. Based on nearby gages and past modeling experience, precipitation used for the model was hourly Seattle-Tacoma International Airport (Seatac) precipitation with a multiplication factor of 1.00. Potential evaporation was converted to pan evaporation by multiplying the daily Puyallup pan evaporation by 0.75. Gaps in evaporation data were either filled with Jensen-Haise formula (based on maximum and minimum daily temperatures) or average daily values from the previous years.

Subcatchment Characteristics

OC1

Land Use: OC1 is the largest of the catchments (416 acres) currently with a wetland covering 58 acres. Current land use is distributed such that: 1 percent (6 acres) is commercial, 0.5 percent (2.5 acres) is multifamily, 3 percent (14 acres) is high density, 21 percent (88 acres) is low-density grass, 11 percent (45 acres) is low-density forest, 38 percent (157 acres) is pasture (mostly from the City of Kent property), 11 percent (47 acres) is forest, and 14 percent (58 acres) is wetland. The wetland, as modeled, is completely located within the Kent property.

Future land use in this catchment has some unique assumptions. Kent is proposing to replace Wetland 24, excavating and berming to create a 3200 acre-feet water storage facility for Pipeline 5. Kent's property measures to be about 157 acres. Wetland 24 as mapped measures to be 58 acres. Future land use thus eliminates the wetland (58 acres) and 22 acres of grass adjacent to the wetland (the reservoir is assumed to cover about 80 acres).

Hydraulics: The outlet of the catchment is located where the stream crossing through a 36" culvert under 118th Avenue SE. The slope of the culvert was measured to be 0.5 percent. It was assumed that the pipe would flow full under most conditions (i.e. not inlet controlled). Only under larger storm events would it act as inlet controlled. The nomagraphs in the King County Surface-Water Design Manual were used for determining the stage-discharge relationships. Depths of 0 to 3 feet were assumed to behave as pipe-full flow. At depths greater than 3 feet the culvert was assumed to act as inlet controlled. The volume-discharge relationship was determined using HEC2 with some simplified cross-sections taken from a topographic map.

Wetland 24 was represented by eight cross-sections for HEC2 modeling. This technique was used rather than a standard stage-discharge relationship with volumetric storage to better approximate wetland hydraulics. Volumes were determined be multiplying the average length and average cross-sections between cross-sections. There were warnings associated with the HEC2 run that were not deemed problematic for these purposes, but they emphasize that this HEC2 model run should not be used for any purpose beyond a rough estimate of the wetland's hydraulics. The results of the HEC2 run were compiled and summarized in Table D-38.

Conversely, future assumptions needed to account for the loss of storage from the wetland as well as the loss or acreage receiving precipitation. It is assumed the stream will be ditched around the reservoir, thus providing significantly less storage. Storage volumes assumed in the future are based on a trapezoidal channel that has the capacity to pond against the berm of the reservoir. Thus, the stage/discharge relationship is the same but with much lower volumes.

Current conditions include precipitation and evaporation to the reach (acting like a lake). For future conditions with the reservoir, the reservoir area receiving precipitation was subtracted from the pervious land segments (this is reflected in the differences between catchment areas in Table D-7 and Table D-8). Future conditions thus assumed that the wetland plus an additional 22 acres of surrounding pasture (total of 80 acres) were eliminated from the catchment. Furthermore, precipitation and evaporation were no longer applied to the reach. However, the future scenario without the reservoir assumed the same hydrologic/hydraulics as current conditions for Wetland 24.

OC2

Land Use: Current conditions for catchment OC2 are virtually undeveloped. Low density-grass is the dominant usage covering 40 percent (55 acres) of the catchment, with 12 percent (17 acres) low density-forest, and the rest in forest, wetland, and grass (33 acres, 15 acres, 5 acres, respectively). One wetland (Wetland 46) within this catchment is very large, covering over 20 percent (28 acres) of the area. However, the assumed hydraulics for this catchment include 13 acres of Wetland 46. Hence, the coverage of wetland soils is reduced to 15 acres.

Wetland 46 is not presumed to change between current and future conditions. However, potential development in the future is very large. The basin goes from near-zero development (no existing densities greater than 0.2 dwelling units per acre) to near 76 percent developed (23 percent EIA and 56 percent grass), nearly all of which is high density (Table D-8).

Hydraulics: The outlet of the catchment is delineated by the stream crossing under SE 284th Street, which coincides with the wetland outlet. The channel leading up to the culvert is a neatly dug trapezoidal channel. The culvert is 24" with a slope of about 0.5 percent. The hydraulics are assumed to be normal flow to a depth of 2 feet; the culvert becomes inlet controlled at depths greater than 2 feet. Storage for the reach is assumed to include half of the wetland area under large events. Because the assumptions from current to future are the same for the wetland, a more detailed HEC2 analysis was not used to estimate hydraulics of the wetland. Table D-40 was used for all four model runs.

OC3

Land Use: Once again, the catchment currently has very low levels of development (less than 3 percent developed). Low density-grass covers about 31 percent (79 acres), low density-forest and grass cover about 20 percent each (51 and 50 acres, respectively), and forest covers 26 percent (65 acres). There is a 1.5-acre wetland along stream 0061 between the confluences of streams 0061D and 0061C.

Future development within this catchment is assumed to be about 91 percent (all high density). This yields an EIA of 23 percent (58 acres) and grass covering 61 percent (155 acres). Similarly, accumulated land use for OC3 goes from 3.5 percent (20 acres of EIA) existing development to near 80 percent (or 160 acres of EIA) developed.

Hydraulics: The outlet of this catchment was defined as a 36" culvert crossing under 112th Avenue SE. Field visits showed that the culvert is about one-half blocked. The downstream end of the culvert was a free fall of about three feet. Because of the blockage with debris, the stage-discharge (rating curve) for this reach was modeled as a V-notch weir. This simplification of the debris jam will allow representation of low flow seeping through the debris. Although it is obvious that the culvert will not always have debris jam present, it was judged the best way to represent lower flows. The effective cross-sectional area assumed was derived by using the same height (i.e. 36 inches) and two-thirds the area of the

culvert. Given those two constraints, it was possible to calculate an assumed cross-sectional "V".

Furthermore, the culvert is several feet below the road (about 20 feet), thus creating the potential for some storage upstream. The channel cross-section is trapezoidal with a trapezoidal thalweg. The thalweg is mostly cobble, whereas, the main channel has heavy vegetation (trees, underbrush, etc.). The bottom width of the thalweg and main channel were estimated to be 7 and 25 feet wide, respectively. Volumes were computed based on a length times cross-section. The stage-area-volume-discharge ("ftable") are shown in Table D-41.

OC4

Land Use: This catchment is the second-least developed of the four catchments (mainly because of Olson Canyon). Current land use is estimated to be one percent (2 acres) high density, sixty-three percent (134 acres) low density, nine percent (19 acres) grass, and twenty-seven percent (57 acres) forest. Combined, this equals 2.7 percent (5.8 acres) effective impervious area or 19 percent of the total effective impervious area within Olson Creek.

Within this catchment, future land use increases from 3.3 percent (5.81 acres) effective impervious area to 19 percent (39.4 acres) effective impervious area, most of which resulting from Single Family-High density (3 to 7 dwelling units per acres). On the other hand, it is estimated that only 12 acres of forest will be lost. Thus, the significant amount of development is a result of redevelopment and not so much deforestation. The determining component of this assumption is based on Olson Canyon's remaining as a severely constrained area without significant development potential. .

Hydraulics: Typically the cross-section assumed for channel representation is at the outlet of the defined catchment. However, OC4 is the lowermost catchment within this subbasin and has the potential to become backwatered from higher elevations of the Green River. Accordingly, the lower lengths of the stream were not considered for hydraulics. The representative cross-section was based on the above assumptions. The steep slope for the channel was based on the estimate taken from a topographic map of Olson Canyon reach.

By virtue of the fact that this basin was delineated for its characteristically steep slope, the channel reach was assumed to flow at very high rates. Therefore, storage is not a significant factor. What is significant are the assumed high flow rates for minimal depths. Variables assumed for channel definition are a slope equal to five percent; Manning's n equal to 0.03; and trapezoidal cross-section with a base width of ten feet, side slopes of 1:1, and a length of 1000 feet. Thus, Manning's equation was used to create Table D-42.

The hydraulics assumed for this catchment could be refined. For example, the amount of sediment transported in this reach is considerable. After the January 1990 storm, the channel and culvert were nearly filled. Given these factors that are not presently included in this analysis, any subsequent reevaluation should probably consider a backwater model instead.

MODEL RESULTS

Model Validation

Procedure. Although calibration of the model was beyond the scope of this project, it would be instructive to do a comparison of model results with gage data if possible. There was a King County gage 32C[1] in place from October 1, 1988 through August 3, 1990 collecting data on 15-minute increments (with about a one month of gap in June of 1989). The gage is located near River Mile 0.1. Secondly, there is a precipitation gage located near 31204 124th Avenue SE (Gage 32U) collecting 15-minute data starting in October 1988 and continuing through the present (July 1994) (Figure D-1).

Given the existence of these two gages, we can check on the validity of using regional parameters. In order to maximize the usage of both gages (32C & 32U), it was necessary to include one prior year of precipitation data (October 1987 through September 1988) from the Seatac data set. This added year in the beginning allows the modeling parameters to become adequately initialized such that day 366 of simulation (10/1/88) can be used for direct comparison with the gage data. The validation was run from 10/1/87 through 5/30/92 at 15-minute time steps.

There are some important caveats about the stream flow gage data. The rating curve used for determining flow rates had no measurements greater than 15 cfs. As a result, confidence in gage values beyond 15 cfs are low. Furthermore, it was estimated for stream gage data that the January 9, 1990 storm peaked out near 50 cfs (a value that is needed for rating curve extrapolation). There was one rating shift needed for stream gage 32C. This was done for the January 9, 1990 storm. However, simulated flows are based on one rating curve for the entire duration of the run. The two rating curves, measured data, and trend of data for gage 32C are shown on Figure D-8. Labeled next to the measured flows are comments regarding the quality (as determined by field personnel) of the measurements themselves. To obtain a useable depth reading from the gage, the GZF (Gage Zero Flow) was subtracted from the measured depths (as plotted in Figure D-8). Given the "net depths", a power regression was done to estimate the trend of measured data. In addition, the rating curve shown in Figure D-8 is based on a theoretical offset (non-measured GZF) and best-fit of the data. Once again the maximum point on the curve is based on what was assumed to be the maximum flow during the record (i.e. 50 cfs in this case). This 50 cfs is not necessarily a correct estimate. In fact by not having a high-flow measurement, we could conversely calibrate the gage data to the simulated, by simply changing the estimated measured maximum flow (e.g. change from 50 cfs to 115 cfs). This would obviously have a significant change in translating depth measurements to higher flows.

Results. The Olson Creek analysis considered several flow statistics: daily averages, daily peaks, seasonal volumes, and flow frequencies. As one might expect from the dominance of till soils, this subbasin is fairly quick in response time, on the order of a couple of hours. More importantly, the assumed hydraulics of Wetland 24 drives much of the runoff experienced throughout the stream system.

The gage and simulated data were examined for two water years, 1989 and 1990.

However, water year 1990 is not a complete year. Thus, any reference to water year 1990 for gage data actually means October 1, 1989 through August 3, 1990. Ground water was assumed to emerge at the surface at the bottom of the subbasin as a result of the geology and topography. Consequently, the ground water component (AGWO) was included in all figures, tables, and calculations.

Runoff volume for the two years of gage data was broken down into wet and dry seasons as defined in Table D-13 and Table D-14. The wet seasons were better correlated than the dry. The wet seasons differed by eight percent, on average; whereas, the dry seasons deviated by as much as 25 percent. Evaluating the role of the ground water component (AGWO) would be warranted in future analyses. Over the entire period of gage data, volume differed by 12 percent. This is illustrating in Figure D-9, Olson Creek Volume Runoff, which depicts volume runoff for the period of record for precipitation (Gage 32U), simulated runoff, and measured gage runoff (Gage 32C). Given the complexities of hydrologic modeling and complete lack of calibration, this result is remarkably good and well within an acceptable range.

A comparison of daily mean and peak flow rates further illustrates the validity and accuracy of the model and the usage of regional parameters. The gage record for water year 1989 had few significant storms, with nothing greater than a 2-year discharge. Regional parameters performed well except for the first couple of months (Figure D-10). In Figure D-10, there are three different plots: flow rate versus time, gage versus simulated (flow rates), and Seatac versus Gage 32U. The Daily Mean Flow Rates Scatter Plot illustrates the deviations and estimated regression (solid line) based on those deviations as well as an example of a one-to-one relationship (dashed line). Also included is the regression computed to create the solid line drawn. The outliers that degrade the regression are due to the poor correlation (simulation exceeds gage data for same days nearly 10 to 1) for months October and November of 1988.

The third graph displayed includes data covering the entire time period, October 1, 1988 through May 30, 1992. There was virtually no difference if separated into water years. The regression between gage 32U and Seatac gage has an r-square of 0.86 with a correlation of 0.94. This basically states the best linear translation from Seatac to Gage 32U is to add 6 percent (or multiply Seatac by 1.06). On the other hand, total volume differences between the two gages are less than 4 percent (Figure D-11). This difference between the two statistics stems from the facts that Gage 32U recorded 92 hours (544 Seatac, 636 32U) more precipitation than Seatac, and that a lag time exists between Seatac and Gage 32U.

Water year 1990 had one large event on January 9. Using regional parameters and Seatac precipitation, this storm produces the largest simulated runoff event. February 9, 1951, typically produces the second largest runoff event. As can been seen in Figure D-13 the simulation deviates dramatically from gage records. Simulated daily mean flow rates are shown to be twice as large (50 and 22 cfs) as the gage record for this storm. Moreover, the three storms that occurred in WY 1990 all were significantly overestimated in peaks relative to the gage record. Additionally, using Seatac's long-term precipitation record raises the simulated peaks for this storm even higher. This is a good example of how distribution of precipitation affects runoff. Seatac recorded 2.83 inches of precipitation for January 9, 1990, whereas Gage 32U recorded 3.36 inches for the same time period (see Figure D-12).

However, Seatac's precipitation was more intense than gage 32U, resulting in 30 cfs greater peak (146 cfs).

The scatter plot in Figure D-13 gives a good representation of the variance in water year 1990. The major outliers, where simulated results were much greater than gage data, are the three storms that correlated poorly during 1990. A regression done on the entire period of record yields an r-squared of 0.74.

Using only average flows incompletely illustrates the quality of the simulation; maximum daily flow rates must be reviewed as well. Hence, Figure D-14 gives the results based on the maximum value recorded and simulated flows per day. When analyzing daily maximum values, one would expect more deviations than daily mean flow rates. This does not seem to be the case (except for January 9, 1990). When analyzing the entire record, daily averages had an r-square of 0.74. Removing the one outlier (January 9, 1990) further improves the variance (i.e. $r^2=0.82$). On the other hand, using Seatac precipitation would result in greater variability on daily maximum flows, especially for the January 9, 1990 storm. In fact, the r-squares for daily averages and maximums (for the same time period) using Seatac precipitation are 0.67 and 0.57, respectively.

Frequencies

Flow frequency analyses were based on peak annual flows using Log Pearson regression. The period of record used starts October 1, 1948, and ends May 30, 1992. In addition to the standard two- through one hundred- year events, average and mean annual flow rates were included. The two land use scenarios, "Future w/" and "Future w/o" correspond to (1) future land use *with* Wetland 24 existing as at present and (2) future land use *without* Wetland 24 (i.e. Kent's reservoir assumed built). The other three catchments assume the same hydraulics for all land use scenarios. Two tables (Table D-16 and Table D-17) show percent increases per catchment relative to two different baseline conditions: fully forested and current, respectively. Figure D-15 shows plots of return frequencies (cumulative) for the four catchments and land-use scenarios. Plot OC2 only shows three land-use scenarios. This is because OC2 is not hydraulically connected to OC1, and as a result, Wetland's 24 existence here is irrelevant.

The greatest increase from current to future without Wetland 24 occurs in catchment OC1 (110 percent based on 25-yr event). This significant increase is largely a result of the loss of Wetland 24, which has an equivalent storage of nearly one inch in OC1. If we assume no loss of Wetland 24 in the future (second future scenario), OC1's 25-year flow event increases 45 percent (only one-third the increase) from current. Runoff increases in OC1 from current to future conditions are moderated by some offsetting factors. First, development does not encroach into the Kent watershed, thereby limiting potential development. Secondly, 80 acres of watershed area is removed, because the reservoir is assumed to be a closed depression. However, the loss of one inch of natural storage overrides any of these moderating factors.

