Newaukum Creek Basin Characterization Project Report

July 2007

King County
Department of
Natural Resources and Parks
Water and Land Resources Division

Funded by
KCD
King Conservation District
A King Conservation District Grant
for the WRIA 9 Forum of Local Governments

In support of the Green/Duwamish
Ecosystem Restoration Project

Newaukum Creek Basin Characterization Project Report

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Acknowledgements

Grant Revenue and Support from the King Conservation District

Thanks to WRIA 9 Forum for demonstrating support for the Duwamish/Green Ecosystem Restoration Project. Special thanks to Kathy Wright (Army Corps Partnerships Coordinator) for her efforts in support of this project.

Funding for Appendix F provided by U.S. Army Corps of Engineers. Additional funding for report from King County.

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BACKGROUND

Newaukum Creek plays a vital role in supporting the productivity of threatened fish, biological production in the Green River, and important rural and urban economies and communities. Sustaining and improving the biological productivity of the Newaukum Creek Basin requires an understanding of its ecological systems. In this report, the basin is subdivided into three parts for simplicity; Upper Basin (RM 0-5.7), Plateau (RM 5.7-11, including Big Spring Creek and Watercress Creek), and the Ravine (RM 11-16, including the North Fork and Stonequarry Creek). The goals of the Newaukum Creek Basin Characterization Report are to:

- characterize the present condition of the Newaukum Creek basin;
- identify ecological impairments to inform restoration;
- identify major gaps in our understanding of how the basin functions;
- anticipate how conditions in Newaukum Creek may change in the future.

This report is intended as a reference document to inform basin management objectives and the planning and implementation of fish and wildlife habitat restoration projects by landowners, private sector organizations, nonprofits, and agencies, within the context of regional plans for habitat restoration as well as salmon recovery.

PRESENT CONDITIONS

Newaukum Creek lies within the Puget Lowlands and Cascades ecoregions, with warm wet winters and cool dry summers. Mean annual air temperature is 52.2˚F. Mean seasonal temperatures range from 36˚F in winter to 75˚F in summer. Rain is the dominant form of precipitation, though snow plays an important role near Boise Ridge. The amount and form of precipitation is strongly influenced by air temperature and the presence of the Cascade foothills.

Both volcanic and glacial processes were instrumental in shaping the topography, geology and soils of the basin. Topography is steep and uneven in the Upper Basin, level and even across the Plateau, and steep and uneven throughout the v-shaped Ravine. Elevations range from 153 feet at the mouth to 2,980 feet along Boise Ridge, with an average elevation of 825 feet. Basin geology includes volcanic rock in the Upper Basin, glacial and volcanic mudflow deposits across the Plateau and river-deposited sediments near the bottom of the Ravine. The Plateau is underlain by fine-grained, compact, clay-rich sediments deposited 5,600 years ago by the massive Osceola Mudflow triggered by a landslide on Mt. Rainier. This material covers 32% of the basin and is relatively impervious and has a high water holding capacity. In fact, 49% of the basin area contains poorly or very poorly drained soils. Low soil permeability, combined with level topography creates broad areas where standing water or saturated soil was historically present for much of the year. Glacial till – generally gravelly silty sand – is also common. These soils are well-drained near the soil surface.

Natural disturbances include fire, floods, landslides and debris flows, wind, and insects. Lightning would have caused most historical fires, especially between July and August. Debris flows occur in streams of the Upper Basin where thin soils cover steep slopes. Landslides resulting from deep seated slumps create uneven topography in the Ravine. Floods are also important disturbances: peak flow magnitude for 10-year floods is 1,300 cubic feet per second (cfs); 50-year floods reach 2,100 cfs; 100-yr floods exceed 2,560 cfs.

Mean daily flows near the stream mouth range from lows of 20-30 cfs in late summer to 100 cfs during winter. Average minimum daily flows in summer are consistently near 10 cfs, whereas mean maximum daily flows range roughly from 30-100 cfs. The mean annual flow for any given year is equal to a daily average flow rate of 59 cfs. Flows are relatively flashy in Newaukum Creek. Relatively little precipitation is stored for long periods because 74% of the basin is underlain with low permeability soils; flows typically return to pre-storm levels within two weeks of a major storm.

Groundwater recharge into the lower zones of the basin is limited by the fine-grained material deposited in the Osceola mud flow. Aquifers were mostly deposited by massive outwash floods carrying coarse materials from glacial melting running north to south. Groundwater recharge is higher along the eastern portion of the basin because the coarse material is exposed at the ground surface. This material is underlain by shallow bedrock, forming springs along the margins of the mudflow. Deeper aquifers occur along the western basin.

Whereas the stream network in the basin has been greatly extended by ditches, the extent of wetlands has been drastically reduced from historical conditions. Newaukum Creek has a drainage area of 26 square miles where it meets the Green River. The Newaukum Creek mainstem measures 16 miles long: 5.7 miles in the Ravine, 5.3 miles in the Plateau, and 5 miles in the Upper Basin. The basin contains approximately 130 miles of channels, including drainage ditches and natural water courses; the mainstem represents only 12% of the total. Ditches and constructed channels represent 59% of the total channel length. Newaukum Creek originates from headwater channels in the Upper Basin with slopes of up to 40%; slopes decrease to 4% near the base of Boise Ridge and the creek exhibits both cascade and step-pool channel form (morphology). Pools are primarily formed by logs and boulders. The stream exhibits relatively featureless gravel-cobble beds (plane-bed) morphology across the alluvial fans at the slope break near the base of Boise Ridge. Across the Plateau, the low-gradient (0.4%) channel is deep and narrow with steep, cohesive, stable channel banks reinforced by vegetation. Pool-riffle channel morphology is locally evident on the eastern portion of the Plateau, but not toward the west. The Ravine transitions from a pool-riffle to plane-bed to step-pool and a meandering reach approaching the mouth. Large wood and sediment inputs are relatively abundant here due to landslides.

Wetlands historically occupied between 6,445 and 7,843 acres, which corresponds to between 38 and 41% of the basin; a huge wetland complex apparently existed near the City of Enumclaw. Currently, only 1,252 acres of wetlands are present, corresponding to only 7% of the basin area. Wetlands were historically sustained by beavers and extensive patches of soils that are saturated for much of the year (hydric soils) across the Plateau. Remaining wetlands that support native vegetation are valuable to wildlife. A total of approximately 407 acres of these wetlands are present. Two outstanding wetland areas remain: one lies north of the City of Enumclaw, south of 424th, along the left bank of Newaukum Creek; another is the forested wetland complex upstream of Big Springs Creek, including Mahler Park. Both wetlands are remnants of what were once much more extensive, connected wetlands. The remainder of wetlands in the Basin is highly altered and has limited value to wildlife in their present state.

Water quality has improved over the past few decades, but some water quality parameters remain problematic. In recent years, water temperatures– specifically, the 7-day average daily maximum – in most portions of the mainstem and tributaries of Newaukum Creek exceeded standards for spawning and incubation habitat as well as core summer salmonid habitat. The only locations that largely met standards for cool water were in Big Spring Creek and in the mainstem just below the forested headwaters. Model simulations suggest seasonal patterns exist in both nutrient and bacteria concentrations. Ammonia and total nitrogen (N) in Newaukum Creek have apparently declined from 1979-2004, though total N, ortho-phosphorus, total phosphorus concentrations are still high relative to the rest of the greater Green River Basin. Nutrient levels are particularly high near areas where agriculture is prevalent, and in stormwater near the mouth of Watercress Creek. Fecal coliform bacteria loading measured at the creek mouth improved from 1979-2004, but still violated water quality standards in 2004.

Riparian and upland forests of Newaukum Creek Basin have been greatly altered from their historic condition. Riparian forests have steeply declined in size from historical conditions and non-native plant species have increased. Approximately 463 acres of riparian forest are present along the channel network. Riparian areas in the Upper Basin are forested with conifer stands of various ages, reflecting a long history of timber harvest. The most degradation to riparian vegetation occurs along the Plateau as a result of extensive clearing and ongoing livestock grazing. Riparian areas in the Ravine are largely forested and undeveloped. Himalayan blackberry was noted in almost all small forest patches on the Plateau, in riparian areas of the Ravine, and at most of the road crossings of Newaukum Creek. Reed canarygrass is pervasive and may be present along streams in any of the landcover types. Each of these non-native plants reduces the amount of habitat for the majority of native wildlife species. Upland forests have been converted from stands that originally contained a conifer patchwork dominated by western hemlock and Douglas-fir. Currently, the Newaukum Creek Basin contains roughly 5,200 acres of upland forest. Fifty-five percent of the upland forest area lies within the Forest Production District (FPD). Conifer stands in the Upper Basin, within the FPD, are almost exclusively composed of Douglas-fir monocultures. Outside the FPD, some monotypic stands of western redcedar also exist, but mixed forests are most common.

Newaukum Creek Basin contains at least 16 special status fish and wildlife species, including federally-protected fall Chinook salmon and native winter steelhead trout. Management efforts typically focus on improving habitat for these species. Chinook and steelhead in the Duwamish/Green River, in general, are at relatively low risk of extinction, compared to other rivers in the Puget Sound Region. However, juvenile life-history diversity in the Duwamish/Green River stock of Chinook has apparently declined. In Newaukum Creek, most Chinook spawning appears to occur in the Ravine during early October. Over-summering habitat is important because juveniles probably outmigrate before winter. An alluvial fan at the mouth of the creek sometimes blocks spawner migrations. Other juvenile passage barriers may exist: an evaluation of passage barriers is underway. Steelhead spawning occurs from February through June in Big Spring Creek, Watercress Creek and most of the mainstem basin, especially from RM 10 to 11. Juveniles rear for one to three years, so freshwater overwintering habitat is important.

Newaukum Creek continues to provide valuable habitat to a wide variety of plants, animals, and wildlife that do not have special management status. For example, Newaukum Creek provides breeding habitat for numerous species of birds (114), mammals (57), and amphibians and reptiles (17). Perhaps the most valuable habitat remaining in the basin for many species of birds is the naturally vegetated and open-water wetlands and the naturally vegetated riparian zones. Based on the Benthic-Index of Biological Integrity rating system, the instream biological integrity of Newaukum Creek is mostly fair, ranging to good/excellent. Instream biological production is supported by algae and diatoms, but also detritus and invertebrates from riparian areas. The majority of the aquatic invertebrates are collector-gatherers, which consume fine particulate matter. The long-lived western pearlshell mussel is present; its life cycle is intimately linked to salmonids. Detritus-eating lamprey are also abundant. Vertebrate predators include Pacific Giant salamanders and fish-eating birds. Coho salmon are year-round residents in much of the channel network. Coho spawn throughout the mainstem, in Big Spring Creek, and North Fork Newaukum Creek. Rearing coho occupy slow water habitats with woody cover. A non-native stock of chum salmon is present, but not widespread. Coastal cutthroat trout are widely distributed and common. Threespine stickleback, sculpin, and speckled dace are also important members of the fish community.

ECOLOGICAL ALTERATIONS

Current conditions in Newaukum Creek appear to be affected by a number of ecological alterations, listed below in no particular order. This is a partial list of the factors warranting consideration in plans to improve habitat conditions in the basin.

Low flow conditions are growing more extreme. The observed low flow rate (annual minimum 7-day mean flow) is declining at a rate of 0.12 cfs per year.

Streamflows are flashier, floods are more frequent than under historic conditions. Model simulations compared the historic ‘forested’ conditions with the ‘current’ developed condition of the basin, holding climate constant. Results suggest that flood events are now more frequent. For example, if Newaukum Creek Basin was completely forested, flows of 800 cfs would occur once every 10 years, whereas under ‘current’ conditions this flow occurs once every three years.