An alternate way to evaluate flow frequencies is to calculate the increase in frequency of an event of a given size. In every catchment, the current 25-year discharge is estimated to

occur between every two and five years in the future. In particular, without Wetland 24 the current 25-yr event would occur more often than every two years. Although the increase in frequency is similar for OC2, the absolute magnitude of flow rates coming out of this subcatchment are very small (4 cfs for the two-year and 10 cfs for the 100-year for current conditions). Future runoff is very similar, ranging from 7 cfs for the 2-year to 11 cfs for the 100-year. Obviously, this is a result of Wetland 46's detention characteristics, current and future.

Table D-21 is a summary of unit area flow frequencies per land type without channel routing (for land type definitions see Table D-4). With the same given area of land type in the model, the unit area flow frequency will be less than the non-routed unit area flow frequencies. The intended use of this table is for reference and to allow further analysis by the reader. For example, applying Table D-21 with Table D-10, Table D-11, and Table D-12, flow frequencies that are non-routed can be computed.

Durational analyses are represented in Figure D-16 and in Tables D-22 through D-37. Also included in Figure D-16 are return flow rate frequencies for current conditions. The duration levels are defined as the percent of total time the flow rate is equal to or exceeds any given flow rate. The duration tables include flow rates, percent time of exceedence, time spent, number of excursions, and average length of excursions. It is noticeable that as development occurs, the duration of low flows decreases substantially. For example, the average duration for a flow rate between 2 and 5 cfs in catchment OC1 drops from 90 hours (forested) to under 25 hours (future w/o wetland) per excursion. This represents a significant drop in base flow condition.

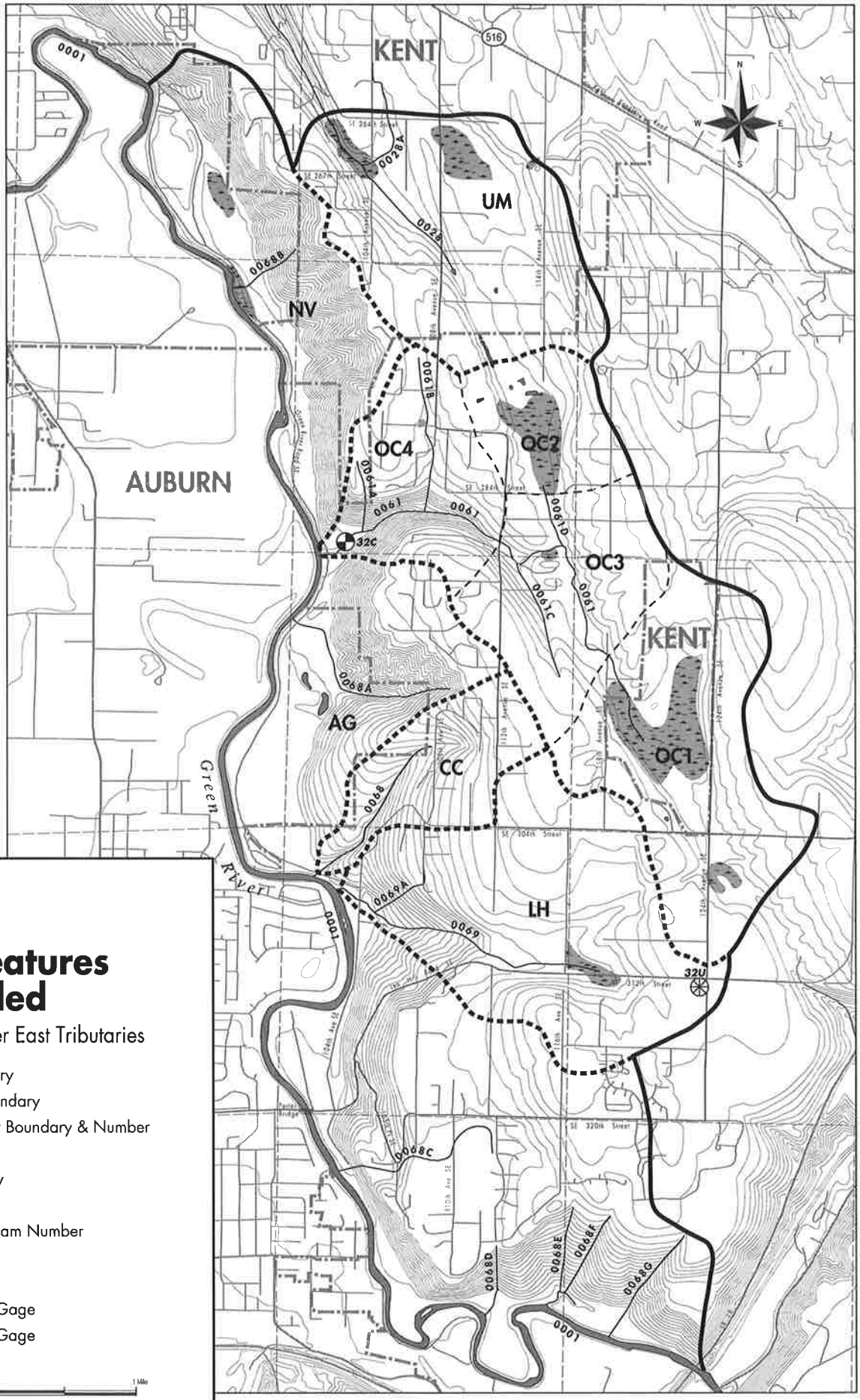


Figure D1

Water Features as Modeled

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- OC3 Subcatchment Boundary & Number
- Wetland
- City Boundary
- Section Line
- 0068C Stream & Stream Number
- River

Gage Sites:

- 32U Precipitation Gage
- 32C Stream Flow Gage

0 1/2 1 Mile

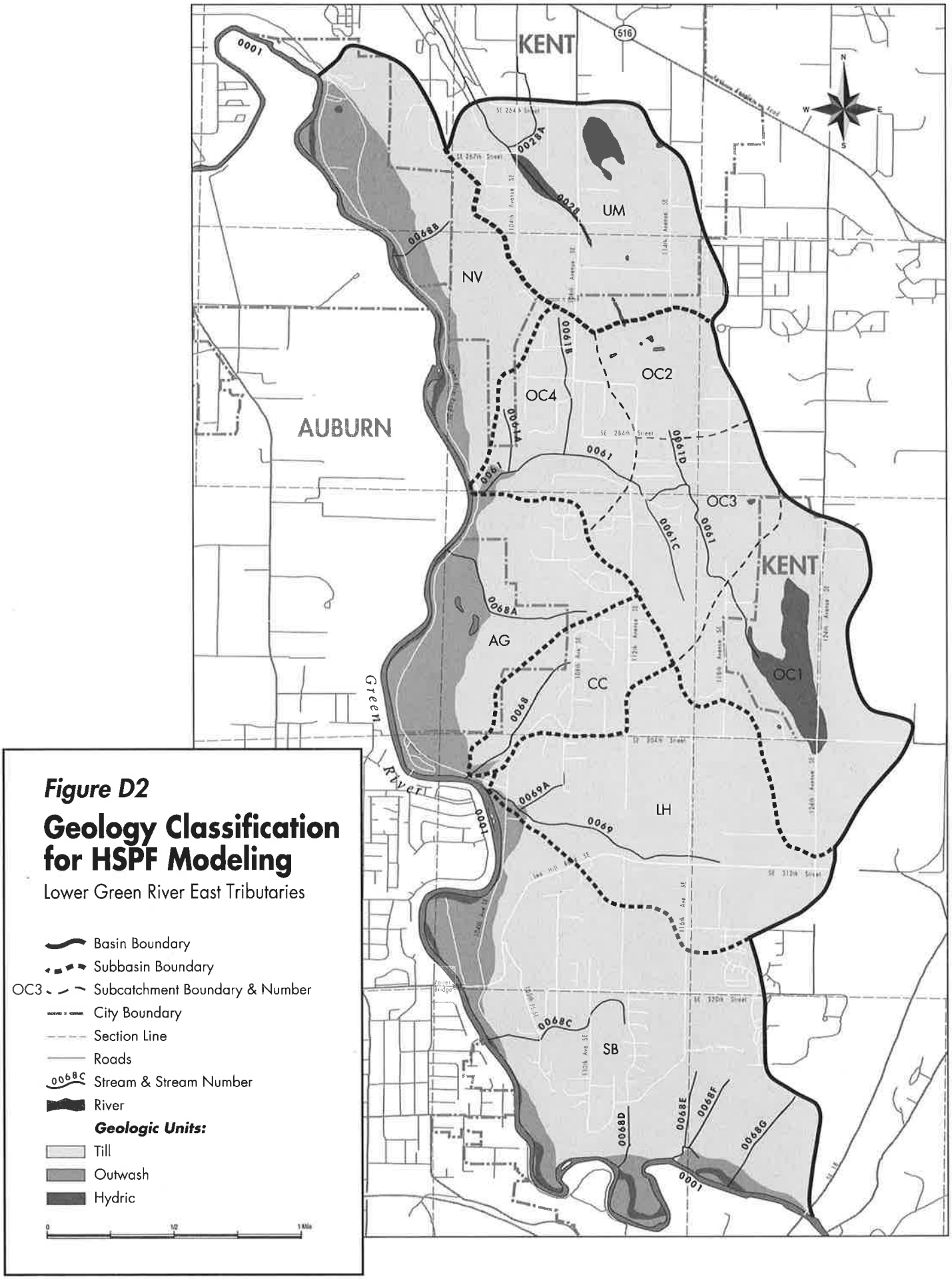


Figure D2

Geology Classification for HSPF Modeling

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- OC3 Subcatchment Boundary & Number
- City Boundary
- Section Line
- Roads
- 0068C Stream & Stream Number
- River

Geologic Units:

- Till
- Outwash
- Hydric

0 1/2 1 Mile

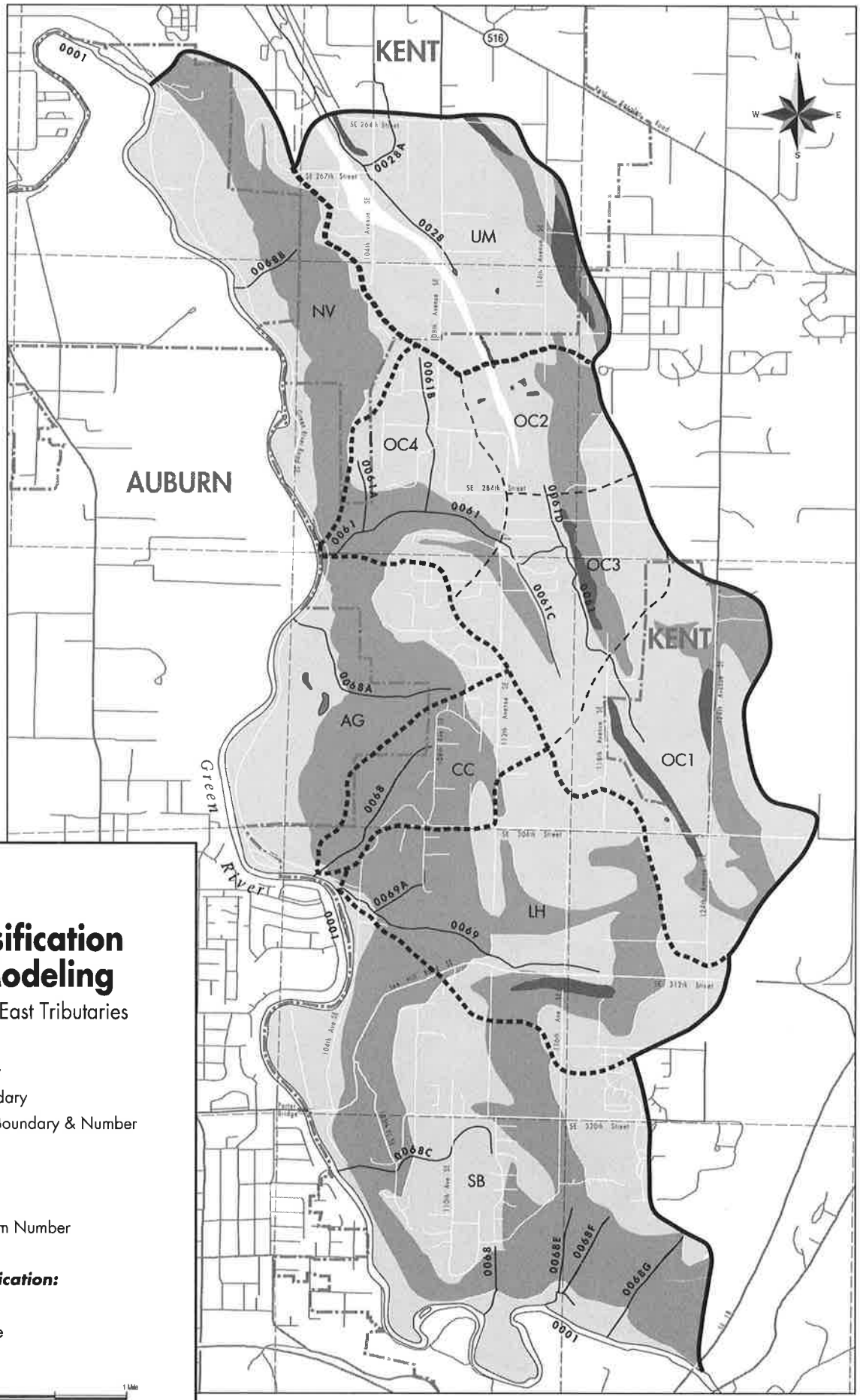


Figure D3

Slope Classification for HSPF Modeling

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- OC1 Subcatchment Boundary & Number
- City Boundary
- Section Line
- Roads
- 0068C Stream & Stream Number
- River

Slope Classification:

- Gentle Slope
- Moderate Slope
- Steep Slope

0 1/2 1 Mile

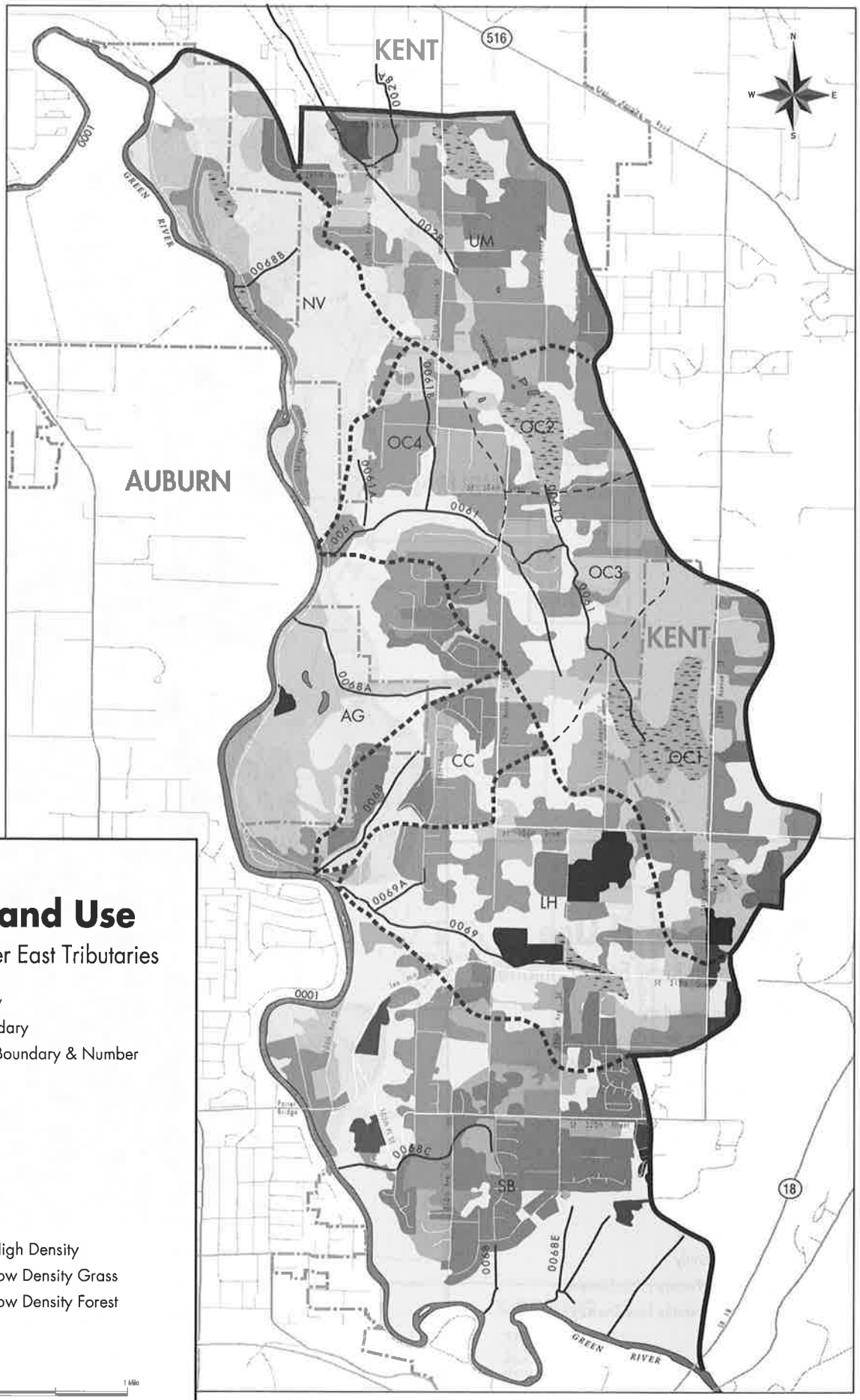


Figure D4

Existing Land Use

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- Subcatchment Boundary & Number
- 0068 Stream
- River/Lake
- City Boundary
- Wetland

- Impervious
- Multifamily
- Single Family High Density
- Single Family Low Density Grass
- Single Family Low Density Forest
- Grass
- Forest

0 1/2 1 Mile

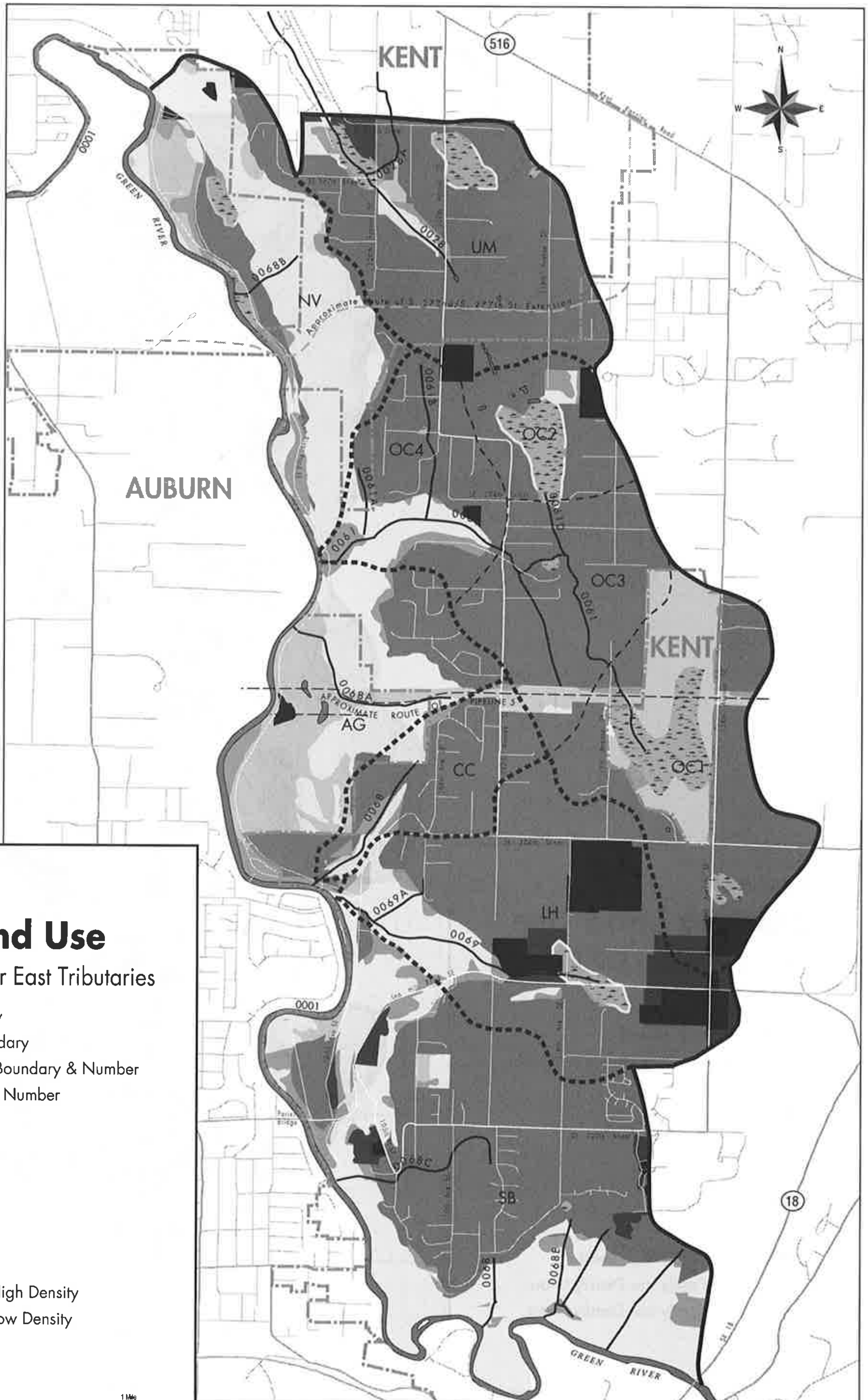


Figure D5

Future Land Use

Lower Green River East Tributaries

- Basin Boundary
- Subbasin Boundary
- CC Subcatchment Boundary & Number
- 0068 Stream/Stream Number
- River/Lake
- City Boundary
- Wetland
- Pipeline
- Impervious
- Multifamily
- Single Family High Density
- Single Family Low Density
- Grass
- Forest

0 1/2 1 Mile

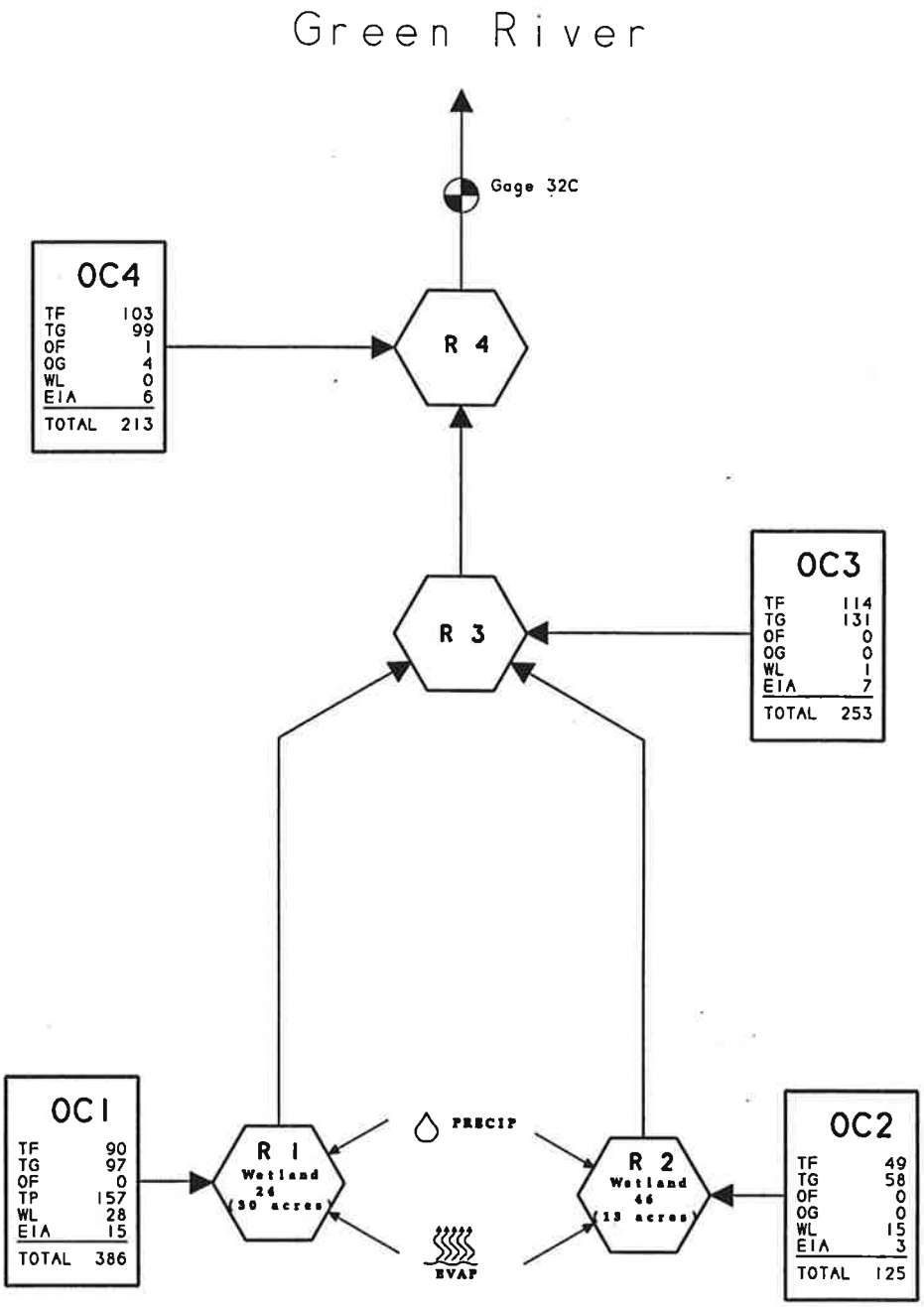


Figure D-6

Olson Creek

HSPF Schematic of UCI file

Current Land use

LEGEND

TF:	Till Forest
TG:	Till Grass
OF:	Outwash Forest
OG:	Outwash Grass
WL:	Wetland & Saturated Soils
TP:	Till Pasture
EIA:	Effective Impervious Area
R 1:	Rchres number
C 1:	Copy function
T7:	Catchment name
⊕	Stream gage

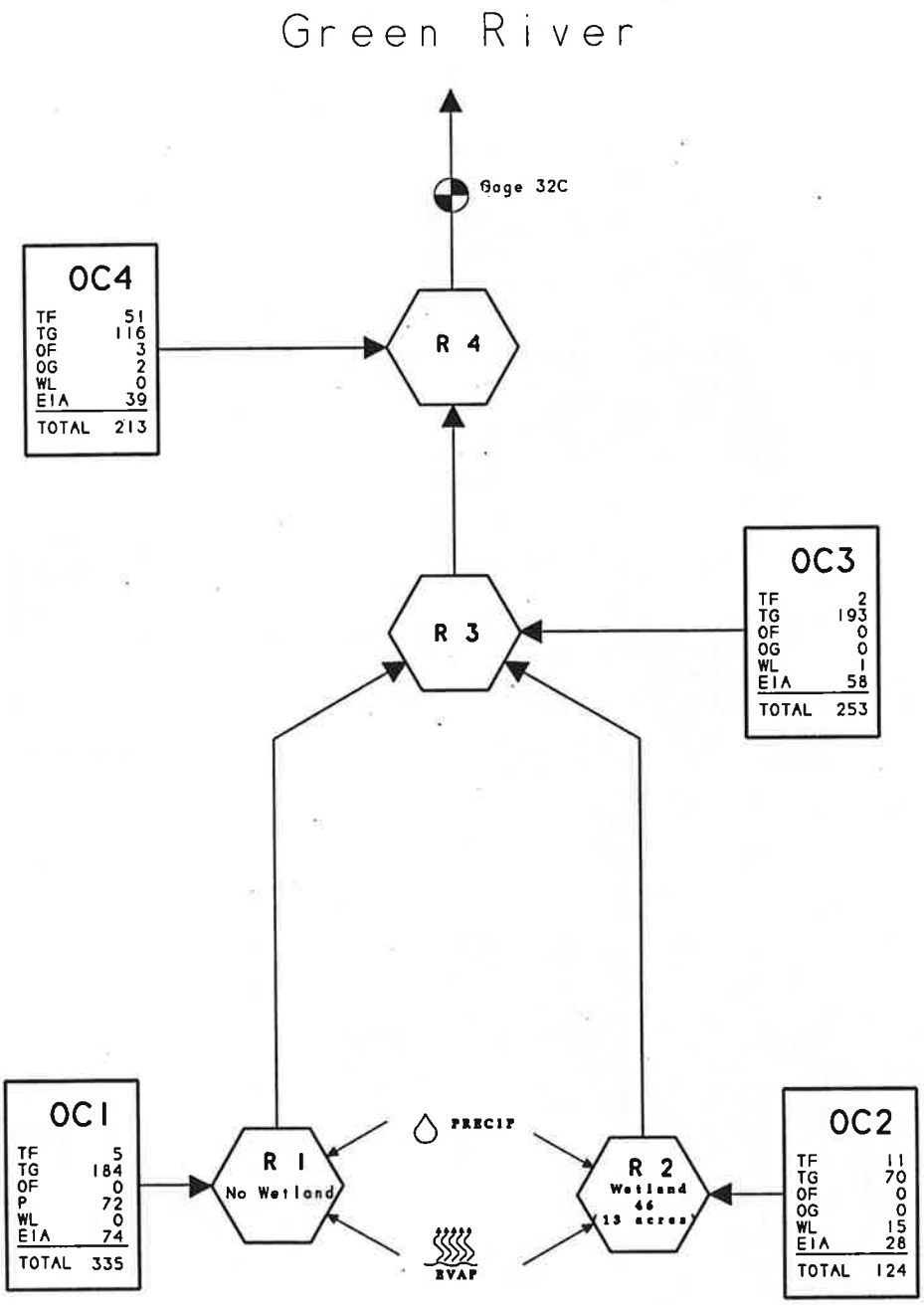


Figure D-7

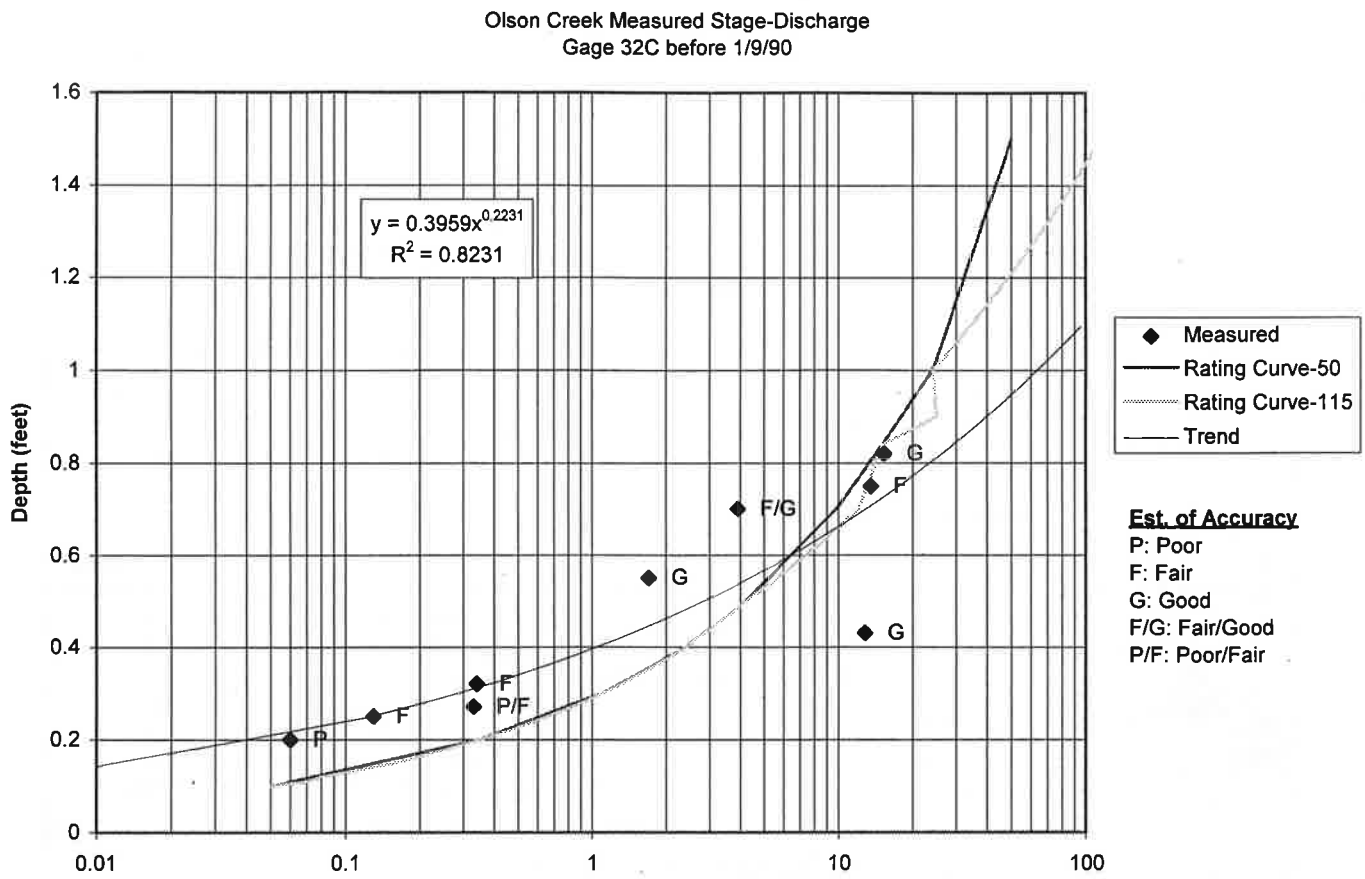
Olson Creek

HSPF Schematic of UCI file

Future Land Use

LEGEND

TF:	Till Forest
TG:	Till Grass
OF:	Outwash Forest
OG:	Outwash Grass
WL:	Wetland & Saturated Soils
EIA:	Effective Impervious Area
R 1:	Reaches number
C 1:	Copy function
T7:	Catchment name
⊗	Stream gage