Peak annual flow magnitude is declining. Observed peak annual flow rates in Newaukum Creek declined at a rate of 5.4 cfs per year over the 60-year period of record, despite increases in impervious area and reductions in forest cover, meadows, and wetlands. Declines in peak flows may reflect both climatic change and impacts from human activities in the basin.

Surface and groundwater hydrology have likely been altered by growth of impervious surfaces. Impervious areas now cover 11% of the Newaukum Creek Basin, ranging from 2 to 59% among sub-basins. Model simulations suggest that forested areas show the least amount of hydrologic change from historic conditions. Areas with the highest amount of impervious surfaces show the greatest degree of change. Increases in the frequency of 10-year floods range from less than 10% to over 200% across the basin. Groundwater hydrology may be altered by landcover changes, as well as three large public water systems for domestic use (including two major springs) and 82 smaller public water systems that are almost entirely supported by wells. Personal wells for irrigation and livestock watering are common but poorly quantified.

Humans have created roughly 77 miles of artificial channels and reduced wetland area by at least 80%. These changes are largely attributable to extensive dredging, diking, draining, and ditching. Near the confluence with the Green River, Newaukum Creek has been locally straightened, armored and confined by berms, and large wood was historically removed. Additional factors contributing to wetland loss likely include declines in the number of beavers in the system and the introduction of reed canarygrass to improve land for cultivating agricultural crops.

Removal of riparian forests from most of the Plateau has likely exacerbated high stream temperatures, simplified stream channels, and encouraged the spread of non-native species. Loss of insulating shade from trees increases the heat load to the stream. Forest removal has also depleted the supply of trees that could otherwise fall into the channel and create pools and complex habitats. Impacts also extend to wildlife, which use riparian areas (and wetlands) extensively. Non-native species, such as reed canarygrass and Himalayan blackberry capitalize on harsh conditions resulting from forest removal. These species often exclude native plants and wildlife and may artificially stabilize streambanks and simplify the channel.

Water quality appears to have improved, but remains degraded. Water temperatures– specifically, the 7-day average daily maximum – in most portions of the mainstem and tributaries of Newaukum Creek consistently exceeded Washington state standards for spawning and incubation habitat as well as core summer salmonid habitat. The only locations that largely met standards for cool water were in Big Spring Creek and in the mainstem just below the forested headwaters. Stream temperature problems may be attributed to human activities that increase the heat load to the stream or reduce stream discharge. Factors can be ranked in order of increasing importance: (1) losses in riparian shade from forest clearing; (2) alterations to groundwater; (3) warming or reduced discharge in tributaries; (4) declines in mainstem discharge; and (5) reduced buffering from groundwater. Simulations suggest that nitrogen concentrations are elevated in the wet season, whereas phosphorous concentrations are elevated during the dry season, because of the relative contribution of groundwater to streamflows. Elevated phosphorus concentrations are likely from surface runoff from pastures during storms. Observed concentrations of bacteria are variable. Bacterial concentrations are higher in spring and fall when storms are large and infrequent, allowing fecal matter to accumulate on the landscape between storms. In summer, storms are small and infrequent; low, variable concentrations during this period are likely a result of animal activity with low potential runoff.

Conversion of native forests to plantations has reduced the structural habitat complexity of forest wildlife and the availability of snags and downed logs for nesting and feeding habitat. Most of the Upper Basin has been converted from natural forests to a high-yield (Douglas-fir) forestry plantation and fires are actively suppressed. Plantation forests have greatly reduced function as wildlife habitat, as snags, downed logs, and trees with broken tops or stands with multilayered canopies are relatively rare. Red alder stands and bigleaf maple are now far more common than they would have been historically.

Landcover changes and fragmentation may have benefited some birds, but have generally resulted in widespread loss of wildlife habitat. The extensive agricultural lands in Newaukum Creek Basin likely provide an increased amount of foraging habitat for species that use open areas and meadows. In contrast, the abundance and richness of bird species has likely decreased within the forest interior. The lack of structural diversity in forests of the Upper Basin likely reduces the diversity and abundance of native mammals. Amphibian species may have been more abundant and widely dispersed prior to habitat conversion, destruction and fragmentation. Road-building is widespread, and this activity is potentially detrimental to wildlife populations because of collisions, altered home ranges or feeding behaviors, and reduced gene flow.

MAJOR KNOWLEDGE GAPS

Agencies and landowners both possess considerable but incomplete knowledge of the streams, lands, and wildlife in the Newaukum Creek Basin. This report is not without substantial limitations, omissions, and speculations. Knowledge of the basin's ecological systems will evolve and improve by coupling scientifically robust studies with the local knowledge and long-term perspective of people that live and work in the basin. Further investigation is warranted on many topics, including the following:

- Mechanistic explanations for declines in peak flows and annual low flow levels.
- Cumulative effects of water withdrawals for irrigation, livestock watering, and domestic use on summer low-flow conditions.
- Spatially continuous evaluation of heat load and discharge in the mainstem to explain and correct exceedingly warm stream temperatures.

- Map of areas that lack fences to prevent livestock from damaging stream banks and better understanding of the potential instream consequences and effects on riparian vegetation.
- Life history, distribution, and productivity of Chinook salmon and steelhead trout using Newaukum Creek for spawning and rearing (for example, is a yearling life history form of Chinook salmon present?).
- Continuous surveys of fish distribution during spawning and rearing, as well as data on the variation in the distribution of spawning over time.
- Comprehensive assessment of road crossings to identify potential barriers to juvenile and adult fish migrations (currently underway).
- Better understanding of non-native plant and animal species distributions within Newaukum Creek Basin and their potential impacts on native plants and wildlife.
- Detailed studies of current water quality conditions, including fecal bacteria loadings, and the identification of ongoing sources of water quality degradation.

ANTICIPATING FUTURE CHANGE

Restoring and maintaining productive habitats for plants, fish, and wildlife in Newaukum Creek warrants consideration of the legacy of human impacts and present conditions, but also the anticipated future. Substantial uncertainty remains, but it is important to 'look before we leap'. This is accomplished by explicitly addressing potential consequences of future changes when planning management strategies.

<u>More people in cities and rural areas:</u> Human population growth and increasing development within the Urban Growth Area and in rural areas around the City of Enumclaw is expected to exacerbate existing ecological impairments and further constrain restoration opportunities in the basin.

<u>Warmer stream temperatures from altered hydrology</u>: Mean annual temperatures in the Newaukum Creek Basin are expected to rise in the future, and such a rise would exacerbate water quality problems in the basin. Results from model simulations suggest stream temperatures are likely to increase as a result of diminished groundwater base flows. Conversely, summer stream temperatures could be improved beyond existing conditions by increasing the riparian shade (e.g., in a forested stream system). Impacts of regional warming trends in air temperatures on stream temperature were not considered here, but may further exacerbate existing problems.

<u>Slightly larger, more frequent floods and lower summer flows from regional warming trends:</u> Streamflows in Newaukum Creek may be affected by regional warming trends. Six percent of the Newaukum Creek Basin receives seasonal snowfall (for example, where elevation exceeds 1,500 feet). Increases in air temperature cause more snow to fall as rain. Storms that drop rain on existing snowpacks (i.e., rain-on-snow events) will likely become more frequent in these areas. An increase in these events would amplify the annual number of storm run-off events, which also affect downstream areas along the stream. Moreover, higher elevations that would normally retain snow cover through May or June will lose their snowpack earlier in the year, causing higher spring flows and lower summer flows. Landcover change alone is not predicted to change flows drastically from current conditions, because agricultural land with naturally

impervious soils will continue to be the dominant land cover type. Anticipated differences between current and future conditions are minimal, because the existing landscape is mostly 'built out' and increases in impervious area are expected to occur in zones that are already impacted by development.

Findings in this report can be used to support a comprehensive set of management objectives that reflect unique aspects of the basin and are consistent with the existing priorities set by the Salmon Habitat Plan for the Duwamish/Green River (WRIA 9 Planning Committee, 2005). Further study is needed to address the knowledge gaps listed above. Resolving these and other uncertainties require community partnerships. This will be a valuable next step to reduce uncertainty in the outcome of future restoration projects. In the meantime, management priorities and habitat improvements should be consistent with general themes outlined in Section 10.4.

1. INTRODUCTION

This study was initiated by the recognition that Newaukum Creek (Fig. 1; #09-0114) plays a vital role in supporting the productivity of threatened fish species (i.e., Chinook salmon *O. tshawytscha* and steelhead *O. mykiss*). Newaukum Creek also supports biological production in the Green River by contributing water, sediments, organic matter, food energy, and nutrients. In addition to its ecological value, the Newaukum Creek basin supports important rural and urban economies and communities that rely on agriculture and forestry.

Sustaining and improving the biological productivity of the Newaukum Creek basin in this growing community requires an understanding of the basin as a 'system'. This understanding can be achieved through the work of interdisciplinary scientific teams, but also by drawing on the extensive knowledge base of local citizens and landowners. In this report, we attempt to synthesize this knowledge to explain how ecological patterns, structures, and the underlying processes have been changed by a long history of human influences. Our hope is that the results will guide decisions about how best to ensure the vitality of Newaukum Creek and inform investments in conservation and restoration that will result in meaningful improvements.

1.1. PURPOSE

This report is intended to strengthen the scientific understanding of the Newaukum Creek watershed (hereafter, basin). This understanding can be used to inform the planning and implementation of fish and wildlife habitat restoration projects in the basin. Accordingly, our general goals are to:

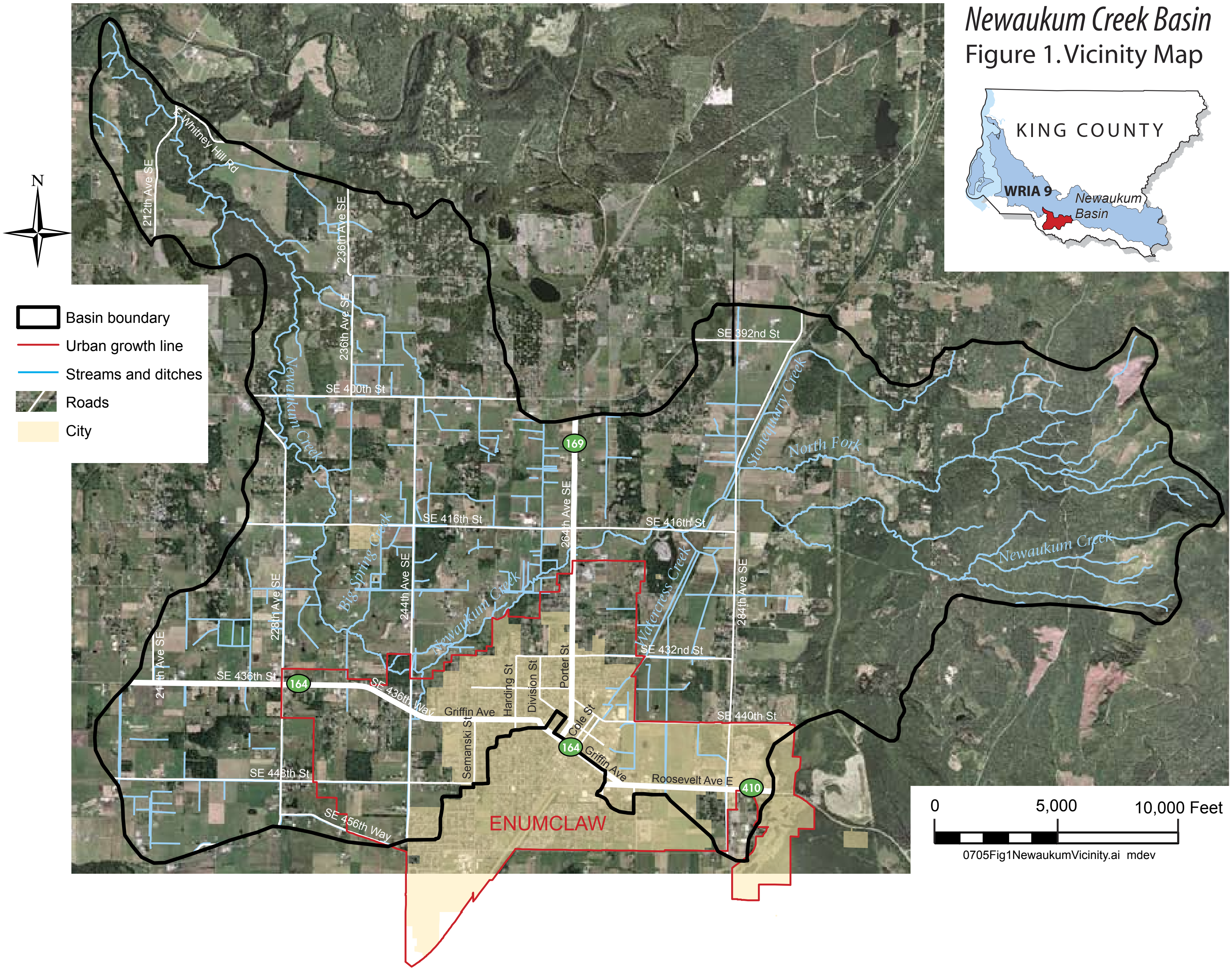
- Characterize the present condition of the Newaukum Creek basin;
- Identify ecological impairments to inform restoration;
- Identify major gaps in our understanding of how the basin functions;
- Anticipate how conditions in Newaukum Creek may change in the future.

This report is an important step forward, but knowledge of the basin must evolve and improve over time, especially through information provided by residents and through additional studies.

1.2. INTENDED AUDIENCE

This is a technical report, but it is intended to support the activities of a diverse interest groups and agencies working to sustain productive habitat in the Newaukum Creek basin. This includes, but is not limited to:

- People who may affect or be affected by the condition of Newaukum Creek;
- People interested in learning how the basin functions and in improving habitat;
- Non-profit organizations, especially those involved in restoration activities;
- Public and tribal agencies involved in resource management, protection, and recovery.



Newaukum Creek Basin
Figure 1. Vicinity Map
KING COUNTY
WRIA 9
Newaukum Basin
N
Basin boundary
Urban growth line
Streams and ditches
Roads
City
Whitney Hill Rd
212th Ave SE
236th Ave SE
SE 392nd St
SE 400th St
Newaukum Creek
Stonequarry Creek
North Fork
169
SE 416th St
264th Ave SE
Newaukum Creek
Big Spring Creek
244th Ave SE
228th Ave SE
Watercress Creek
284th Ave SE
SE 432nd St
SE 436th St
164
SE 436th Way
Griffin Ave
Semanski St
Harding St
Division St
Porter St
Cole St
SE 440th St
Griffin Ave
Roosevelt Ave E
410
SE 448th St
SE 456th Way
ENUMCLAW
0
5,000
10,000 Feet
0705Fig1NewaukumVicinity.ai mdev

We hope that most readers will find the report accessible, interesting, and useful. However, the scope of the report is relatively broad. Readers seeking detailed information at very small scales are encouraged to use this report as a 'springboard' for further investigation.

1.3. APPROACH

Our general approach is to blend site-specific data on historical and current conditions with relevant principles of terrestrial and fluvial ecology, geology, and hydrology. We emphasize an understanding of the Newaukum Creek 'system' as well as its parts. We explain the nature and consequences of the long history of human activities throughout the report, when sufficient information exists. The framework for this report is adapted from a time-tested 'state factor' model of ecosystems (Jenny 1941; Admundson and Jenny 1997), focusing on main drivers and secondary drivers of ecosystem structure and processes. Refer to Section 1.4 (below) for more detail.

In this report, we subdivide the Newaukum Creek basin (26 square miles) into three parts representing abrupt shifts in basin topography along the channel network (Fig. 2):

Ravine (RM 0 to 5.7)

Plateau (RM 5.7 to 11, including Big Spring Creek and Watercress Creek)

Upper Basin (RM 11 to 16, including the North Fork and Stonequarry Creek)

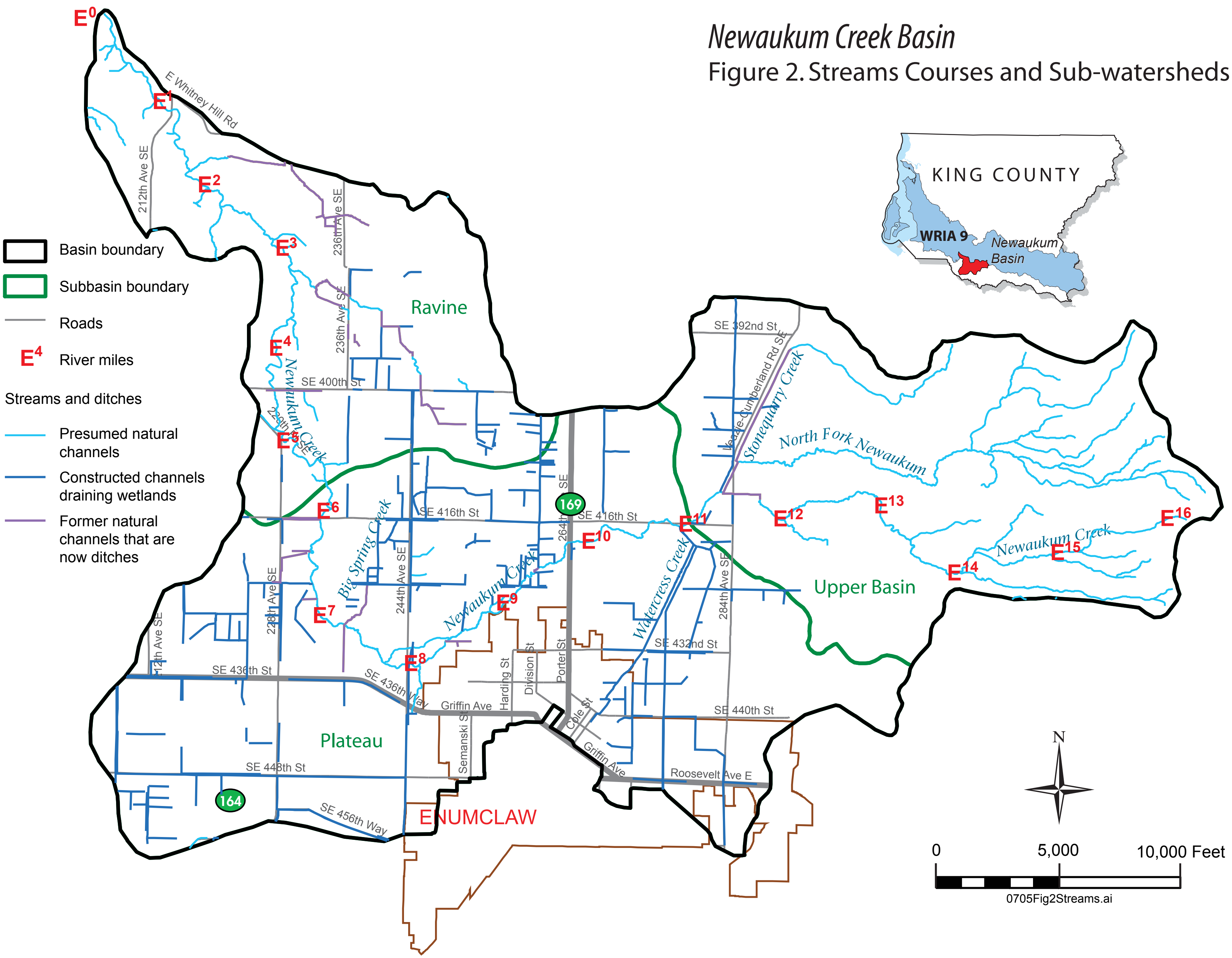
These divisions are ecologically relevant, but are mostly for convenience. Hydrological analyses are an exception, based on 29 individual sub-watersheds. Note that we describe analytical methods in footnotes or in appendices to improve readability.

This report is organized by 11 chapters (for example, 9.0 Plants and Animals) consisting of variable numbers of sections (9.1. Special Status Wildlife Species) and subsections (9.1.1. Chinook salmon). The report can also be navigated from the Figure List and Table List. Note that there are also five appendices containing important information.

1.4. MAIN DRIVERS VS. SECONDARY DRIVERS

We begin with the 'big picture' by identifying and describing the main drivers (also called 'state factors'; Jenny 1941; Admundson and Jenny 1997) affecting the basic structure and functioning of the Newaukum Creek basin. Main ecosystem drivers include: (1) climate; (2) geologic setting (or parent material); (3) topography; (4) potential organisms (plants and animals); and (5) time, including key changes in the human culture within the basin. These factors are relatively independent. They represent primary controls on the range of ecological processes evident in the basin.

Newaukum Creek Basin
Figure 2. Streams Courses and Sub-watersheds



Second, we explain the secondary drivers, which are influenced by the main drivers (above) and interact with one another. Examples include: (1) disturbances; (2) aquatic resources[1]; (3) riparian and terrestrial soils; and (4) plant and animal (including fish) communities. These are sometimes called 'interactive controls' (Chapin et al. 2003). These drivers affect patterns in the availability of the fundamental ecological resources (i.e., light, water, nutrients, sediments and soils) that support biological production and provide useful insight into how the system 'works'.

Recognizing that the 'parts' of a system are also important, we provide 'snapshots' of the life histories of individual species in special management categories (threatened species, for example). Plants and animals are mostly described in groups according to where they live (streams, wetlands, riparian areas, and uplands) or how they 'make a living' (their biological roles in the community). We discuss wildlife separately because many use a variety of habitats throughout their life cycle.

1.5. ECOREGIONS

The main drivers described in the preceding section can be integrated by classifying landscapes into ecological regions, or 'ecoregions'; "areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources" (USEPA 2007). Many different classifications exist (e.g., USEPA, USFS, NRCS, WAGAP[2]) have developed systems to suit various purposes[3].

In one system, Newaukum Creek exists within the Pacific Coastal ecoregion. This ecoregion runs from southeast Alaska to northern California, and is bounded to the east by the Cascade and Coastal mountain ranges (Naiman and Bilby 1998). In this report, we refer to classifications developed by the Environmental Protection Agency (EPA) to achieve finer spatial resolution (see below; Omernik 1987; Pater et al. 1998).

The EPA mapped ecoregions across North America and classified them into four hierarchical levels of increasing complexity and detail (i.e., Levels I, II, II, IV). We focus on Level III and IV regions which allow identification of locally defining characteristics and formulation of specific management strategies. Level IV classifications identify "potential natural vegetation," which facilitates characterization of historic conditions, in lieu of other data.

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[1] Here we use the term 'resources' in reference to the energy and materials (and space) in the environment used by organisms (mostly plants and animals) to support their growth, maintenance, and reproduction.

[2] U.S. Environmental Protection Agency (USEPA), U.S. Forest Service (USFS), National Resources Conservation Service (NRCS), Washington Gap Analysis Program (WAGAP).

[3] See comparison summary of three systems on Native Seed Networks web page: http://www.nativeseednetwork.org/article_view?id=27 (note: does not include WAGAP ecoregions in summary).

Newaukum Creek contains two Level III and three Level IV ecoregions[4] (Table 1). The Puget Lowlands Ecoregion is defined as having the following distinguishing characteristics (EPA 2002):

> This broad rolling lowland is characterized by a mild maritime climate. It occupies a continental glacial trough and is composed of many islands, peninsulas, and bays in the Puget Sound area. Coniferous forest originally grew on the ecoregion's ground moraines. outwash plains, floodplains, and terraces. The distribution of forest species is affected by the rainshadow from the Olympic Mountains.