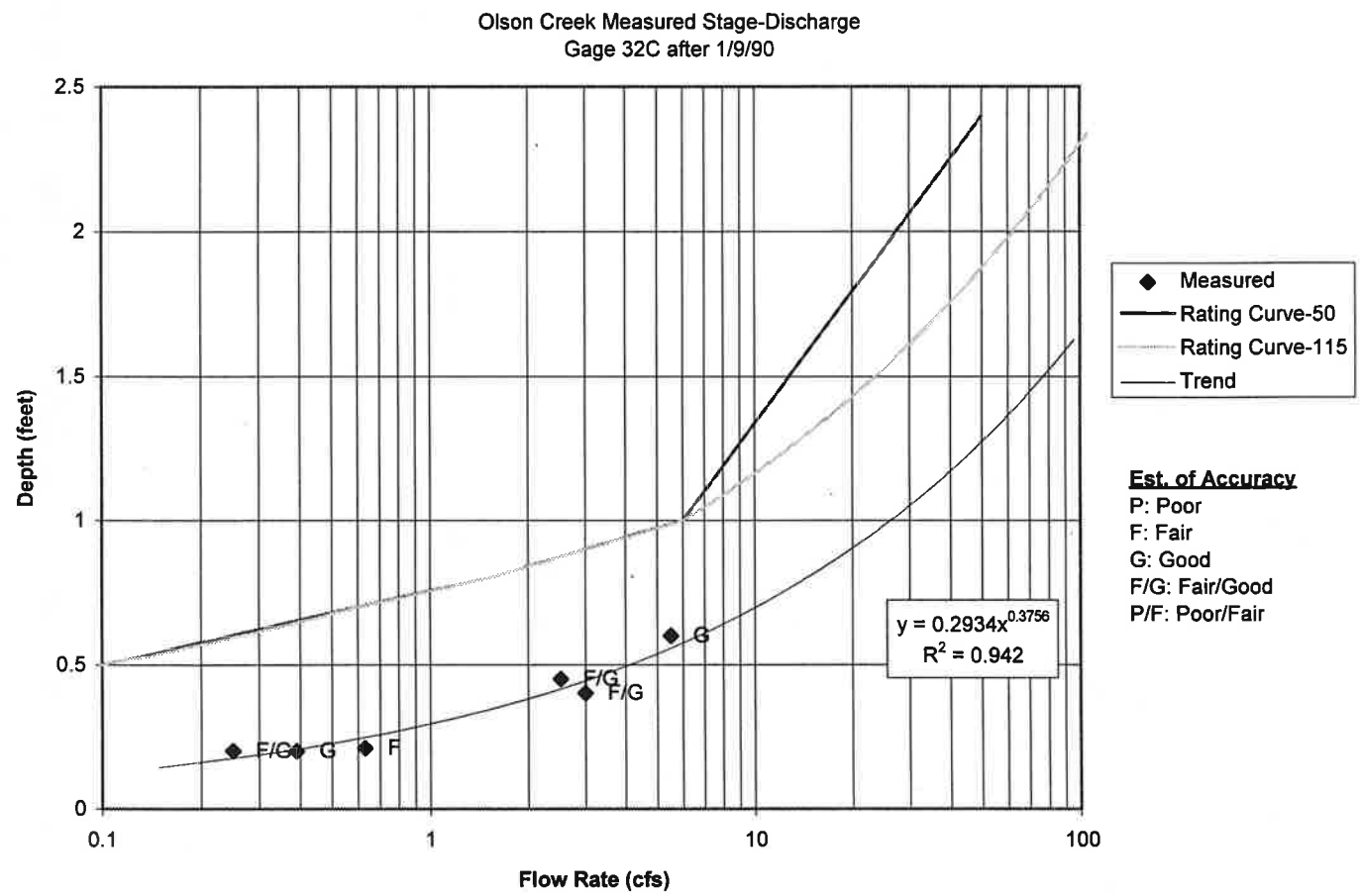


Figure D-8. Measured Stage-Discharge for Gage 32C.

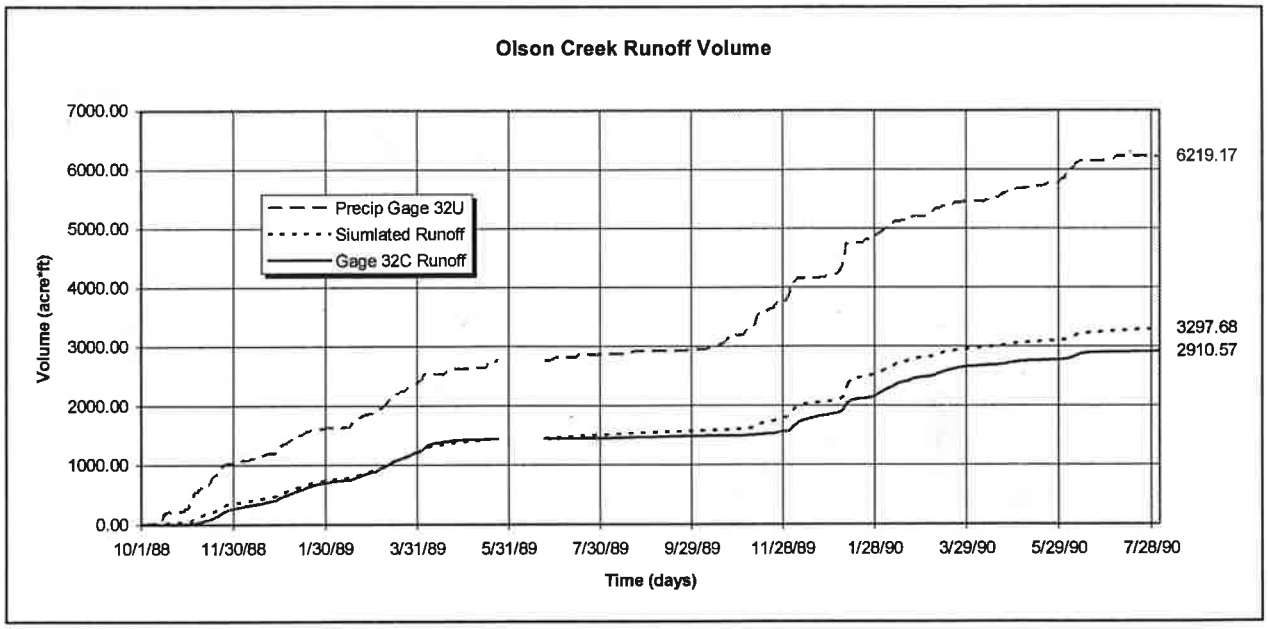
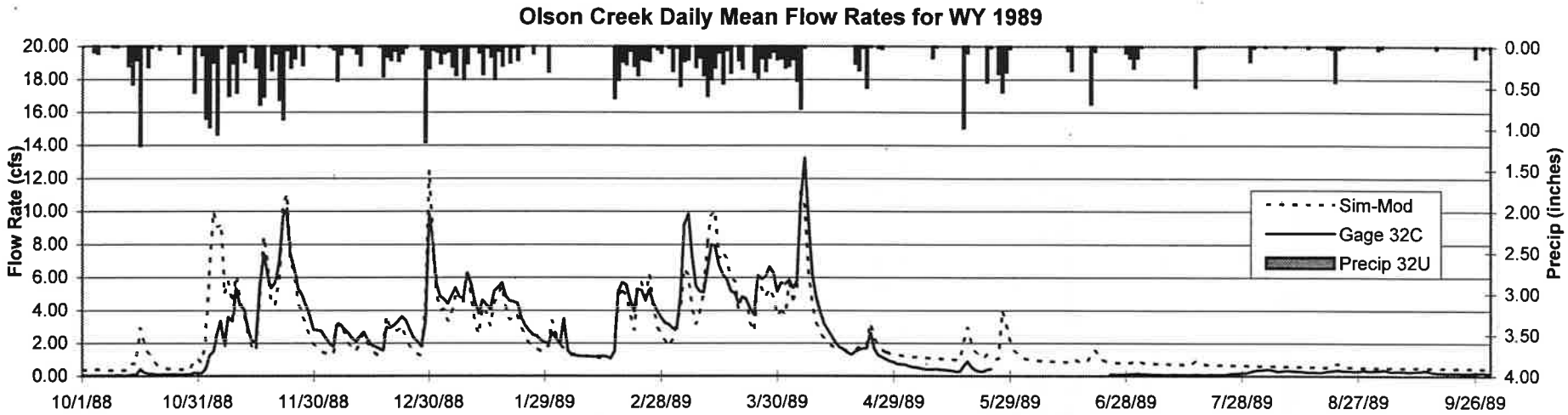
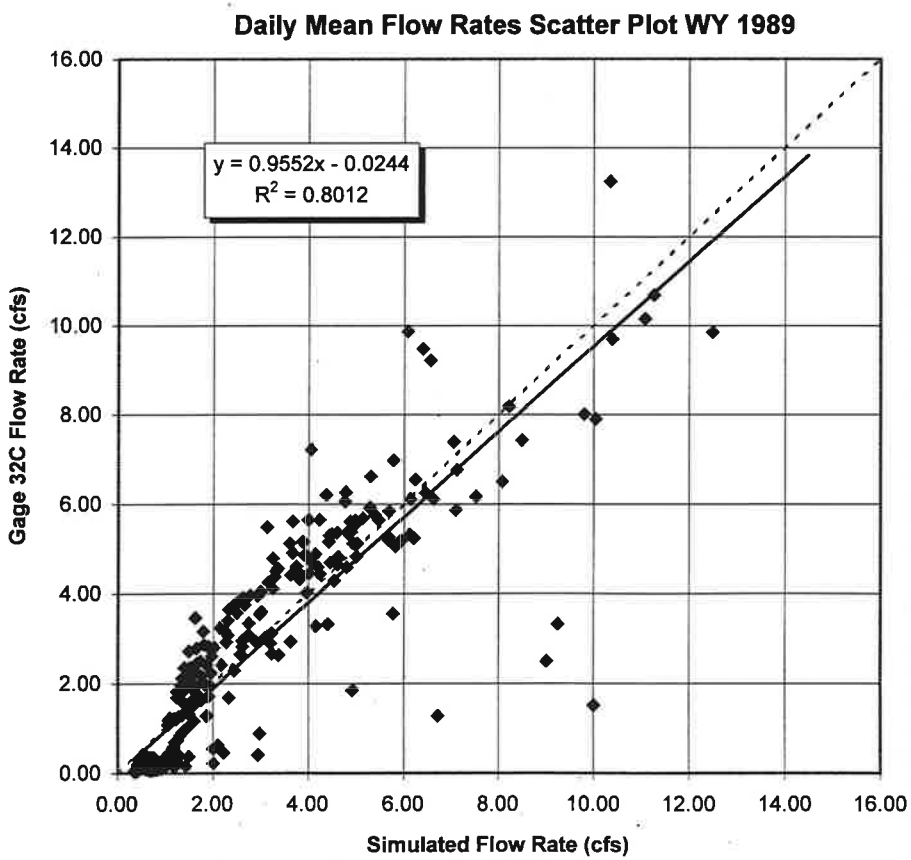