In contrast, the Cascades Ecoregion has other distinguishing characteristics (U.S. EPA, 2002):

> This mountainous ecoregion is underlain by Cenozoic volcanics and has been affected by alpine glaciations. It is characterized by steep ridges and river valleys in the west [Newaukum Creek is here], a high plateau in the east, and both active and dormant volcanoes. Elevations range upwards to 4,390 meters. Its moist, temperate climate supports an extensive and highly productive coniferous forest. Subalpine meadows occur at high elevations.

Table 1. Characteristics of Level III and IV ecoregions represented in the Newaukum Creek basin.

Level III Ecoregion (Omernik 1987)*	Level IV Ecoregion (Pater et al. 1998)	Physiography	Elevation (ft)	Potential Natural Vegetation	Land Use and Land Cover (current conditions)
Puget Lowland Region	Eastern Puget Riverine Lowlands	Floodplains and terraces with meandering rivers, oxbow lakes, and meander scars. Freshwater and estuarine wetlands	0-800	Western redcedar, western hemlock; some red alder, black cottonwood, bigleaf maple, Sitka spruce.	Crop and pastureland (e.g., reclaimed wetland); some riparian deciduous woodland, coniferous forests, wetlands; rural/residential/suburban/urban/ industrial activity
	Eastern Puget Uplands	Rolling moraines and foothills with lakes and sinuous streams and rivers	0-2677	Western hemlock western redcedar; some Douglas-fir.	Douglas-fir/western hemlock forests. Forestry, pasture and cropland, rural residential/suburban/urban development
Cascade Region	Western Cascades Lowlands and Valleys	Westerly trending ridges and valleys with reservoirs and medium gradient rivers and streams. U-shaped, glaciated valleys in the east	800-4000	Western hemlock, western red cedar, Douglas-fir.	Douglas-fir/western hemlock/western redcedar/vine maple/red alder forests are widespread. Forestry and recreation are important land uses and pastureland occurs in lower valleys

[4] The EPA mapped ecoregions across North America and classified them into four hierarchical levels of increasing complexity and detail (i.e., Levels I, II, II, IV). We focus on Level III and IV regions which allow identification of locally defining characteristics and formulation of specific management strategies. Level IV classifications identify “potential natural vegetation”, which facilitates characterization of historic conditions, in lieu of other data.

1.6. LIMITATIONS

This report represents our best attempt to synthesize the existing knowledge of the Newaukum Creek basin within existing constraints, but is not without substantial limitations, omissions, and speculations. Whereas general patterns in climate, geology, topography, land cover and hydrology are well-documented, substantial uncertainty remains in the physical condition of specific locations, especially in regards to stream and wetland habitats and the distribution and abundance of the plants and animals that inhabit them. Much of this uncertainty can be attributed to three interrelated factors: (1) time constraints; (2) difficulties in reaching private landowners to request permission to conduct field studies on private lands; and (3) some landowners that were contacted refused to grant permission to study their lands. Accordingly, we provide clear statements regarding data quality and identify significant uncertainty where it exists (see the summary for a synthesis).

Management agencies and local landowners both possess considerable, but incomplete knowledge of the rivers, lands, and wildlife. A more complete understanding of the basin will require coupling field surveys that meet established scientific standards with the unique local knowledge and long-term perspective of basin residents and landowners. This coupling is needed for the following reasons:

- To improve the level of scientific rigor in future assessments;
- To better reflect the extent of the local knowledge base and history of the basin;
- To ensure future management actions are biologically effective; and
- To ensure restoration dollars are spent wisely.

Additional work is necessary. In the meantime, we suggest using an appropriate level of deliberation when enacting new strategies based on the information herein.

2.0. CLIMATE

Climate (temperature and precipitation, for example) influences the distribution of plants and animals and shapes basin hydrology. Regional climate patterns are typified by relatively warm and wet winters and cool, dry summers. Climate within Newaukum Creek basin varies along an elevation gradient. In general, precipitation increases from the Ravine towards the Upper Basin, whereas mean annual temperatures decline. Details are provided in Sections 2.1 and 2.2. below.

Table 2. Average seasonal air temperatures for the Plateau.

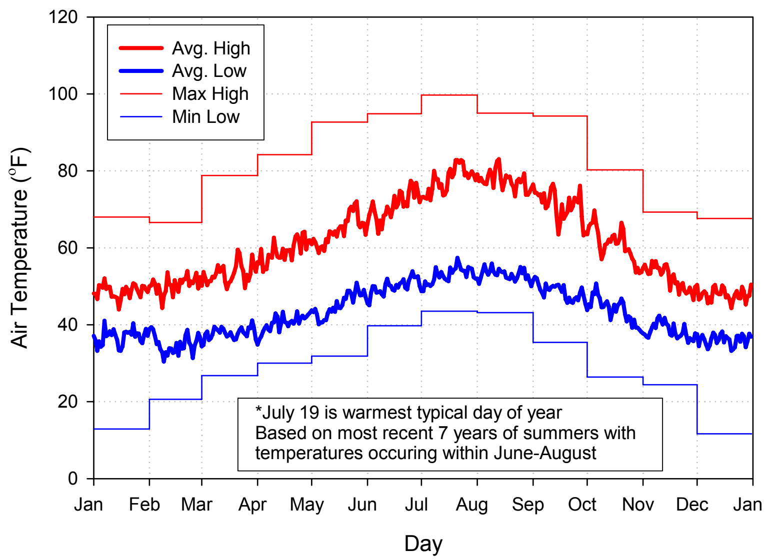
Season	Max (˚F)	Min (˚F)
Winter (Dec-Feb)	49	36
Spring (Mar-May)	59	41
Summer (June-Aug)	75	52
Fall (Sept-Nov)	61	44

2.1. TEMPERATURE

Mean annual air temperature is 52.2˚F, based on observations from a station[5] on the Plateau. Mean seasonal temperature extremes range from a low of 36˚F in winter to 75˚F in summer (Table 2). Within-day temperature fluctuations are very similar among spring and fall, though exceed 23˚F in summer (Fig. 3).

Mean annual temperatures in the Newaukum Creek basin are expected to rise in the future. The period of record (1999-2006) is obviously insufficient to conduct climatic trend analyses for Newaukum Creek basin, alone. However, regional climate forecasting efforts, including the work of the University of Washington Climate Impacts Group[6] indicate a continued trend of regional warming.

Figure 3. Seasonal variation in mean maximum (red) and minimum (blue) daily temperatures (bold lines) in the Newaukum Creek basin. Historical monthly maximum and minimum temperatures are depicted as thin lines. Note that the annual maximum temperature will occur on July 19, on average, whereas this is estimated to occur in the first week of August when longer term records from Sea-Tac are used.



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[5] King County monitoring station 44U is located near the foothills east of Enumclaw (see Fig. 5). Near real-time data is available at (http://dnrp.metrokc.gov/WLR/Waterres/hydrology/DataDownload.aspx?G_ID=656).

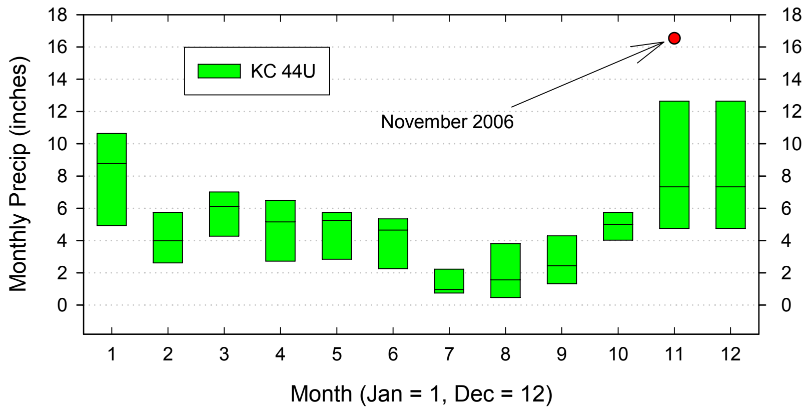
[6] (http://www.cses.washington.edu/cig/)

2.2. PRECIPITATION

Rain is the dominant form of precipitation in Newaukum Creek basin, though snow plays an important role in the upper basin near Boise Ridge. The amount and form of precipitation is strongly influenced by air temperature and 'orographic effects' caused by the Cascade foothills.

Total monthly precipitation ranges from a low of 0.33 inches (July) to a high of 13.8 inches (January) (Fig.4). The maximum amount measured in any month over the period of eight years occurred during November 2006, when massive storms consistently set historical records around the Puget Sound region.

Figure 4. Monthly precipitation observed at King County Gauge 44U. Box plots depict the median (50th) and 25th/75th percentiles of monthly precipitation volumes. The red dot indicates the total precipitation for November 2006, which was the highest on record.

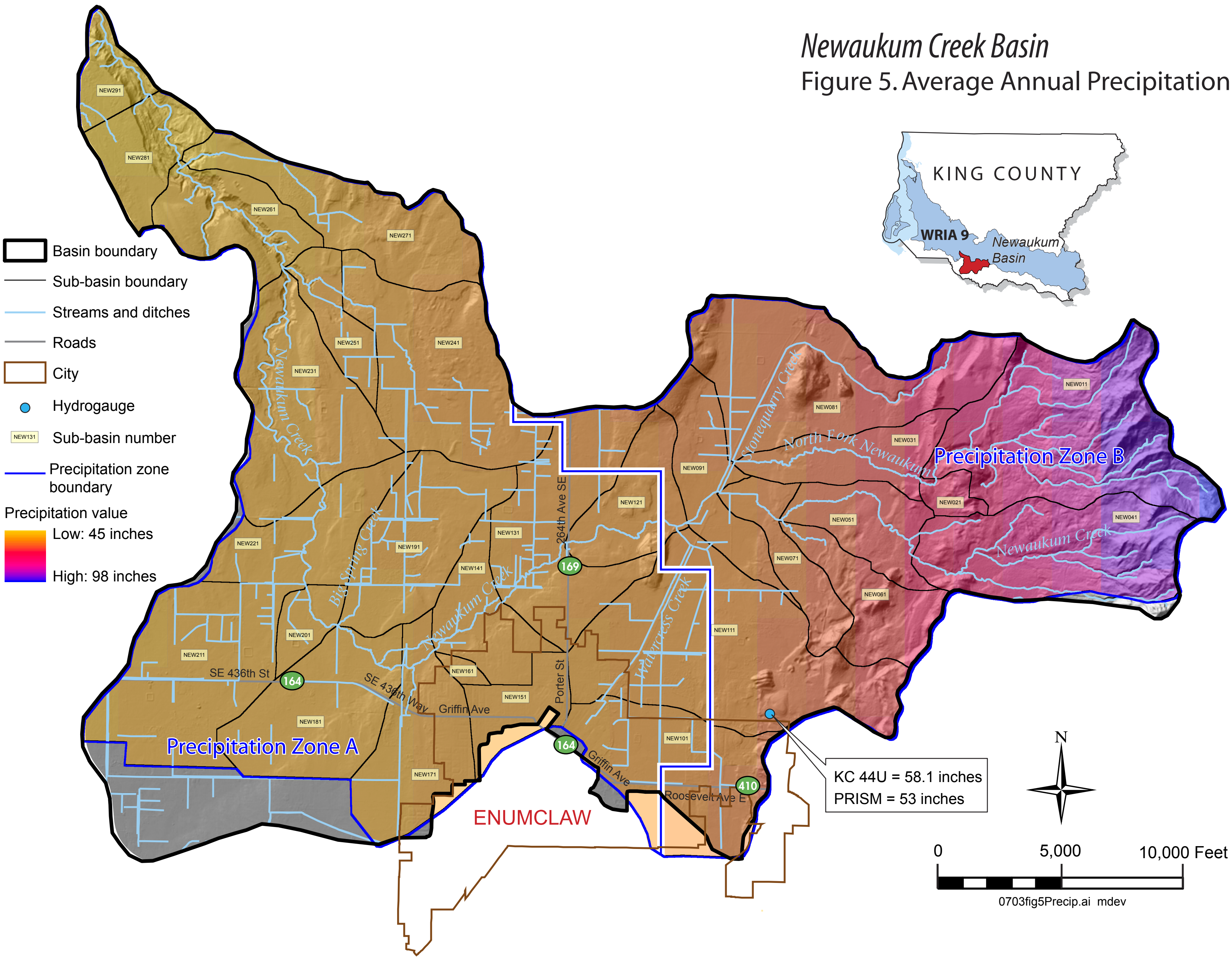


Mean annual precipitation at King County gauge 44U (Fig.4) was 58.1 inches. Unlike air temperature, precipitation levels in the Newaukum Creek basin are *not* similar (i.e., 49% greater) to those at Sea-Tac, where annual precipitation is only 39 inches.

The weighted basin average annual precipitation[7] is 54.5 inches though annual levels vary widely within the basin according to the proximity of the Cascade mountain range (Fig. 5). Estimates for mean annual precipitation volumes for coincident locations differ by 10%. We attribute this divergence to differences in the period of record among the data sources used to compute weighted basin averages. PRISM estimates are based on a period of record 1971-2000, whereas King County records used in this analysis range from 10/1/1998 through the end of water year 2006 (i.e. 9/30/2006).

---

[7] Significant efforts have gone into quantifying spatial variation in the magnitude of rainfall; taking into account most known and quantifiable influences on climate. The Oregon climate group known as PRISM (not to be mistaken with UW PRISM consortium; http://www.prism.washington.edu/), staffed by Oregon State University personnel, is a regional leader in this technology (http://www.ocs.orst.edu/prism/index.phtml). They have analyzed and estimated variations in annual precipitation quantities throughout the United States.



Newaukum Creek Basin
Figure 5. Average Annual Precipitation
KING COUNTY
WRIA 9
Newaukum Basin
Basin boundary
Sub-basin boundary
Streams and ditches
Roads
City
Hydrogauge
Sub-basin number
Precipitation zone boundary
Precipitation value
Low: 45 inches
High: 98 inches
Precipitation Zone A
Precipitation Zone B
ENUMCLAW
KC 44U = 58.1 inches
PRISM = 53 inches
N
0
5,000
10,000 Feet
0703fig5Precip.ai mdev
Newaukum Creek
Big Spring Creek
Stonequarry Creek
North Fork Newaukum
Watercress Creek
SE 436th St
SE 436th Way
Griffin Ave
Porter St
264th Ave SE
Roosevelt Ave E
169
164
410

Six percent of the Newaukum Creek basin receives seasonal snowfall (i.e., where elevation exceeds 1,500 ft) and is therefore sensitive to hydrological impacts of regional warming trends. Storms that drop rain on existing snowpacks (i.e., rain-on-snow events) will likely become more frequent in these areas. This would amplify the annual number of storm run-off events, which also affect downstream areas along the stream. Moreover, higher elevations that would normally retain snow cover through May or June will lose their snowpack earlier, and higher spring flows, and lower summer flows would result. However, given the small percentage of the basin in those higher elevations, these phenomena likely will be less significant than in the greater Green River watershed, where snowmelt runoff is more important.

3.0. GEOLOGIC SETTING

The geologic setting – including the character and arrangement of both bedrock and non-lithified sediment – influences topography, soil development, drainage patterns, and erosional and depositional processes. The geology of the Newaukum Creek watershed includes volcanic rock in the Upper Basin, glacial and volcanic mudflow deposits across the Plateau and alluvial sediments near the mouth. Note that soils are discussed in Section 8.

3.1. BEDROCK GEOLOGY

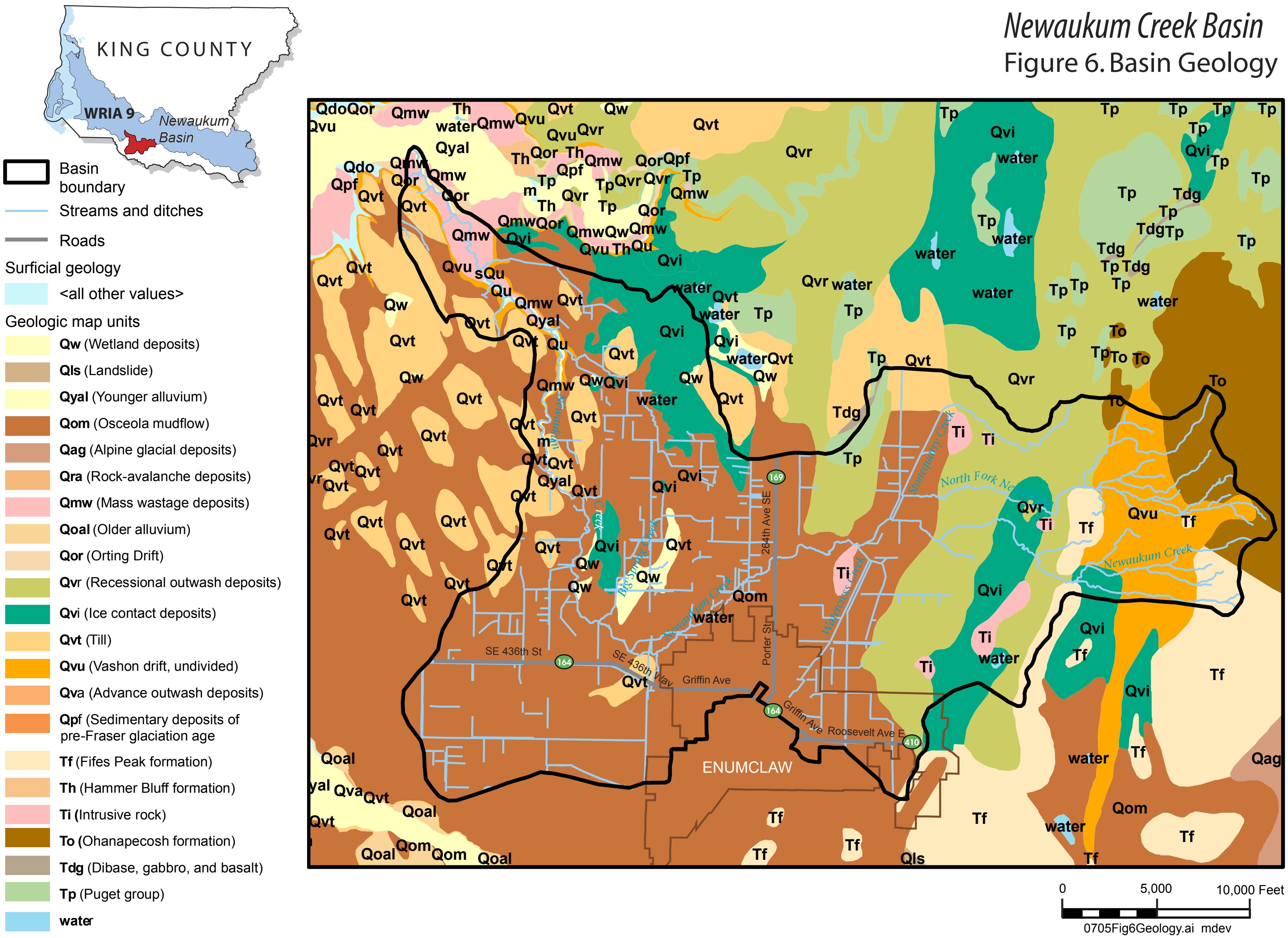
Newaukum Creek basin originates on the western slopes of Boise Ridge (elevation 2,980 ft), which is entirely composed of volcanic rocks. These rocks have been divided into two geologic units; the Fifes Peak and Ohanapecosh formations (Tabor et. al., 2000) (Fig. 6). The Fifes Peak formation consists primarily of andesite, a dark gray porphoritic rock characteristic of Cascade volcanos. The Ohanapecosh consists of volcaniclastic rocks including tuff[8] and volcanic breccia[9], rocks that form during explosive volcanic eruptions. A number of prominent bedrock knobs protrude through Quaternary deposits (Fig. 7) on the eastern side of the Plateau (west of Boise Ridge). These knobs are composed of andesite which is locally quarried for crushed rock and rip-rap.

[8] Rock composed of the finer kinds of volcanic detritus usually fused together by heat.

[9] A rock composed of sharp fragments embedded in a fine-grained matrix

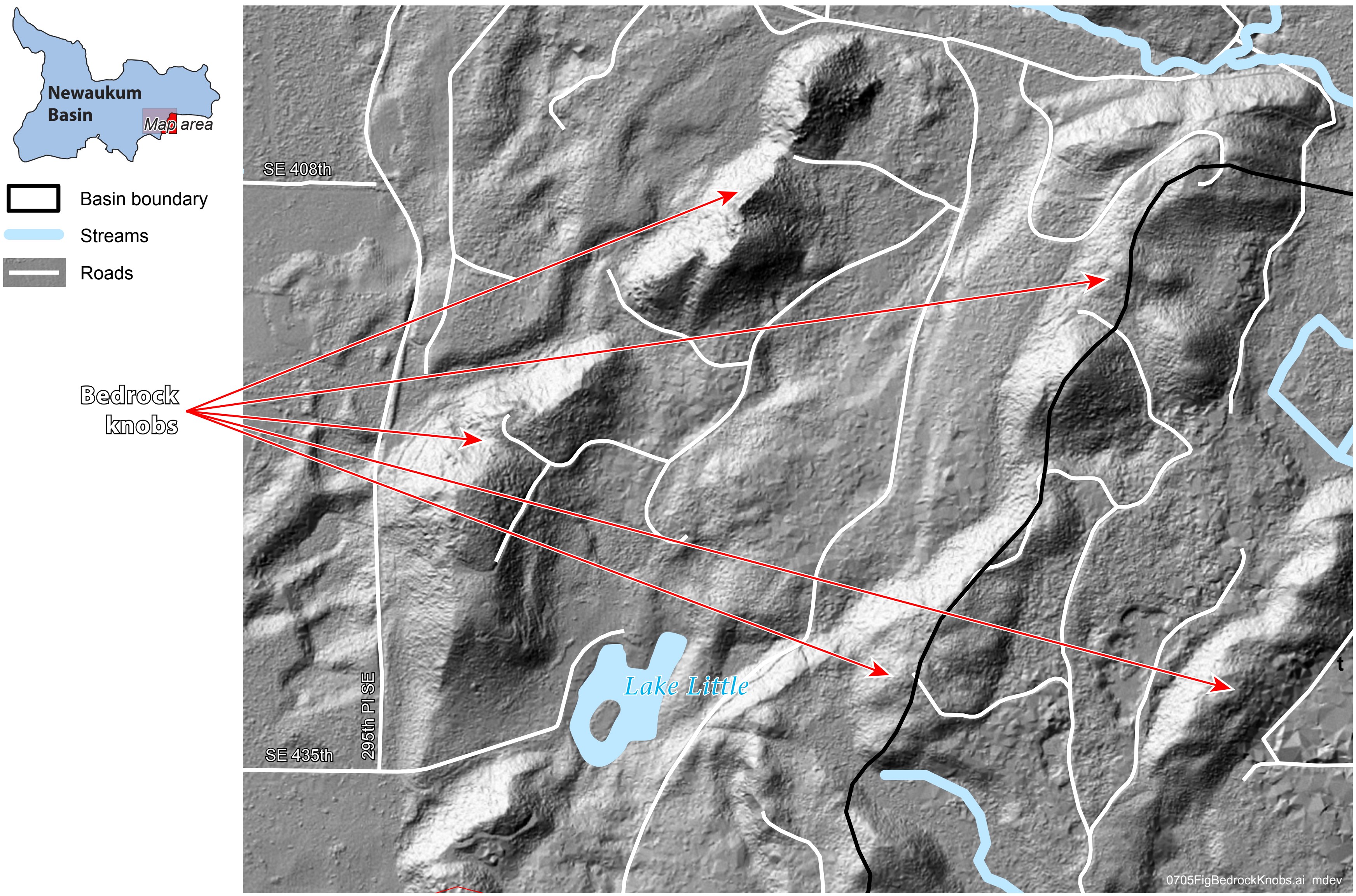
Newaukum Creek Basin

Figure 6. Basin Geology



Newaukum Creek Basin

Figure 7. Glacially Sculpted Bedrock Knobs Near Boise Ridge



3.2. QUATERNARY GEOLOGY - GLACIAL AND POST-GLACIAL DEPOSITS

The Puget lowland, including the Newaukum Creek basin has been covered by *continental glaciers* repeatedly during the Quaternary Period, which lasted from approximately 1.8 million to 8,000 years ago. These glaciers formed in the mountains of British Columbia and Vancouver Island and extended south, filling the Puget Lowland between the Olympic and Cascade Mountains, stopping near where the City of Olympia now exists.