Figure D-9. Volume Runoff for 10/1/88 - 8/3/90





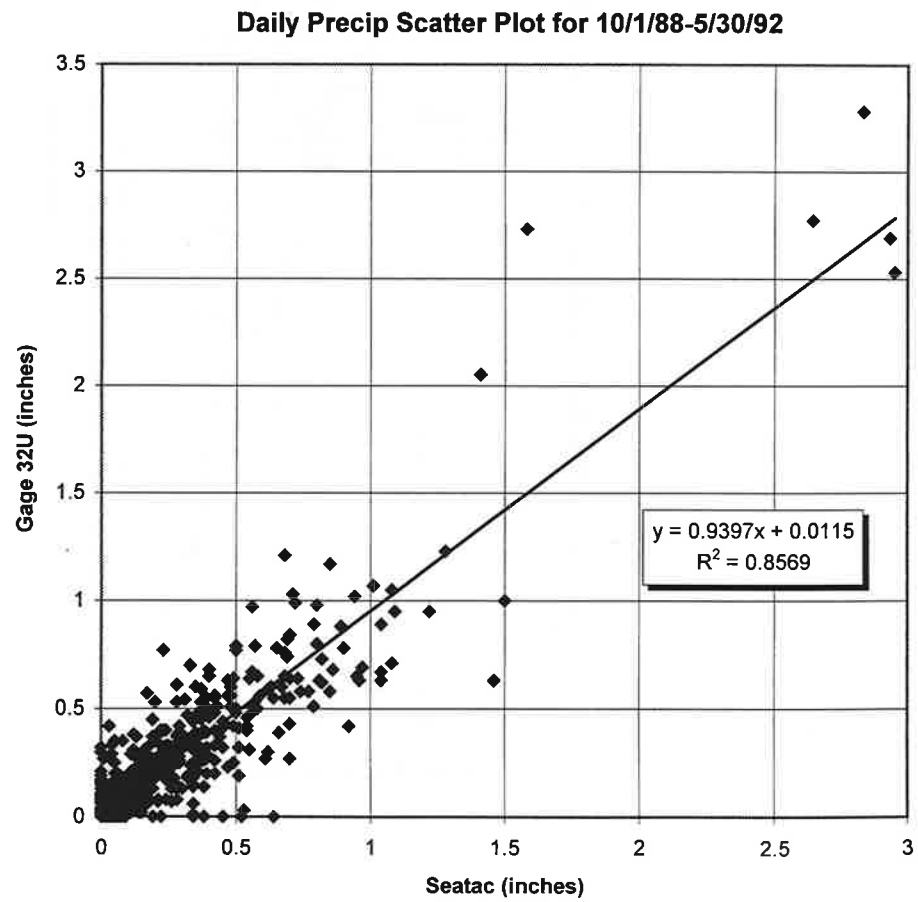


Figure D-10. Daily Mean Flow Rates for WY 1989

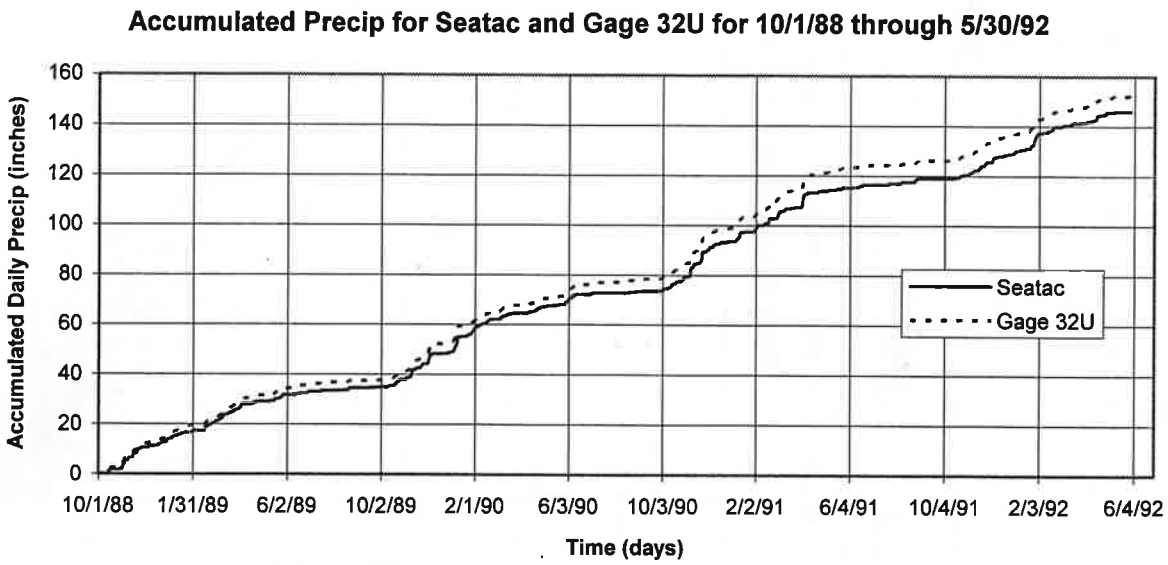


Figure D-11. Accumulated Precip for Seatac and Gage 32U

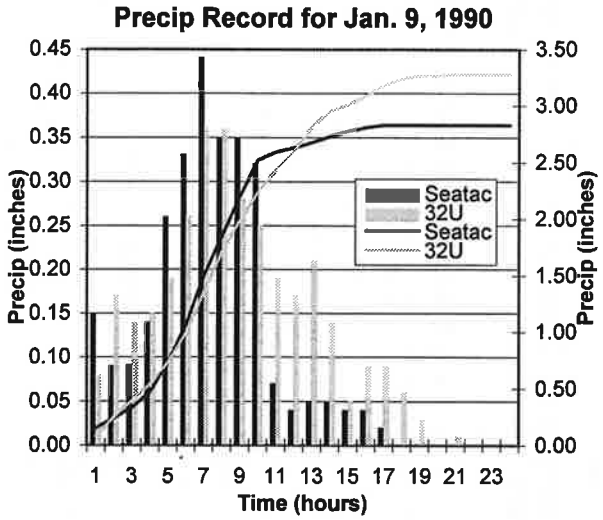


Figure D-12. Precipitation for Jan. 9, 1990

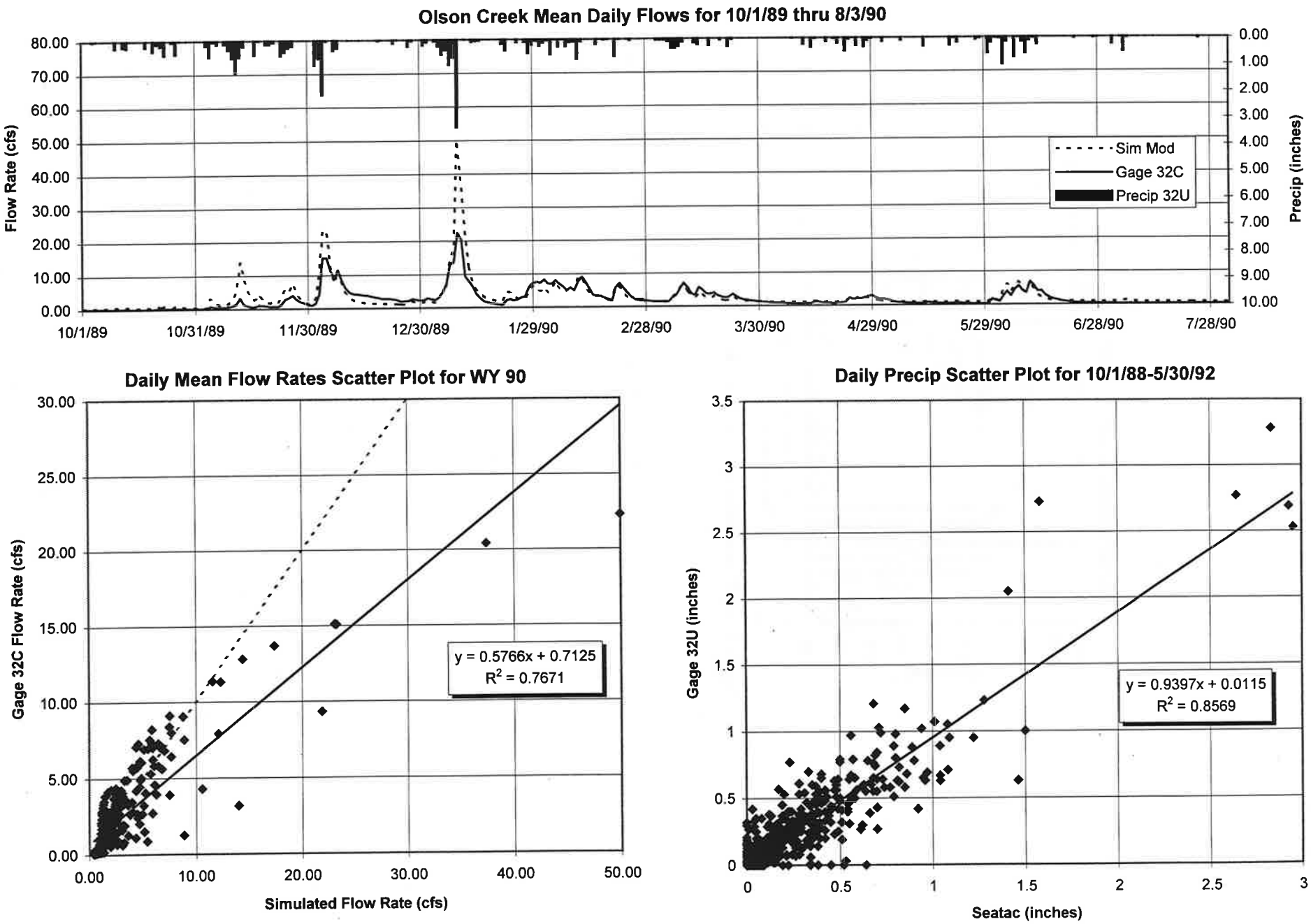
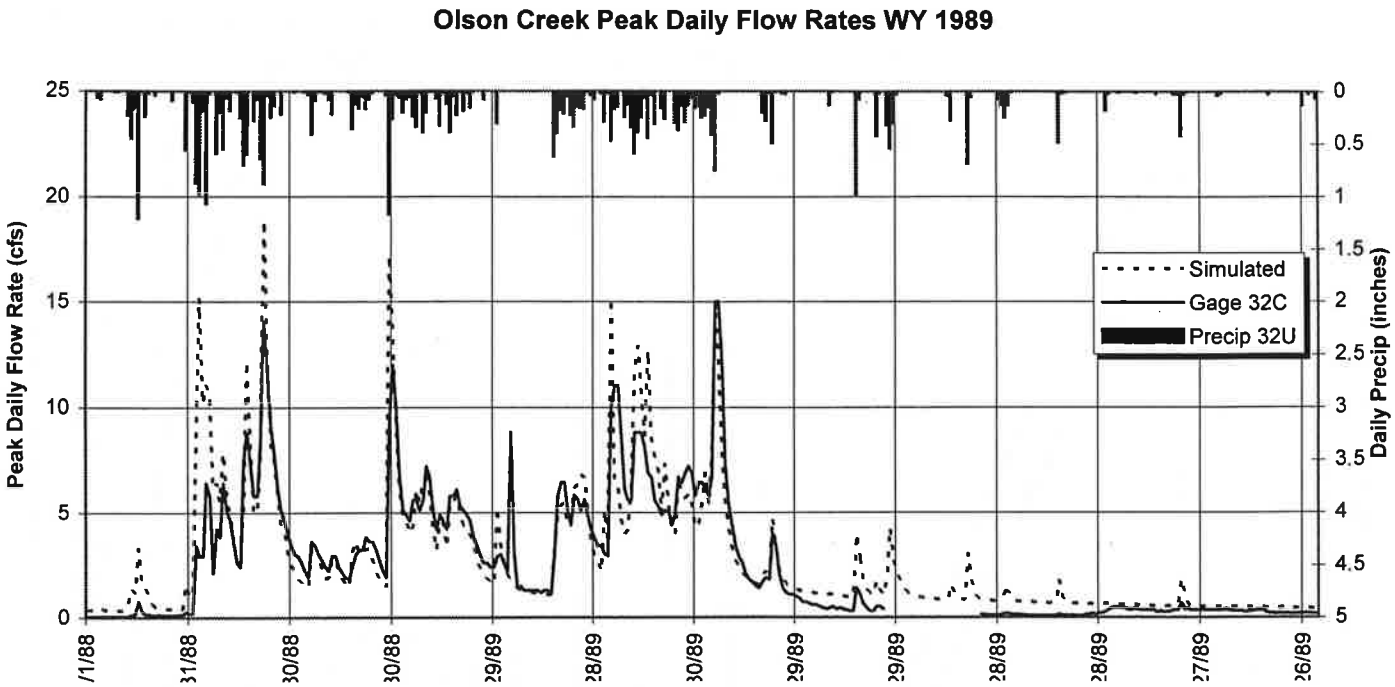
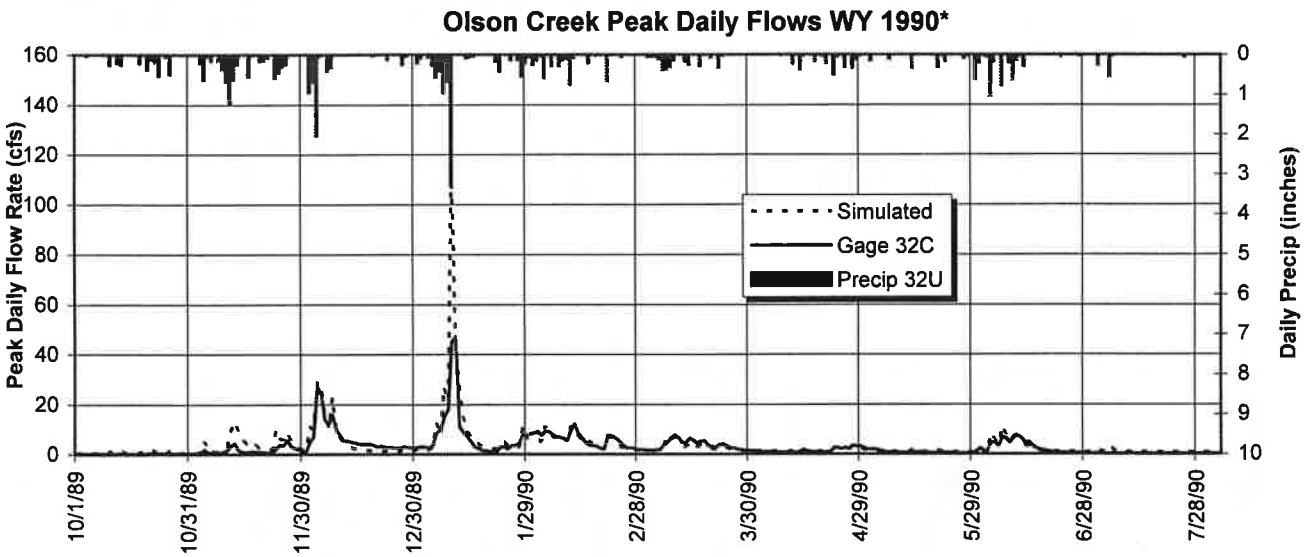


Figure D-13. Daily Mean Flow Rates for WY1990





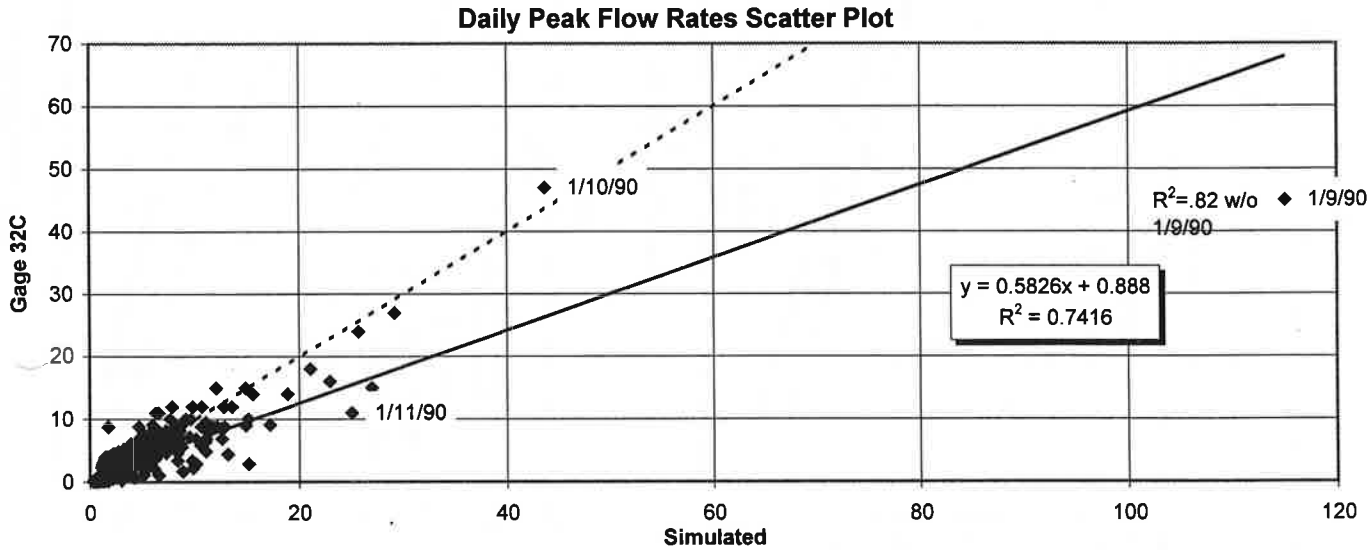


Figure D-14. Peak Daily Flow Rates

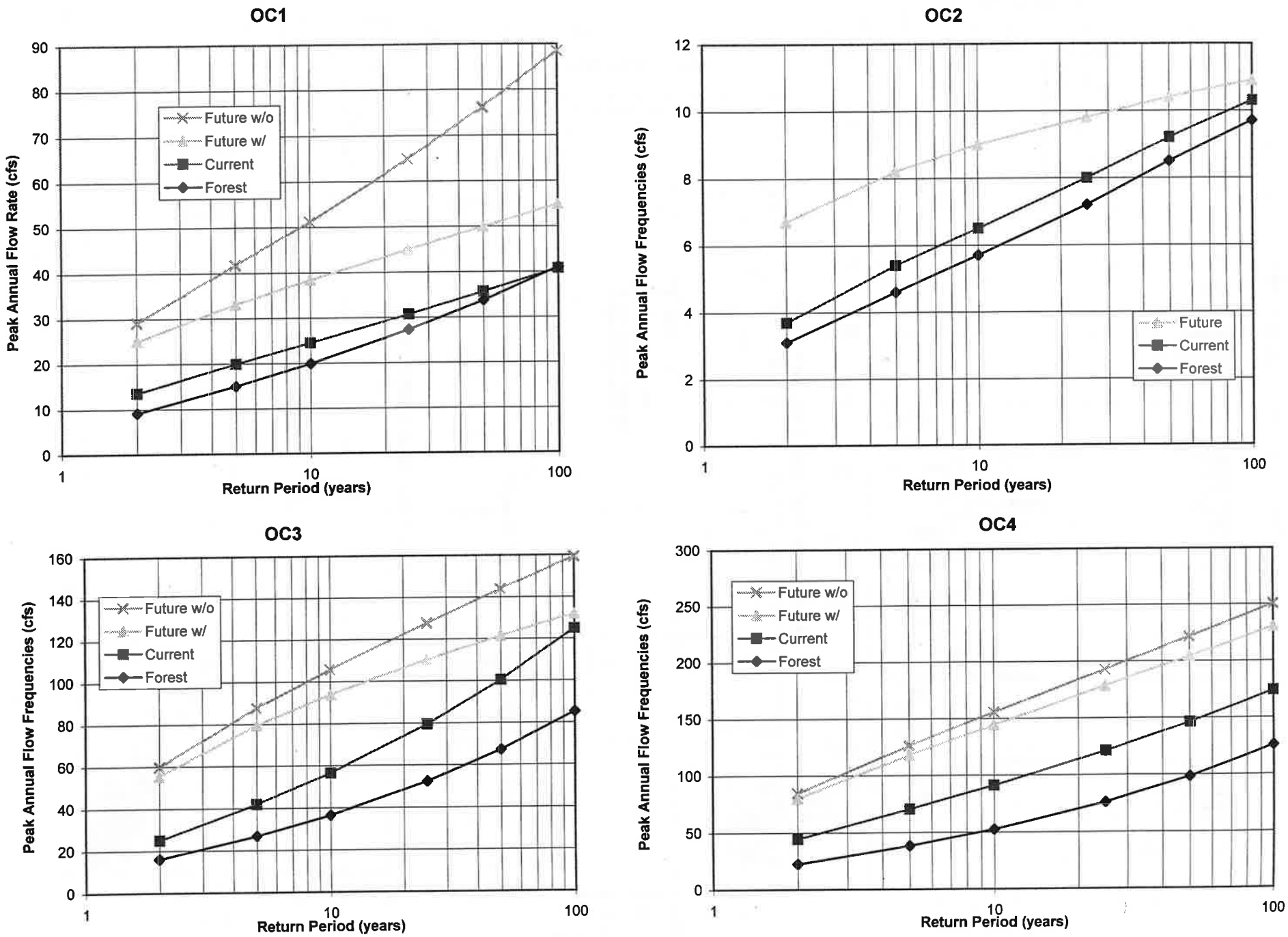


Figure D-15. Olson Creek Flow Frequencies

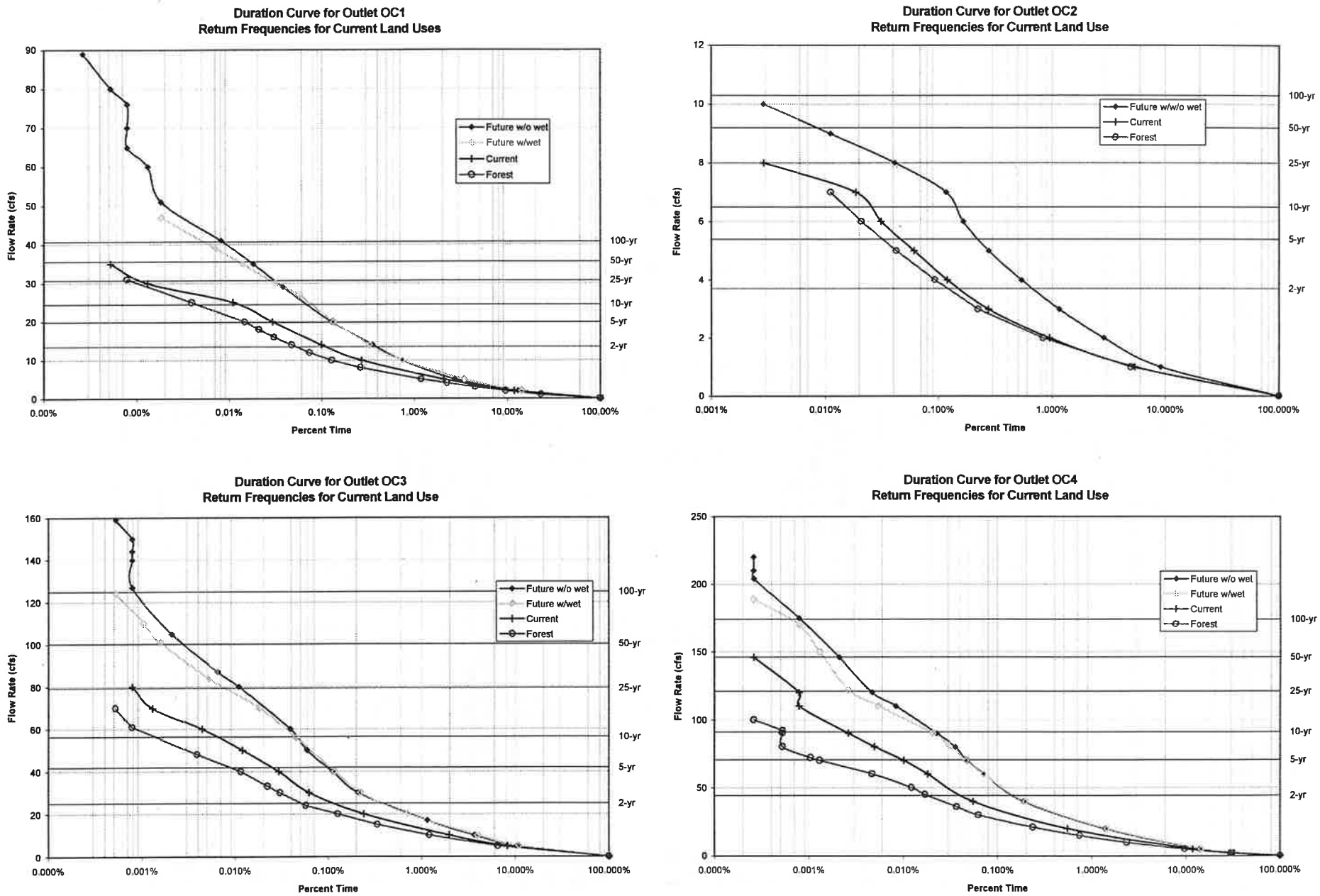


Figure D-16. Olson Creek Duration Curves

Table D-1. USGS Regional Parameters

		USGS Regional Parameters for HSPF						
		PWAT-PARAM2						
Land Type	*Perlnd #*	*FOREST*	*LZSN*	*INFILT*	*LSUR*	*SLSUR*	*KVARY*	*AGWRC*
TFF	11	0.75	4.5	0.08	400	0.050	0.5	0.996
TFM	15	0.75	4.5	0.08	400	0.100	0.5	0.996
TFS	19	0.75	4.5	0.08	200	0.200	0.5	0.996
TGF	21	0.05	4.5	0.03	400	0.050	0.5	0.996
TGM	25	0.05	4.5	0.03	400	0.100	0.5	0.996
TGS	29	0.05	4.5	0.03	200	0.200	0.5	0.996
OF	31	0.75	5.0	2.00	400	0.050	0.3	0.996
OG	41	0.05	5.0	0.80	400	0.050	0.3	0.996
WET	51	0.75	4.0	2.00	100	0.001	0.5	0.996
TP	74	0.75	4.5	0.06	400	0.100	0.5	0.996
OP	80	0.75	5.0	1.40	400	0.050	0.3	0.996

Table D-2. USGS Regional Parameters (cont'd)

		USGS Regional Parameters for HSPF (cont'd)				
		PWAT-PARAM3				
Land Type	*Perlnd #*	*INFEXP*	*INFILD*	*DEEPFR*	*BASETP*	*AGWETP*
TFF	11	3.5	2	0	0	0
TFM	15	2.0	2	0	0	0
TFS	19	1.5	2	0	0	0
TGF	21	3.5	2	0	0	0
TGM	25	2.0	2	0	0	0
TGS	29	1.5	2	0	0	0
OF	31	2.0	2	0	0	0
OG	41	2.0	2	0	0	0
WET	51	10.0	2	0	0	0.7
TP	74	2.0	2	0	0	0
OP	80	2.0	2	0	0	0

Table D-3. USGS Regional Parameters (cont'd)

		USGS Regional Parameters for HSPF (cont'd)					
		PWAT-PARAM4					
Land Type	*Perlnd #*	*CEPSC*	*UZSN*	*NSUR*	*INTFW*	*IRC*	*LZETP*
TFF	11	0.2	1.00	0.35	3	0.7	0.70
TFM	15	0.2	0.50	0.35	6	0.5	0.70
TFS	19	0.2	0.30	0.35	7	0.3	0.70
TGF	21	0.1	0.50	0.25	3	0.7	0.25
TGM	25	0.1	0.25	0.25	6	0.5	0.25
TGS	29	0.1	0.15	0.25	7	0.3	0.25
OF	31	0.2	0.50	0.35	0	0.7	0.70
OG	41	0.1	0.50	0.25	0	0.7	0.25
WET	51	0.1	3.00	0.50	1	0.7	0.80
TP	74	0.1	0.28	0.25	6	0.5	0.25
OP	80	0.1	0.50	0.25	0	0.7	0.25

Table D-4. Perlnd (land type) definition

Perlnd #	Soil	Slope	Cover	Short Form
11	till	flat	forest	TFF
15	till	moderate	forest	TMF
17	till	steep	forest	TSF
21	till	flat	grass	TFG
25	till	moderate	grass	TMG
27	till	steep	grass	TSG
31	outwash	all	forest	OF
41	outwash	all	grass	OG
51	any	all	wetland	Wet
74	till	all	pasture	TP
81	outwash	all	pasture	OP
11*	any	all	impervious	Imp

* Implnd operation number

Table D-5. Soils Classification

SCS Classification	*Name*	*HSPF*
Qlc		HYDRIC
Qlm		HYDRIC
Qlp		HYDRIC
Qls		HYDRIC
Qw	Wetland Deposits	HYDRIC
water		HYDRIC
af	Alluvial fan	OUTWASH
Qag	Alderwood gravel	OUTWASH
Qas	Alluvium Sand	OUTWASH
Qaw	Alluvium Waste	OUTWASH
Qf	Stream Alluvium	OUTWASH
Qva	Vashon Advance	OUTWASH
Qvr_2	Vashon Recession	OUTWASH
Qgt		TILL
Qid		TILL
Qit		TILL
Qiv		TILL
Qmc		TILL
Qmw	Mass Waste	TILL
Qpf	Pre-Fraiser	TILL
Qpv		TILL
Qpy		TILL
Qsa		TILL
Qss	Sandstone	TILL
Qvt	Vashon Till	TILL

Table D-6. Modeling assumptions used for converting land use to perlnds

Land Use	*Density/Zoning*	*% EIA*	*% Grass*	*% Forest*	*% Pasture*	*% Wetland*
Impervious/Commercial	Commercial	85	15	0	0	0
Multifamily	7-30 du/acre	48	52	0	0	0
High	3-7 du/acre	25	75	0	0	0
Medium	1-3 du/acre	10	90	0	0	0
Low Density(Future LU)	<1 du/acre	4	48	48	0	0

Table D-6. Modeling assumptions used for converting land use to perlnds

Land Use	*Density/Zoning*	*% EIA*	*% Grass*	*% Forest*	*% Pasture*	*% Wetland*
Low Density-Grass	<1 du/acre	4	96	0	0	0
Low Density-Forest	<1 du/acre	4	0	96	0	0
Grass	N/A	0	100	0	0	0
Pasture	N/A	0	0	0	100	0
Forest	N/A	0	0	100	0	0
Wetland	N/A	0	0	0	0	100

Table D-7. Olson Creek Current Land Use (1992)

Olson Creek Current Land Use

Land Use	*OC1 (acres)*	*Cumulative (acres)*	*OC2 (acres)*	*Cumulative (acres)*	*OC3 (acres)*	*Cumulative (acres)*	*OC4 (acres)*	*Total (acres)*
I	6.18	*6.18*	0.00	*0.00*	0.00	*6.18*	0.00	6.18
MF	2.47	*2.47*	0.00	*0.00*	0.00	*2.47*	0.00	2.47
SH	14.30	*14.30*	0.00	*0.00*	6.20	*20.49*	1.74	22.23
LG	88.01	*88.01*	55.25	*55.25*	79.46	*222.72*	86.37	309.09
LF	44.57	*44.57*	16.66	*16.66*	50.72	*111.95*	48.03	159.98
G	0.00	*0.00*	4.77	*4.77*	50.46	*55.23*	18.94	74.17
F	46.91	*46.91*	33.13	*33.13*	65.35	*145.39*	57.21	202.60
P	156.72	*156.72*	0.00	*0.00*	0.00	*156.72*	0.00	156.72
W	28.04	*28.04*	15.28	*15.28*	1.47	*44.79*	0.29	45.08
Total	386.20	*386.20*	125.09	*125.09*	253.67	*765.06*	212.57	977.52

Table D-8. Future Land Use (with Kent Reservoir) assumed for Olson Creek

Olson Creek Future Land Use - w/Kent Reservoir (w/o Wetland 24)

Land Use	*OC1 (acres)*	*Cumulative (acres)*	*OC2 (acres)*	*Cumulative (acres)*	*OC3 (acres)*	*Cumulative (acres)*	*OC4 (acres)*	*Total (acres)*
I	12.14	*12.14*	7.23	*7.23*	0.00	*19.37*	2.60	21.98
MF	12.56	*12.56*	0.00	*0.00*	0.00	*12.56*	0.00	12.56
SH	229.06	*229.06*	88.09	*88.09*	231.21	*548.37*	145.75	694.12
SL	8.12	*8.12*	6.92	*6.92*	0.74	*15.79*	18.38	34.16
G	0.00	*0.00*	0.18	*0.18*	18.74	*18.92*	0.00	18.92
F	1.00	*1.00*	7.38	*7.38*	1.50	*9.88*	45.38	55.26
P	72.06	*72.06*	0.00	*0.00*	0.00	*72.06*	0.00	72.06
W	0.00	*0.00*	15.28	*15.28*	1.47	*16.75*	0.45	17.20
Total	334.94	*334.94*	125.08	*125.08*	253.66	*713.70*	212.57	926.27

Table D-9. Forested Conditions Assumed for Olson Creek

Olson Creek Forested Conditions Land Use

Land Use	*OC1 (acres)*	*Cumulative (acres)*	*OC2 (acres)*	*Cumulative (acres)*	*OC3 (acres)*	*Cumulative (acres)*	*OC4 (acres)*	*Total (acres)*
F	358.27	358.27	109.8	109.8	252.19	720.26	212.28	932.54
W	28.04	28.04	15.28	15.28	1.47	44.79	0.29	45.08
Total	386.31	386.31	125.08	125.08	253.66	765.05	212.57	977.62

Table D-10. Tabulation of Perlnds Used for Current Land Use in HSPF Model

Olson Creek Current Land Use Perlnds

Catchment	*OC1 (acres)*	*Cumulative (acres)*	*OC2 (acres)*	*Cumulative (acres)*	*OC3 (acres)*	*Cumulative (acres)*	*OC4 (acres)*	*Total (acres)*
PERLND 11	76.70	*76.70*	30.64	*30.64*	85.53	*192.87*	49.75	242.62
PERLND 15	11.45	*11.45*	15.45	*15.45*	10.36	*37.26*	0.20	37.46
PERLND 19	1.56	*1.56*	3.03	*3.03*	18.16	*22.75*	52.73	75.48
PERLND 21	52.41	*52.41*	36.10	*36.10*	109.20	*197.71*	91.44	289.16
PERLND 25	42.60	*42.60*	20.48	*20.48*	14.92	*78.00*	2.03	80.03
PERLND 29	1.50	*1.50*	1.22	*1.22*	7.26	*9.98*	5.23	15.21
PERLND 31	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	0.63	0.63
PERLND 41	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	4.46	4.46
PERLND 51	28.04	*28.04*	15.28	*15.28*	1.47	*44.79*	0.29	45.08
PERLND 74	156.72	*156.72*	0.00	*0.00*	0.00	*156.72*	0.00	156.72
IMPLND 11	15.34	*15.34*	2.88	*2.88*	6.76	*24.98*	5.81	30.79
Total	386.32	*386.32*	125.08	*125.08*	253.67	*765.07*	212.57	977.64

Table D-11. Tabulations of Perlnds Use for Future Land Use (with Kent Reservoir)

Olson Creek Future Land Use Perlnds - w/Kent Reservoir (w/o Wetland 24)

Catchment	*OC1 (acres)*	*Cumulative (acres)*	*OC2 (acres)*	*Cumulative (acres)*	*OC3 (acres)*	*Cumulative (acres)*	*OC4 (acres)*	*Total (acres)*
PERLND11	3.24	*3.24*	2.45	*2.45*	1.77	*7.45*	4.26	11.71
PERLND15	0.68	*0.68*	7.82	*7.82*	0.08	*8.58*	1.21	9.80
PERLND19	0.98	*0.98*	0.43	*0.43*	0.00	*1.42*	45.88	47.29
PERLND21	124.23	*124.23*	49.50	*49.50*	153.87	*327.60*	105.16	432.76
PERLND25	56.97	*56.97*	17.15	*17.15*	19.37	*93.49*	1.01	94.51
PERLND29	3.03	*3.03*	2.92	*2.92*	19.26	*25.21*	9.73	34.94
PERLND31	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	2.86	2.86
PERLND41	0.00	*0.00*	0.00	*0.00*	0.00	*0.00*	2.23	2.23
PERLND51	0.00	*0.00*	15.28	*15.28*	1.47	*16.75*	0.45	17.20
PERLND74	72.06	*72.06*	0.00	*0.00*	0.00	*72.06*	0.00	72.06
IMPLND11	73.94	*73.94*	28.44	*28.44*	57.83	*160.22*	39.39	199.61
Total	335.13	*335.13*	124.00	*124.00*	253.66	*712.79*	212.18	924.97

Table D-12. Tabulation of Perlnds Used for Forested Conditions

Olson Creek Forested Conditions Land Use Perlnds

Catchment	*OC1 (acres)*	*Cumulative (acres)*	*OC2 (acres)*	*Cumulative (acres)*	*OC3 (acres)*	*Cumulative (acres)*	*OC4 (acres)*	*Total (acres)*
PERLND11	240.96	240.96	66.74	66.74	194.73	502.43	141.19	643.62
PERLND15	101.68	101.68	38.81	38.81	32.04	172.53	8.04	180.57
PERLND19	15.63	15.63	4.25	4.25	25.42	45.3	57.96	103.26
PERLND31	0	0	0	0	0	0	5.09	5.09
PERLND51	28.04	28.04	15.28	15.28	1.47	44.79	0.29	45.08
Total	386.31	386.31	125.08	125.08	253.66	765.05	212.57	977.62

Table D-13. Seasonal Runoff WY 1989		
	Seasonal Volume Runoff (acre*feet)	
WY 1989	Oct-Mar	Apr-Sept
Precip	2375	569
Simulated	1201	365
Gage 32C	1210	270