The Vashon Stade of the Fraser Glaciation was the most recent of these glacial advances, reaching a maximum extent approximately 17,000 BP (before present), but persisted less than a thousand years in the Enumclaw area (Porter and Swanson, 1998). During the Vashon advance glacial ice reached a maximum elevation of approximately 2300 ft in the Enumclaw area (700 m) (Thorson, 1980). As the ice sheet extended and retreated, it formed sculpted bedrock exposures and transported and deposited sediments, forming advance outwash, glacial till, ice-contact deposits, and glacial recessional deposits, which are explained below.

As the Vashon glacier was advancing south into the Puget lowland, a broad expanse of sandy sediment was deposited in front of the ice as it moved forward. These sediments were subsequently over-ridden by the ice sheet and covered by other sediments as the glacier continued to move south. In the Newaukum basin, this deposit, called (Vashon advance outwash (Qva)) is only visible in limited exposures on the walls of the Ravine along lower Newaukum Creek, but probably underlies much of the Plateau.

As the glacier continued to move south distinctive sediment called glacial till (Qvt) was deposited directly at the base of the ice. Glacial till, commonly known as hardpan, is a dense, poorly sorted mixture of silt, sand and gravel that is relatively impervious to water. Till underlies much of the ground surface in the western portion of the Plateau.

At the glacial maximum, and especially as the glacier began to retreat, wedges of sediment would accumulate between the glacial ice and the adjoining hillsides. These texturally heterogeneous deposits formed are called ice-contact deposits (Qvi) They locally show evidence of collapse and displacement resulting from melting of the adjacent ice. Below its volcanic headwaters, Newaukum Creek crosses an irregular bench composed of Vashon-age ice-contact sediments (Qvi) at the base of Boise Ridge.

More than 10,000 years after Vashon glacial retreat the White River valley and surrounding areas, including the Enumclaw area were buried under sediment carried by the Osceola mudflow. This massive volcanic mudflow (or lahar) occurred approximately 5600 years ago. Starting as a landslide on the northeast flank of Mt. Rainier, the mudflow grew to an estimated volume of one cubic mile (3.8 km^3) as it traveled down the White River Valley. Transported material filled the White River Valley upstream of the present Mud Mountain Dam to a depth of 450 feet above the present valley bottom (Crandell, 1971). When the mudflow reached the approximate location of modern dam site it overflowed the White River valley walls and spilled north toward the Green River. Much of the ground surface on the Plateau is directly underlain by sediment deposited during this event. The mudflow deposits consist of gravel to boulder-sized clasts of Mt. Rainier volcanics, largely andesite in a fine-grained, clay-rich matrix.

After crossing the Osceola mudflow on the Plateau, down through the Ravine, Newaukum Creek flows onto floodplain deposits of the Green River. These floodplain deposits extend from the confluence to a point roughly 1200 feet upstream. The modern Creek traverses floodplain that is forested and appears static. However, much of the ground surface underlying this section of the creek consists of gravelly alluvium that was once a part of the (then wider) active channel of the Green River, prior to completion of Howard Hansen Dam in 1961 (see Appendix B, Fig. B1).

4.0. TOPOGRAPHY AND LANDFORMS

Topography generally influences microclimatic variation, soil development, hydrology, sediment routing, and the distribution of organisms. Topographic relief in the Newaukum Creek basin is most pronounced (steep and uneven) in the upper basin, relatively level and even across the Plateau, and steep and uneven throughout the v-shaped ravine. Elevations range from 153 ft at the mouth to 2,980 ft along Boise Ridge, with an average elevation for the basin estimated at 825-feet. Basin aspect is strongly oriented toward the west. Landform refers to the shape of landscape-scale topographic features. Landforms reflect both the structure and composition of the underlying geology, and sculpting of the land surface by past and ongoing geomorphic processes.

4.1. GLACIAL LANDFORMS

Continental glacial ice occupying the Enumclaw area was the primary architect of the present land surface, smoothing and scouring exposed bedrock, mantling broad expanses with glacial deposits, then eroding these deposits streams of glacial meltwater. As described glacial till deposited by glacial ice directly at the base of the glacier. Broad areas of till deposition are often sculpted into a pattern of low, streamlined hills known as drumlins. A well-developed drumlin field covers much of western portion of the Plateau (Fig. 8).

The intricate, rounded bedrock topography at and west of the base of Boise Ridge (Fig. 9) is similar in both character and landscape position to topography east of the Snoqualmie River described by Booth and Hallet (1993). These authors ascribe the formation of this distinctive topography to erosion by sub-glacial meltwater streams. The similarity between the two areas suggests a similar origin for this landform in the Enumclaw area.

There is clear evidence of a large glacial meltwater stream system that flowed south along the base of the Cascade foothills in this area during the glacial retreat. In addition to leaving the gravelly outwash deposits described previously described, relict glacial meltwater channel remnants are also preserved. The Veazy Valley is a relict meltwater channel, and smaller channels (some partially buried by subsequent mudflow deposits) are common across the Plateau.

Figure 8. Map of drumlins on the Plateau.

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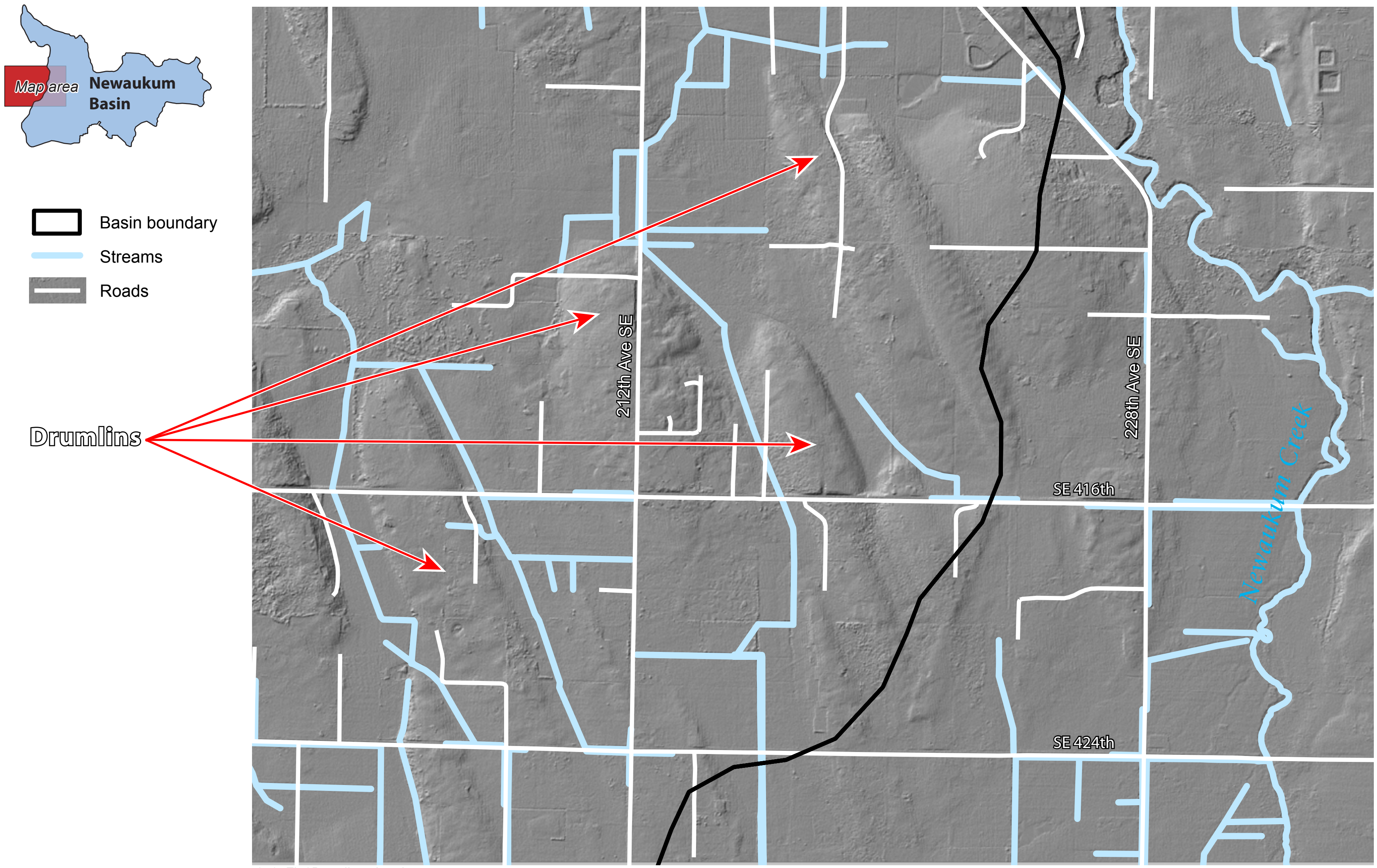
Newaukum Creek Basin