Table D-14. Seasonal Runoff WY 1990*		
	Seasonal Volume Runoff (acre*feet)	
WY 1990*	Oct-Mar	Apr-Aug
Precip	2507	768
Simulated	1394	337
Gage 32C	1177	253

Table D-15. Olson Creek Flow Frequencies

Land Use	Catchment	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	2-100 avg	Mean Ann.
		Olson Creek Flow Frequencies							
Forest	OC1	9	15	20	27	34	41	24	0.82
Current	OC1	14	20	25	31	36	41	27	0.97
Future w/	OC1	25	33	38	45	50	55	41	1.07
Future w/o	OC1	29	42	51	65	76	89	59	0.96
Forest	OC2	3	5	6	7	9	10	6	0.32
Current	OC2	4	5	7	8	9	10	7	0.35
Future w/	OC2	7	8	9	10	10	11	9	0.41
Future w/o	OC2	7	8	9	10	10	11	9	0.41
Forest	OC3	16	27	36	52	67	85	47	1.68
Current	OC3	25	42	56	79	100	125	71	1.93
Future w/	OC3	55	79	94	110	122	132	99	2.20
Future w/o	OC3	60	88	106	128	144	159	114	2.09
Forest	OC4	23	38	53	76	98	126	69	2.52
Current	OC4	44	71	91	121	146	174	108	2.84
Future w/	OC4	80	118	144	178	204	230	159	3.16
Future w/o	OC4	85	127	155	193	222	251	172	3.05

Table D-16. Olson Creek Percent Increase from Forest Conditions

Land Use	Catchment	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	2-100 avg	Mean Ann.
		Olson Creek Percent Increase from Forest Conditions							
Current	OC1	48%	33%	23%	12%	6%	-1%	13%	18%
Future w/	OC1	175%	121%	93%	65%	48%	34%	69%	31%
Future w/o	OC1	220%	178%	157%	137%	126%	116%	141%	17%
Current	OC2	19%	17%	14%	11%	8%	6%	11%	10%
Future w/	OC2	116%	78%	58%	36%	22%	12%	42%	30%
Future w/o	OC2	116%	78%	58%	36%	22%	12%	42%	30%
Current	OC3	55%	56%	55%	52%	49%	47%	51%	15%
Future w/	OC3	244%	196%	158%	111%	81%	55%	109%	31%
Future w/o	OC3	271%	227%	190%	145%	114%	87%	141%	25%
Current	OC4	96%	84%	74%	59%	48%	38%	56%	12%
Future w/	OC4	254%	209%	175%	135%	107%	83%	131%	25%
Future w/o	OC4	274%	230%	196%	154%	125%	99%	149%	21%

Table D-17. Olson Creek Percent Increase from Current Conditions

Land Use	Catchment	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	2-100 avg	Mean Ann.
		Olson Creek Percent Increase from Current Conditions							
Future w/	OC1	85%	66%	57%	47%	40%	35%	49%	11%
Future w/o	OC1	116%	110%	109%	111%	114%	117%	113%	-1%
Future w/	OC2	81%	52%	38%	23%	13%	6%	28%	18%
Future w/o	OC2	81%	52%	38%	23%	13%	6%	28%	18%
Future w/	OC3	122%	89%	66%	39%	21%	6%	38%	14%
Future w/o	OC3	139%	109%	87%	61%	43%	28%	60%	8%
Future w/	OC4	80%	68%	59%	47%	40%	32%	48%	11%
Future w/o	OC4	91%	79%	71%	60%	52%	44%	59%	8%

Table D-18. Olson Creek Flow Frequencies cfs/acre

Land Use	Catchment	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	2-100 avg
		Olson Creek Flow Frequencies cfs/acre						
Forest	OC1	0.024	0.039	0.052	0.072	0.088	0.108	0.064
Current	OC1	0.035	0.052	0.064	0.081	0.093	0.107	0.072
Future w/	OC1	0.066	0.087	0.101	0.118	0.131	0.144	0.108
Future w/o	OC1	0.076	0.109	0.134	0.170	0.200	0.232	0.154
Forest	OC2	0.025	0.037	0.046	0.058	0.068	0.078	0.052
Current	OC2	0.030	0.043	0.052	0.064	0.074	0.082	0.057
Future w/	OC2	0.054	0.066	0.072	0.078	0.083	0.087	0.073
Future w/o	OC2	0.054	0.066	0.072	0.078	0.083	0.087	0.073
Forest	OC3	0.021	0.035	0.048	0.069	0.088	0.112	0.062
Current	OC3	0.033	0.055	0.074	0.104	0.132	0.164	0.094
Future w/	OC3	0.073	0.104	0.123	0.145	0.160	0.174	0.130
Future w/o	OC3	0.079	0.115	0.139	0.168	0.189	0.210	0.150
Forest	OC4	0.023	0.039	0.054	0.078	0.101	0.129	0.071
Current	OC4	0.046	0.073	0.094	0.124	0.150	0.179	0.111
Future w/	OC4	0.082	0.122	0.149	0.183	0.210	0.237	0.164
Future w/o	OC4	0.087	0.130	0.160	0.199	0.228	0.258	0.177

Table D-19. Olson Creek Flow Frequencies- Not Accumulated

Land Use	Catchment	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	2-100 avg
		Olson Creek Flow Frequencies- Not Accumulated						
Forest	OC1	9	15	20	27	34	41	24
Current	OC1	14	20	25	31	36	41	27
Future w/	OC1	25	33	38	45	50	55	41
Future w/o	OC1	33	45	53	65	74	85	59
Forest	OC2	3	5	6	7	9	10	6
Current	OC2	4	5	7	8	9	10	7
Future w/	OC2	7	8	9	10	10	11	9
Future w/o	OC2	7	8	9	10	10	11	9
Forest	OC3	7	11	15	21	26	31	18
Current	OC3	14	20	25	31	37	43	28
Future w/	OC3	22	33	43	59	73	89	53
Future w/o	OC3	22	33	43	59	73	89	53
Forest	OC4	9	16	23	33	43	54	30
Current	OC4	23	34	42	53	62	71	47
Future w/	OC4	33	46	55	67	78	88	61
Future w/o	OC4	33	46	55	67	78	88	61

Table D-20. Olson Creek Flow Frequencies (cfs/acre)-Not Accumulated

Land Use	Catchment	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	2-100 avg
		Olson Creek Flow Frequencies (cfs/acre)- Not Accumulated						
Forest	OC1	0.02	0.04	0.05	0.07	0.09	0.11	0.06
Current	OC1	0.04	0.05	0.06	0.08	0.09	0.11	0.07
Future w/	OC1	0.07	0.09	0.10	0.12	0.13	0.14	0.11
Future w/o	OC1	0.09	0.12	0.14	0.17	0.20	0.22	0.16
Forest	OC2	0.02	0.04	0.05	0.06	0.07	0.08	0.05
Current	OC2	0.03	0.04	0.05	0.06	0.07	0.08	0.06
Future w/	OC2	0.05	0.07	0.07	0.08	0.08	0.09	0.07

Table D-20. Olson Creek Flow Frequencies (cfs/acre)-Not Accumulated

Olson Creek Flow Frequencies (cfs/acre)- Not Accumulated								
Land Use	**Catchment**	*2-yr*	*5-yr*	*10-yr*	*25-yr*	*50-yr*	*100-yr*	***2-100 avg***
Future w/o	OC2	0.05	0.07	0.07	0.08	0.08	0.09	0.07
Forest	OC3	0.03	0.04	0.06	0.08	0.10	0.12	0.07
Current	OC3	0.05	0.08	0.10	0.12	0.15	0.17	0.11
Future w/	OC3	0.09	0.13	0.17	0.23	0.29	0.35	0.21
Future w/o	OC3	0.09	0.13	0.17	0.23	0.29	0.35	0.21
Forest	OC4	0.04	0.08	0.11	0.16	0.20	0.26	0.14
Current	OC4	0.11	0.16	0.20	0.25	0.29	0.33	0.22
Future w/	OC4	0.15	0.21	0.26	0.32	0.37	0.42	0.29
Future w/o	OC4	0.15	0.21	0.26	0.32	0.37	0.42	0.29

Table D-21. Perlnd/Implnd Regional Parameters Q Frequencies- cfs/acre

Perlnd/Implnd Regional Parameters Flow Frequencies-cfs/acre							
Perlnd	*2-yr*	*5-yr*	*10-yr*	*25-yr*	*50-yr*	*100-yr*	***2-100 avg***
TFF	0.037	0.066	0.092	0.132	0.168	0.210	0.118
TFM	0.026	0.039	0.049	0.062	0.074	0.086	0.056
TFS	0.037	0.054	0.067	0.084	0.097	0.111	0.075
TGF	0.130	0.181	0.214	0.255	0.285	0.314	0.230
TGM	0.057	0.088	0.113	0.148	0.177	0.210	0.132
TGS	0.070	0.101	0.124	0.155	0.180	0.206	0.139
OF	0.005	0.007	0.008	0.010	0.011	0.013	0.009
OG	0.009	0.019	0.030	0.053	0.078	0.113	0.050
WET	0.049	0.094	0.127	0.168	0.198	0.227	0.144
TP	0.036	0.054	0.067	0.086	0.102	0.119	0.077
OP	0.006	0.009	0.012	0.017	0.021	0.025	0.015
IMP	0.245	0.303	0.342	0.390	0.427	0.464	0.362

Table D-22. Olson Creek Durational Analysis for OC1 Forested Conditions

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.00%	382800	1	382800
1	22.890%	87590	376	233
2	9.566%	36610	406	90.18
3	4.553%	17430	329	52.96
4	2.260%	8651	241	35.9
5	1.188%	4548	154	29.53
8	0.264%	1012	61	16.59
10	0.129%	492	32	15.38
12	0.074%	282	22	12.82
14	0.047%	181	18	10.06
16	0.031%	117	15	7.8
18	0.021%	80	10	8
20	0.015%	56	9	6.222
25	0.004%	15	3	5
31	0.001%	3	1	3
39	0.000%	0	0	0

Table D-23. OC1 Durational Analysis Current Conditions

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.00%	382800	1	382800
2	11.850%	45350	713	63.6
5	2.065%	7904	314	25.17
10	0.270%	1033	78	13.24
14	0.100%	381	37	10.3
20	0.029%	112	16	7
25	0.011%	42	6	7
30	0.001%	5	1	5
35	0.001%	2	1	2
40	0.000%	0	0	0

Table D-24. OC1 Durational Analysis Future LU w/wetland 24

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.00%	382800	1	382800
2	14.271%	54630	1673	32.65
5	3.467%	13270	1001	13.26
10	0.740%	2834	363	7.807
14	0.327%	1250	183	6.831
20	0.133%	508	71	7.155
27	0.057%	217	34	6.382
30	0.031%	119	24	4.958
35	0.014%	53	8	6.625
39	0.007%	27	7	3.857
47	0.002%	7	2	3.5
55	0.000%	0	0	0

Table D-25. OC1 Durational Analysis Future LU w/o Wetland 24

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.00%	3.83E+05	1	382800
2	13.000%	4.98E+04	2014	24.71
5	2.741%	1.05E+04	1105	9.494
10	0.733%	2807	567	4.951
14	0.356%	1361	278	4.896
20	0.127%	486	109	4.459
29	0.038%	146	37	3.946
35	0.018%	69	23	3
41	0.008%	31	11	2.818
51	0.002%	7	2	3.5
60	0.001%	5	2	2.5
65	0.001%	3	1	3
70	0.001%	3	1	3
76	0.001%	3	1	3
80	0.001%	1	1	1
89	0.000%	1	1	1

Table D-26. OC2 Durational Analysis Forested Conditions

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
1	4.978%	19050	483	39.45
2	0.833%	3190	137	23.28
3	0.225%	861	48	17.94
4	0.094%	358	20	17.9
5	0.043%	164	11	14.91
6	0.021%	80	7	11.43
7	0.011%	43	4	10.75

Table D-27. OC2 Durational Analysis Current Conditions

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
1	5.384%	20610	441	46.73
2	0.947%	3623	162	22.36
3	0.277%	1060	71	14.93
4	0.120%	461	29	15.9
5	0.061%	235	19	12.37
6	0.031%	120	11	10.91
7	0.019%	72	7	10.29
8	0.003%	11	2	5.5

Table D-28. OC2 Durational Analysis Future LU w/Wetland 24

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
1	9.110%	34870	1617	21.56
2	2.849%	10900	780	13.98
3	1.152%	4410	394	11.19
4	0.537%	2057	191	10.77
5	0.278%	1064	97	10.97
6	0.167%	638	53	12.04
7	0.118%	451	32	14.09
8	0.042%	160	14	11.43
9	0.011%	43	5	8.6
10	0.003%	10	2	5

Table D-29. OC2 Durational Analysis Future LU w/o Wetland 24

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
1	9.110%	34870	1617	21.56
2	2.849%	10900	780	13.98
3	1.152%	4410	394	11.19
4	0.537%	2057	191	10.77
5	0.278%	1064	97	10.97
6	0.167%	638	53	12.04
7	0.118%	451	32	14.09
8	0.042%	160	14	11.43
9	0.011%	43	5	8.6
10	0.003%	11	2	5

Table D-30. OC3 Durational Analysis Forested Conditions

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
5	6.496%	24860	387	64.24
10	1.217%	4659	150	31.06
15	0.337%	1290	52	24.81
20	0.127%	487	20	24.35
24	0.057%	220	15	14.67
30	0.030%	116	12	9.667
33	0.022%	85	11	7.727
40	0.012%	44	8	5.5
48	0.004%	15	6	2.5
61	0.001%	3	1	3
70	0.001%	2	1	2

Table D-31. OC3 Durational Analysis Current Conditions

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
5	8.206%	31410	625	50.25
10	1.986%	7602	347	21.91
20	0.242%	925	49	18.88
30	0.062%	238	30	7.933
40	0.030%	113	21	5.381
50	0.012%	46	13	3.538
60	0.004%	17	6	2.833
70	0.001%	5	2	2.5
80	0.001%	3	1	3

Table D-32. OC3 Durational Analysis Future LU w/Wetland 24

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
5	10.980%	42040	1751	24.01
10	3.960%	15160	1057	14.34
20	0.717%	2743	219	12.53
30	0.222%	849	117	7.256
40	0.117%	449	73	6.151
56	0.045%	171	39	4.385
70	0.018%	70	22	3.182
84	0.005%	20	8	2.5
101	0.002%	6	2	3
110	0.001%	4	1	4
124	0.001%	2	1	2

Table D-33. OC3 Durational Analysis Future LU w/o Wetland 24

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
5	10.520%	40260	1855	21.71
10	3.673%	14060	1088	12.92
17	1.158%	4433	417	10.63
30	0.209%	801	131	6.115
40	0.111%	426	85	5.012
50	0.059%	226	53	4.264
60	0.039%	150	39	3.846
80	0.011%	42	17	2.471
87	0.007%	25	9	2.778
105	0.002%	8	2	4
127	0.001%	3	1	3
140	0.001%	3	1	3
144	0.001%	3	1	3
150	0.001%	3	1	3
159	0.001%	2	1	2

Table D-34. OC4 Durational Analysis Forested Conditions

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
2	29.890%	114400	370	309.2
5	9.690%	37090	426	87.06
10	2.358%	9027	268	33.68
15	0.742%	2839	98	28.97
21	0.238%	909	39	23.31
30	0.063%	241	19	12.68
36	0.037%	142	14	10.14
45	0.017%	66	11	6
50	0.012%	47	8	5.875
60	0.005%	18	5	3.6
70	0.001%	5	2	2.5
72	0.001%	4	1	4
80	0.001%	2	1	2
90	0.001%	2	1	2
92	0.001%	2	1	2
100	0.000%	1	1	1

Table D-35. OC4 Durational Analysis Current Conditions

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
2	32.510%	124400	816	152.5
5	11.770%	45050	763	59.04
20	0.554%	2120	188	11.28
40	0.055%	212	32	6.625
60	0.018%	70	16	4.375
70	0.010%	39	15	2.6
80	0.005%	19	8	2.375
90	0.003%	10	5	2
110	0.001%	3	1	3
120	0.001%	3	1	3
146	0.000%	1	1	1

Table D-36. OC4 Durational Analysis Future LU w/Wetland 24

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
2	32.341%	123800	1702	72.75
5	14.475%	55410	1992	27.81
20	1.443%	5522	549	10.06
40	0.197%	756	117	6.462
60	0.072%	274	53	5.17
70	0.046%	178	42	4.238
81	0.031%	117	36	3.25

Table D-36. OC4 Durational Analysis Future LU w/Wetland 24

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
90	0.021%	79	27	2.926
110	0.005%	21	10	2.1
122	0.003%	10	4	2.5
150	0.001%	5	2	2.5
170	0.001%	3	1	3
189	0.000%	1	1	1

Table D-37. OC4 Durational Analysis Future LU w/o Wetland 24

Flow Rate (cfs)	*Fraction of Time*	*Time Spent (hours)*	*Number of Excursions*	*Avg. Length of Excursion (hours)*
0	100.000%	382800	1	382800
2	30.560%	117000	1758	66.54
5	13.950%	53410	2055	25.99
20	1.380%	5282	553	9.552
40	0.189%	723	122	5.926
60	0.072%	275	69	3.986
70	0.048%	183	43	4.256
80	0.036%	137	41	3.341
90	0.023%	87	27	3.222
110	0.008%	32	14	2.286
120	0.005%	18	8	2.25
146	0.002%	8	2	4
175	0.001%	3	1	3
204	0.000%	1	1	1
210	0.000%	1	1	1
220	0.000%	1	1	1

Table D-38. Current Land Use Ftable 1.

Depth (feet)	Area (acres)	Volume (ac-ft)	Disch (cfs)
0.00	2.00	0.00	0.00
0.40	6.02	0.88	1.00
1.20	9.17	1.42	8.31
1.50	10.34	4.60	12.81
1.80	11.25	5.65	16.63
2.82	13.79	9.50	27.55
3.50	15.45	12.74	33.00
4.50	21.28	21.56	50.00
5.50	24.85	35.10	57.00
6.00	26.88	46.31	61.00
7.00	32.32	93.19	215.4

Table D-39. Future Land use Ftable 1.

DEPTH (FT)	AREA (ACRES)	VOLUME (AC-FT)	DISCH (CFS)
0.00	6.00	0.00	0.00
0.40	6.85	0.10	0.43
0.90	9.17	0.25	4.66
1.50	11.25	0.72	12.81
2.10	12.00	1.21	21.10
2.82	12.00	1.83	27.55
3.50	12.00	2.85	33.00
4.50	12.00	4.44	50.00
5.50	12.00	6.36	57.00
6.00	12.00	7.23	61.00
7.00	12.00	9.64	215.44

Table D-40. FTable 2.

Depth (feet)	Area (acres)	Volume (ac-ft)	Disch (cfs)
0.00	0.00	0.00	0.00
0.50	9.50	0.50	0.90
1.00	10.00	2.00	3.60
1.50	10.50	4.50	7.20
2.00	11.00	10.00	9.00
2.50	11.50	17.50	12.00
3.00	12.00	27.00	15.00
3.50	12.50	35.00	17.00
4.00	13.00	52.00	19.00

Table D-41. FTable 3

Depth (feet)	Area (acres)	Volume (ac-ft)	Disch (cfs)
0.00	0.00	0.00	0.00
0.50	9.50	0.50	0.90
1.00	10.00	2.00	3.60
1.50	10.50	4.50	7.20
2.00	11.00	10.00	9.00

Table D-41. FTable 3

Depth (feet)	Area (acres)	Volume (ac-ft)	Disch (cfs)
2.50	11.50	17.50	12.00
3.00	12.00	27.00	15.00
3.50	12.50	35.00	17.00
4.00	13.00	52.00	19.00

Table D-42. FTable 4

Depth (feet)	Area (acres)	Volume (ac-ft)	Disch (cfs)
0.00	0.00	0.00	0.00
0.50	0.13	0.06	10.29
1.00	0.14	0.13	29.88
1.50	0.15	0.20	56.38
2.00	0.16	0.28	89.16
2.50	0.17	0.36	128.0
3.00	0.18	0.45	172.8
3.50	0.20	0.54	223.5
4.00	0.21	0.64	280.3

APPENDIX E
STREAM-EROSION STUDY DATA ON COBBLE CREEK (0068)

INTRODUCTION

Beginning in 1986, King County staff began an ongoing project to identify and monitor actively or potentially eroding stream channels. The purpose of this program has been to document those areas and establish their rates of channel change; to test the hyposthesis that these areas preferentially exist under specific geologic, topographic, and land-use conditions; and to predict and so protect ssusceptible areas prior to irreversible impacts from development. In total, about 40 sites (mainly channel cross sections) have been established on tributary streams in the western part of King County and resurveyed annually or biannually.

SITE

The Cobble Creek site was established at RM 0.11 in 1986, to collect data in anticipation of the Green River basin plan, and resurveyed annually through the summer of 1990 and again in mid-1993[1]. The valley of the channel here forms a moderately steep-walled ravine; the channel itself is slightly incised into a firm silt and clay substrate. Urban development in the contributing subbasin is moderate, at about seven percent impervious area.

RESULTS

To date, only moderate channel changes have been observed (Figure E-1, next page). Downcutting was most pronounced during the winter of 1986-1987 (about one foot near the right bank), followed by several years where limited erosion on one side of the channel was about balanced by commensurate aggradation on the other side. The winter of 1990-1991 probably caused the modest incision measured in 1993, along with the two feet of widening that also occurred during this three-year period.

By analogy to other channels, the cohesion and compactness of the fine-grained hillside sediments into which the channel is incised probably accounts for the relative stability here. Although the intensity of future upstream development will probably affect the channel morphology, dramatic changes in the channel profile or cross section are not particularly likely.

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[1]The section is found by descending the ravine sidewalls 100 feet north of the change of 104th Avenue SE to SE 304th Way, or by walking 1100 feet downstream of 106th Avenue SE.

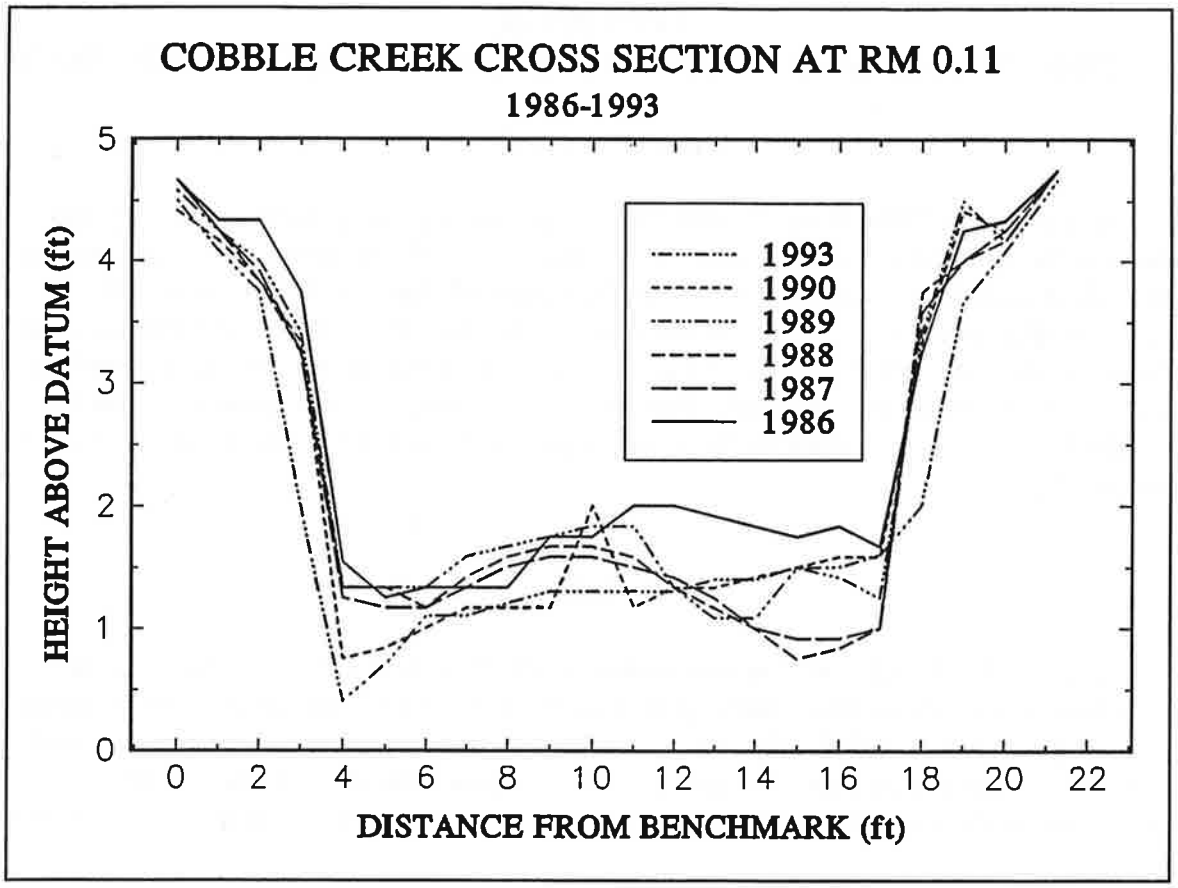
COBBLE CREEK CROSS SECTION AT RM 0.11
1986-1993
HEIGHT ABOVE DATUM (ft)
DISTANCE FROM BENCHMARK (ft)
1993
1990
1989
1988
1987
1986
0
1
2
3
4
5
0
2
4
6
8
10
12
14
16
18
20
22

Figure E1

APPENDIX F
PREPARATION OF THIS REPORT--TASKS, TIME, AND COSTS

BACKGROUND

The development of watershed-scale plans has been a keystone of SWM's watershed management program, recognized in both the 1991 Strategic Plan and the Division's 1992 Policy Plan as "an essential activity of surface water management because the cost of capital projects and the impacts of inadequately controlled runoff demand a well-guided, defensible program." Basin plans have defined an overall basin management strategy, set priorities for the expenditure of resources, and integrated a variety of management actions and tools.

Since 1987, SWM has been developing basin plans according to a priority order targeting the fastest-growing basins first. By the end of 1994, almost three-quarters of the SWM Service Area will have been covered by completed basin plans. However, the Strategic Plan's goal of completing all Basin Plans by 1997 cannot be achieved for two reasons. First, annexations and incorporations have reduced, and will continue to reduce, the program base available to perform planning. Second, basins remaining to be completed involve coordination with an increasing number of jurisdictions, complicating and delaying the process of agreeing to a scope-of-work and cost-sharing arrangement for completing a plan.

Delay in completion of the basin plans poses several problems. First, it delays SWM's ability to identify and begin solving problems in the later basins. Second, delay hinders our ability to set priorities across the Service Area in a consistent, defensible manner, and to target limited capital facility funds and programmatic resources to areas of highest need and benefit. Third, it may run contrary to NPDES permit requirements, which are likely to emphasize development of water quality protection measures in degraded water bodies, and many of which are in the remaining "urban" basins. Finally, it is likely to interfere with SWM's ability to take on an appropriate role in regional watershed management, as is likely to be required by NPDES "watershed-based" permits, and as a regional service role is defined over the next several years.

To address these issues, the Basin Planning Program proposed in early 1994 that its work be reorganized into two parallel tracks. First, Enhanced Reconnaissance Reports would be completed by the end of 1996 for the largely urban basins that lack recent Basin Plans (Boeing, McAleer, Lyon, Thornton, Juanita, East and West Lake Washington, West Lake Sammamish, Sammamish River tributaries, and Lower Green River tributaries). Second (and concurrently), Long-term Watershed Management of the County's major river basins would be established as the formal organization of the Program's ongoing and future tasks. The present study represented the prototype Enhanced Reconnaissance effort. This Appendix enumerates the tasks and resources that went into its preparation, in case this approach is ever considered for future basin investigations.

TASKS

As with past basin plans, the Enhanced Reconnaissance first characterized conditions in the watershed and then determined a set of recommendations for long-term surface-water management. Excluding the development of the Enhanced Reconnaissance model as a whole, the sequence of tasks for this particular study area was as follows:

A. START-UP

1. Define area boundaries and produce base maps.
2. Collect and compile existing information on surface-water system (1987 Reconnaissance report, NDA complaints, proposed SWM CIP's, Stormwatch sampling data).
3. Collect and compile existing land-use information (land cover from aerial photographs, zoning boundaries, DDES permit activity).
4. Define road-drainage elements (outfalls and stream crossings).

B. DATA COLLECTION

5. Systematic field visits or traverses of:
   - All channels (including crossings)
   - All wetlands
   - All road-drainage outfalls
   - All substantive NDA complaints
   - All proposed or planned CIP sites.
6. Update base map.

C. DATA ANALYSIS AND SOLUTIONS

7. Produce HSPF-generated flows in selected subbasin(s) (current and future).
8. Produce WQ model of predicted loadings (current and future).
9. Assemble list of all identified problems.
10. Apply problem-significance criteria established by previous basin plans.
11. Identify major issues in study area.
12. Propose site-specific solutions, where feasible, for significant problems.
13. Determine appropriate on-site R/D standards for new development.
14. Write report and circulate for review.

This study offers an opportunity to determine which of the various avenues for determining specific problem sites (prior knowledge, road-drainage analysis, or field visits) were effective. In the study area, a total of 54 specific conditions were identified (Appendix A) from all sources; of those 54, 14 were judged not to be problematic. The other 40 were identified as follows:

METHOD OF PROBLEM IDENTIFICATION

PROBLEM SIGNIFI-CANCE	HOW FIRST IDENTIFIED				
	PRIOR CIP or REPORT	NDA/DI	OUTFALL LIST[1]	CROSSING LIST[1]	OTHER FIELD
MEDIUM	3	4	0 (2)	1 (3)	1
LOW	3	5	5	3 (5)	14
<none>			6	8	

[1] Numbers in parentheses include all road-drainage problems that appear on the outfall or crossing lists but were previously identified by prior CIP, report, or NDA/DI (and so are included in the first two columns).

Not surprisingly, most of the medium-priority problems listed here (7 of 9) had been previously identified. For these, the major value of this study is to determine (1) their significance in the context of the watershed as a whole, and (2) their priority relative to all basins in the SWM Service Area. In particular, three of those medium-ranked problems previously identified through the NDA program owe their assigned significance in this study more to downstream consequences than to on-site effects. Their overall priority has therefore been raised as a result of this study. (The tenth medium-priority problem, that of future water-quality degradation, was also identified and quantified through this study but was not included on this table because of its non-site-specific nature.)

Of the low-priority problems, over two-thirds were newly identified as a result of this study, either by systematic review of the road-drainage system (5 outfalls and 3 crossings) or by field traverses of stream channels and wetlands (14 in total). Interestingly, about one-half of the identified road-drainage outfalls and crossings (15 of 29) have generated at least low-priority problems, suggesting that these elements of the surface-water system should be *systematically* reviewed in all future assessments of any developed basin.

This tabulation does not include the more systemic problems of nonpoint water pollution and increased discharges as a result of land-use changes, although the study tasks included analyses of both. The scope of potential solutions was limited because future land-use changes, which could effectively address the progressive worsening of these problems but only through significant reduction in future development, were explicitly precluded for analysis in this study. No capital projects were recognized to address these problems effectively or feasibly; on-site R/D standards were evaluated and recommended to address much of the increased discharges that would otherwise cause significant future problems. Actions to improve water quality for the given future urban land uses are not as clearly defined or developed at this time, and so the major effort in this report has been to better quantify the magnitude of potential pollutant loads for future actions on a broader, watershed basis.

COSTS

Project costs were almost exclusively staff time. Where relevant, our accounting of time distinguished between the work that was specific to this study area ("Project") and the work necessary to establish the methodology but that would not need to be repeated in any subsequent effort ("Method"). The major contributors to the study and their estimated time were as follows:

STAFF	RESPONSIBILITY	NUMBER OF WEEKS	
		Project	Method
D. Booth	Project Mgmt., Geology	3.0 4.5	0.6
A. Stonkus	Fisheries, Engineering	4.2	0.7
M. Lampard	Engineering	2.7	1.3
S. Kaufman	Water Quality	1.5	1.3
R. Schaefer	Wetlands	3.1	
J. Burkey	Hydrologic Modeling	7.0	0.3
W. Kara	Water Quality	1.2	2.0
T. Bennett	Water Quality	1.1	2.8
Graphics Staff	Base Maps, Figures	10.4	
TOTALS		**38 WEEKS (0.7 FTE)**	**9.0 WEEKS**

Including all staff expenses (salary, benefits, time off, and indirect costs) this effort in total will cost about $90,000. Because of efficiencies in having completed this first project, any subsequent effort of equivalent scope and scale would cost about $60,000.

TIMING

Because of the breadth of expertise in the Basin Planning program, the workload of this study was remarkably uniform across the staff involved. The typical demand was one month or less; only one, owing to start-up management needs in combination with technical work exceed 5 weeks. The largest single demand, a little over 2 months of Graphics support, was spread among three individuals. Owing to multiple project demands on each of the major personnel, approximately half-time attention was possible. Thus the duration of the project, from first basin-specific data collection to release of a review draft document, extended over almost exactly two months. Of that time perhaps one-half depended directly on the size of the study area; so, for example, any future such effort on a watershed twice

the size of this one would require about three months' time in total.