Figure 8. Drumlins on Plateau



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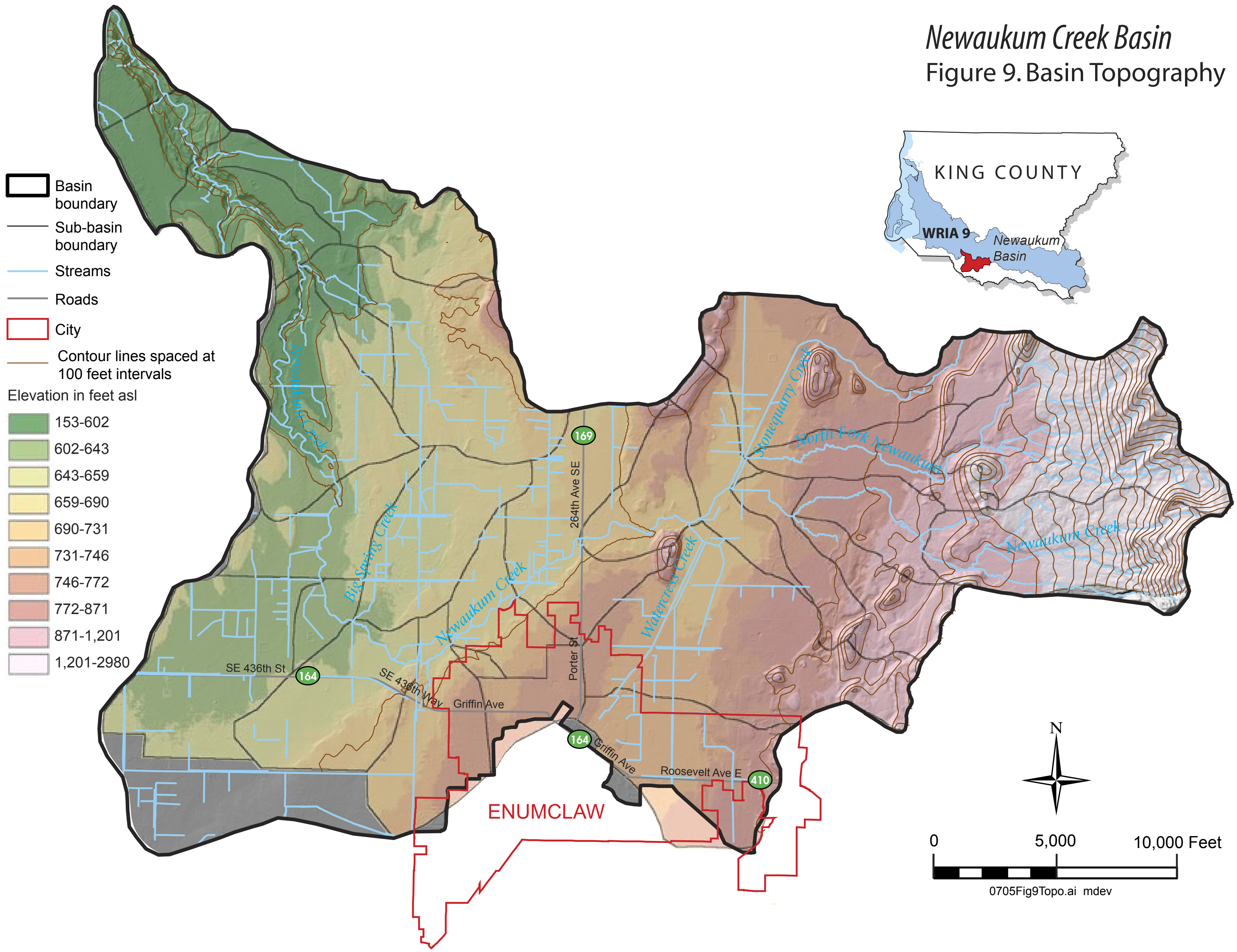
Newaukum Creek Basin
Figure 9. Basin Topography



4.2. POST-GLACIAL LANDFORMS

Post-glacial processes also created prominent and distinctive landforms in the Newaukum basin. The most extensive such post-glacial landform is the extensive planer surface created by the Osceola Mudflow. The mudflow surface forms most of what is locally known as the Plateau. The surface of the mudflow slopes gently to the northwest reflecting the flow direction of the saturated volcanic sediment. The mudflow surrounded some preexisting glacial features leaving only the top of these features exposed (Plate 4.1).

Plate 4.1. Drumlin exposed above Osceola mudflow deposits.

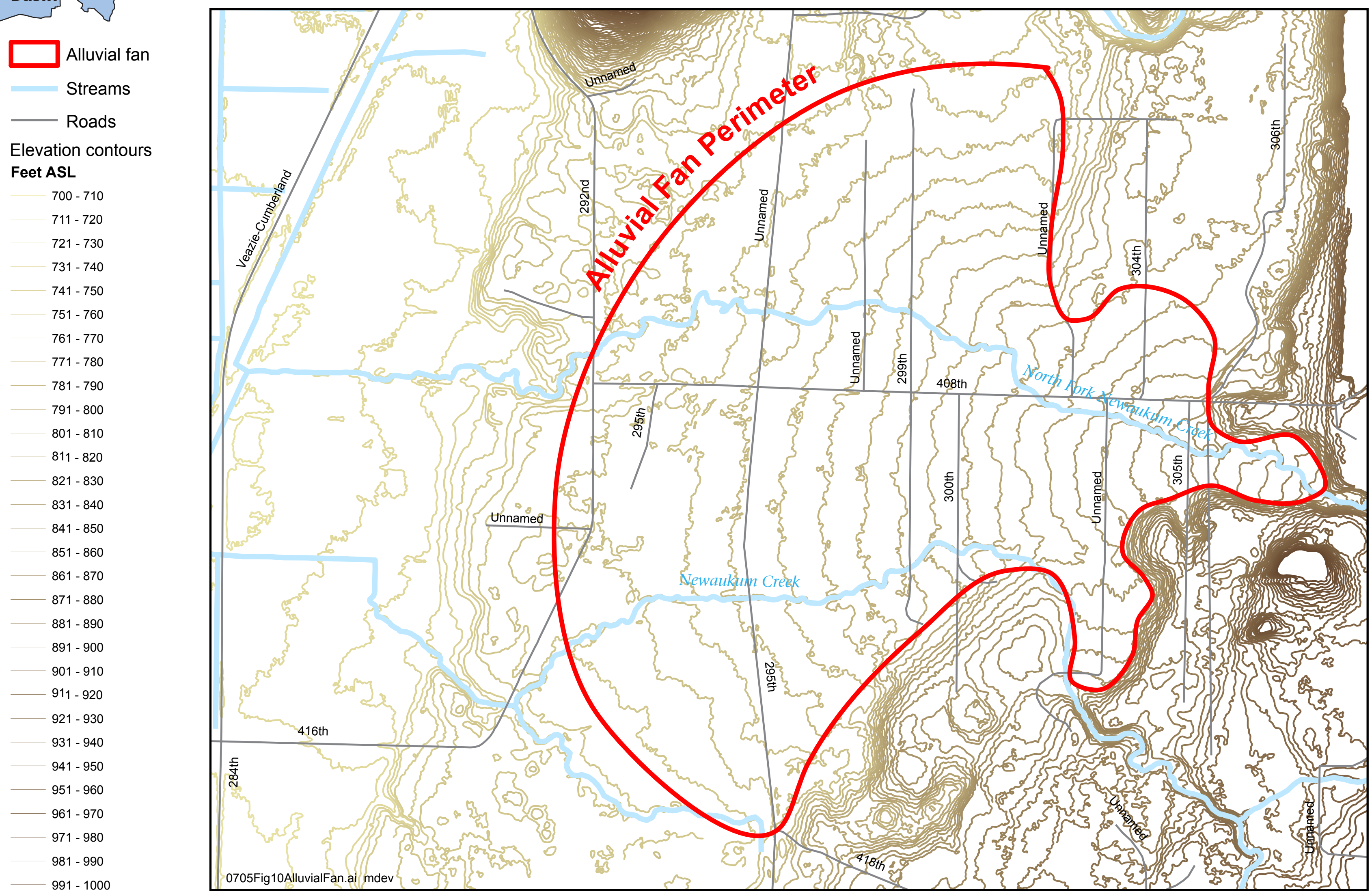
In post glacial time Newaukum Creek and its tributaries have constructed substantial alluvial fans at the slope break near the base of Boise Ridge (Fig. 10). Alluvial fans are sediment deposits that occur where a stream flows from an area of steep topography to an area of subdued topography. Sediment deposition occurs in these locations because the downstream decrease in gradient reduces the streams' ability to transport sediment any further. These fans remain areas of modern sediment deposition, channel migration and flooding (Plate 4.2).

Plate 4.2. Evidence of over-the-road flooding

Between river miles 1.8 and 0.2 Newaukum Creek flows through a landscape dominated by landslide topography (Figure 11). Through this section of the Newaukum Ravine the jumbled, hummocky topography clearly reflects a history of massive landslide movement.

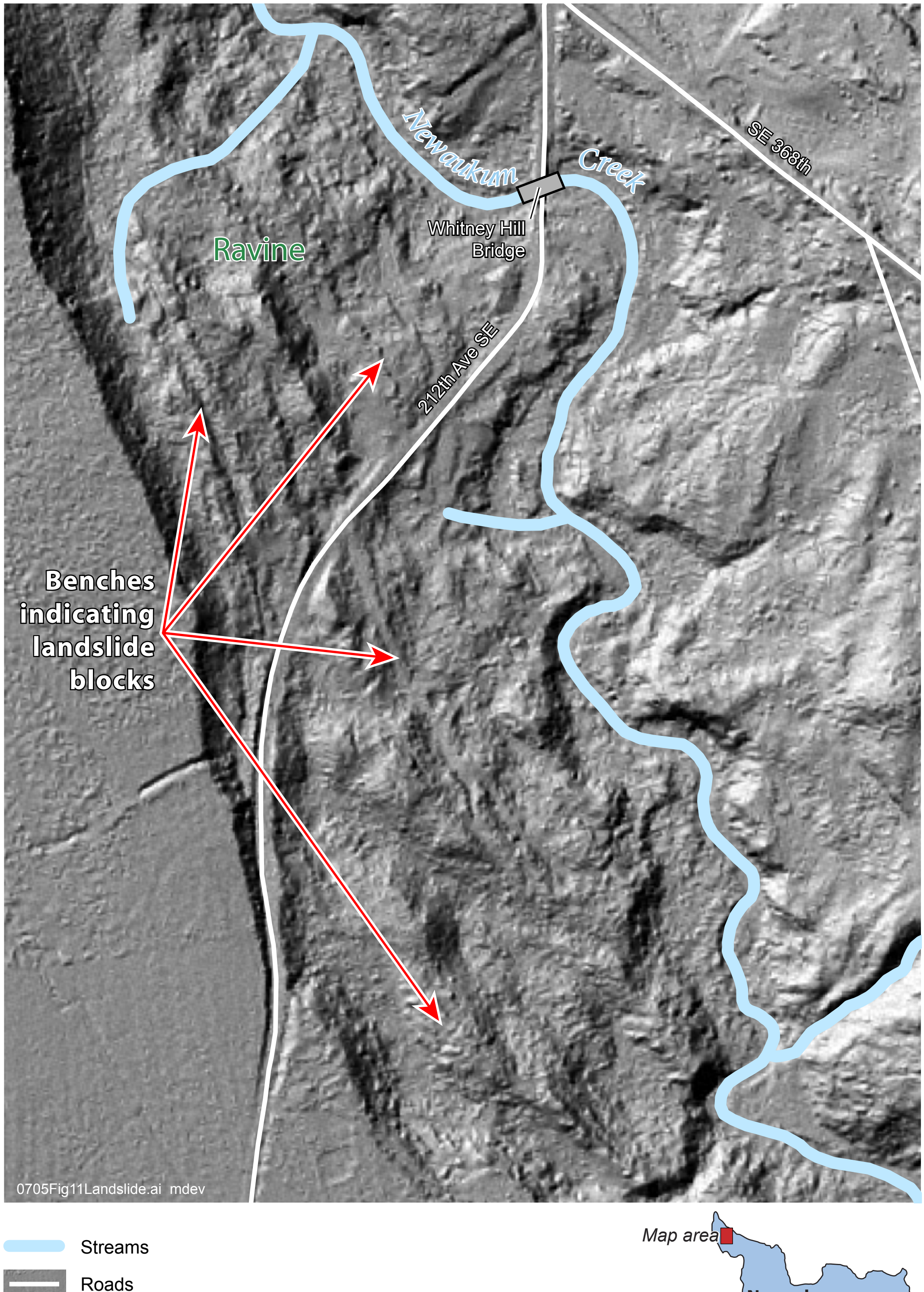
Newaukum Creek Basin

Figure 10. Alluvial Fan on the North Fork of Newaukum Creek



Newaukum Creek Basin

Figure 11. Landslide Topography in the Ravine



5.0. TIME

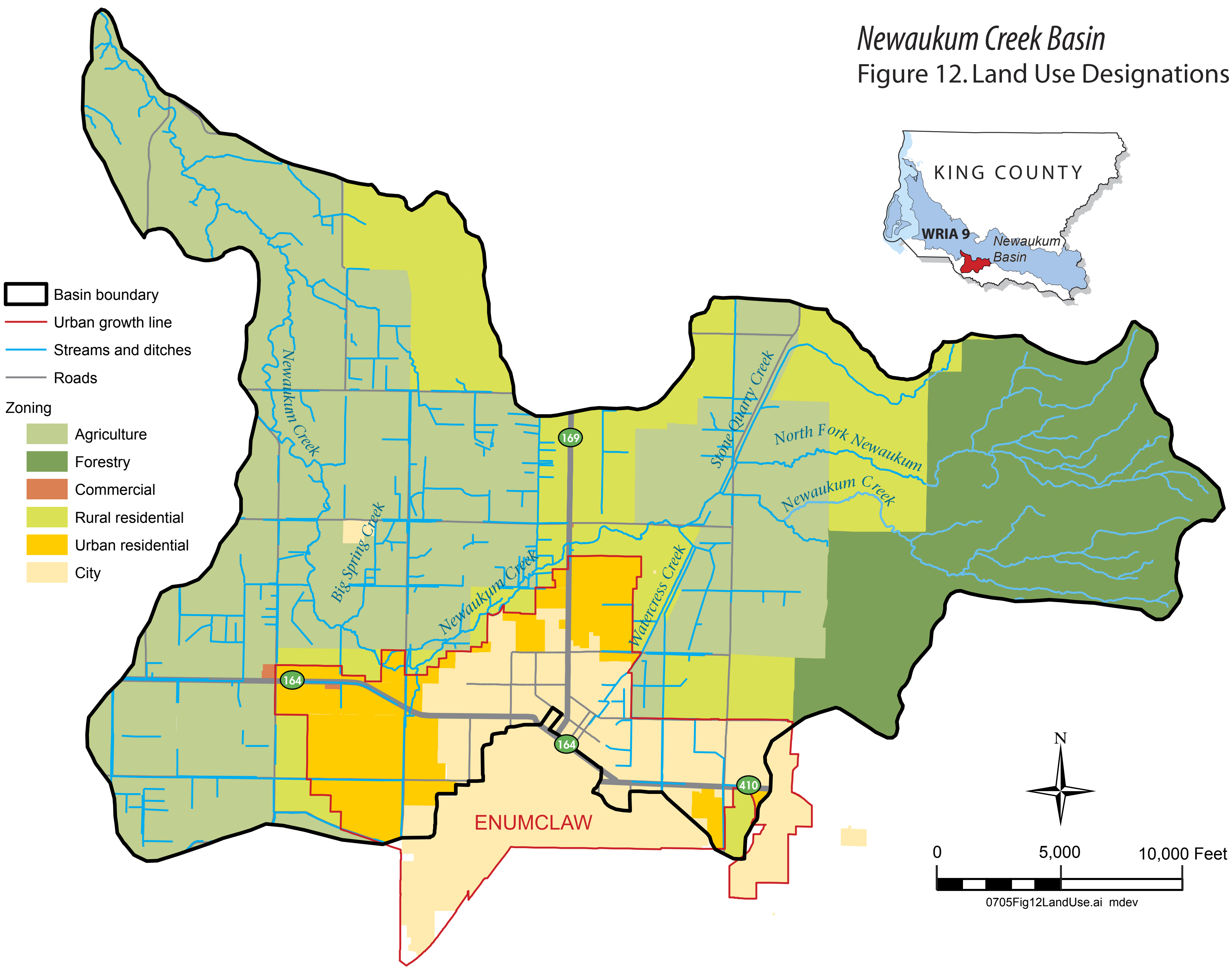
In a general sense, time (as a state factor) refers to the time elapsed since a system either began forming, or was last reset (by a major disturbance, for example). For our purposes, we address the importance of time by considering the implications of site-specific history of the Newaukum Creek basin.

Both natural and human-related historical events were pivotal in shaping the current condition of Newaukum basin. Significant geological and climatic events shaped the current Newaukum Creek basin, as described in Section 3. Puget Sound was covered in thousands of feet of glacial ice 13,000 to 15,000 years ago, which began to retreat 11,000 years ago. Warmer and drier climates existed in the region from 3,000 to 8,500 years ago. The Osceola mud flow occurred 4,800 years ago. Here we focus on the importance of the passage of time from a human perspective, and the consequences for the Newaukum Creek basin.

A long history of human activities has shaped the Newaukum Creek basin. The type, extent, and intensity of these activities varied over time as cultures changed. Cultural inheritance – consisting of technologies, ideas, and philosophies passed to later generations - is recognized as an important influence on ecosystem processes (Admundson and Jenny 1997). In the past 100 years intensive human activities and the changes that result have greatly accelerated. These activities potentially affect all of the processes that shape ecosystems, and they reflect long-term changes in technology, land ownership patterns, jurisdictions, designated land uses, as well as the current characteristics and interests of the human population. Examples of intense human activity include the leveling of the land for buildings and farms, forest clearing, diking and channelizing streams, ditching and draining wetlands, snagging of wood from streams, and many others. Humans alter disturbance regimes (by suppressing fire, for example), species composition (through agricultural production), and create human-made habitats (e.g., ditches, agricultural fields, lagoons).

The most significant change is the transformation of native forests to timber plantations, agricultural lands, and residential areas (Fig. 12). However, the landscape also reflects more subtle influences, including a long history of social, economic, and legislative changes. The history of the basin includes the important events and milestones (this is only a partial list):

- Native American populations have existed in Puget Sound for at least 8,000 years (Kruckeberg 1991).
- Initial forest surveys were conducted in spring and summer of 1792 by Archibald Menzies (Kruckeberg 1991).
- The first lumber mill in Washington was erected in 1827 by the Hudson's Bay Company (Kruckeberg 1991).
- Game laws were first passed in 1853, when Congress created the Territory of Washington and Henry Yesler built a steam-powered mill on Puget Sound (Kruckeburg 1991).
- The City of Enumclaw was homesteaded in 1879 by Frank and Mary Stevenson, and was platted for the first time in 1885.



Newaukum Creek Basin
Figure 12. Land Use Designations
KING COUNTY
WRIA 9
Newaukum Basin
Basin boundary
Urban growth line
Streams and ditches
Roads
Zoning
Agriculture
Forestry
Commercial
Rural residential
Urban residential
City
Newaukum Creek
Big Spring Creek
Stone Quarry Creek
North Fork Newaukum
Watercress Creek
169
164
410
ENUMCLAW
N
0
5,000
10,000 Feet
0705Fig12LandUse.ai mdev

- Washington became the 42nd state of the United States in 1889.
- The first salmon hatcheries (in the Puget Sound region) were built in 1895, eight years after the Northern Pacific railroad was linked to Puget Sound, and only six years after Washington State was admitted to the Union.
- Drainage districts were authorized in 1895 and later modified by a series of related acts in 1909, 1913, 1917, and 1961[10]. This enabled any portion of a county, requiring drainage, which contains five or more inhabitants to be organized into a drainage district.
- Two years after hatcheries were first built, Alaskan gold fueled an economic boom in the region, beginning in 1897.
- By the 1900's, major logging operations were underway in Puget Sound, utilizing new patch cut and clear-cut techniques (Kruckeberg 1991).
- City of Enumclaw becomes incorporated on January 27, 1913.
- The Washington Department of Game (now W. Dept. of Fish and Wildlife) was created in 1933 (Kruckeberg 1991).
- The Flood Control District Act was passed in 1937. This created districts for the protection of life and property, the preservation of the public health and the conservation and development of the natural resources.
- The W. Department of Natural Resources was created in 1957 (Kruckeberg 1991)
- In 1961, the Flood Control Zone District Act allowed the designation of zones for the purpose of undertaking, operating, or maintaining flood control projects or storm water control projects or groups of projects that are of special benefit to specified areas of the county.
- Federal environmental protections began in 1969 with the establishment of the National Environmental Protection Agency.
- The W. Department of Ecology was created in 1970 (Kruckeberg 1991).
- Federal protection of threatened and endangered species was substantially strengthened in 1973 by the enactment of the Endangered Species Act.
- Judge Boldt upheld Indian fishing rights of 1855 treaties in 1974, making tribes co-managers of fisheries.
- Water quality impacts from livestock manure were assessed beginning in the early 1970's and in 1984 by Washington Department of Ecology and the Conservation District.
- Aquifer Protection Areas were permitted by law in 1985.
- King County Sensitive Areas Ordinance went into effect in 1986.
- Ordinance 7590 was adopted in 1986, establishing a comprehensive surface water management program in King County in response to growing concern over the impact of surface water runoff on flooding, erosion, and environmental quality. This program was

[10] http://www.doh.wa.gov/survey/Special_purpose.htm

funded by the Surface Water Management (SWM) fee, paid by property owners in unincorporated King County.

- The “Timber, Fish, and Wildlife” rule package created in 1987 established Riparian Management Zones (RMZ) and associated rules for buffers around streams in timber operations. These rules became effective for the first time January 1, 1988. This plan or agreement was used as the basis for a 2005 application for a programmatic, statewide Habitat Conservation Plan for forestry on state and private lands.
- Dairies in Newaukum Creek basin began constructing manure lagoons to reduce water quality degradation.
- Northern spotted owls received federal protection under the Endangered Species Act in 1990.
- Growth Management Act was passed in 1990 with the aim of improving coordination and comprehensiveness of land use planning.
- The SWM program was extended in 1991 and reorganized in 1997 to address the legal requirements of King County’s NPDES Municipal Stormwater Discharge Permit, granted by the Washington State Department of Ecology and the federal government.
- The Critical Areas Ordinance is passed in 1996, replacing the SAO.
- Puget Sound Chinook salmon and bull trout were designated as ‘threatened’ in 1999.
- In 1999, the Forest and Fish Act was passed and in 2001, the Forest Practices Board adopted the rules.
- The Forests and Fish plan was approved by federal authorities in 2006 and is currently affects forestry in the Upper Basin of Newaukum Creek[11]. Riparian buffers are a featured element of this agreement. A forested buffer of variable width and is mandated to remain around certain streams.
- Steelhead were designated as ‘threatened’ in 2007.

In subsequent sections, we incorporate explanations of the importance of historical and current human influences on the current function and patterns in the Newaukum Creek basin. It is also important to consider how future economic and population growth will alter patterns of human activities across the basin.

6.0. DISTURBANCES

The frequency and magnitude (or ‘regime’) of disturbances strongly affects the structure of the ecosystem as well as the rate of ecological processes (Pickett and White 1985). Dominant disturbance processes in the Newaukum Creek basin include fire, floods, mass-wasting, wind, and insect infestations. Humans have strongly altered the fire regime through fire suppression and forest clearing, and have altered the flooding regime through stormwater management, wetland destruction, and the transformation of the channel network.

We explain – in general terms – the historical regime of each major type of disturbance typical of the Newaukum Creek basin. We also briefly speculate about the likely long-term

[11] http://www.dnr.wa.gov/htdocs/agency/federalassurances/

consequences of human alterations to the ‘natural’ disturbance regime. We acknowledge the importance of earthquakes and volcanic eruptions in structuring ecosystems (see Section 3.2). Also, many other human activities can be considered disturbances (road building, for example), but we chose to integrate them into other sections of the report.

6.1. FIRE

Fire was once a dominant natural disturbance in the upland forests of the Newaukum Creek basin. Fire is considered the primary natural disturbance type in the Westside Lowlands Conifer-Hardwood Forest wildlife-habitat type (Chappell et al. 2001). Newaukum Creek basin is within the western hemlock (*Tsuga heterophylla*) zone in which the frequency, intensity, and extent of fires vary widely (Agee 1993).

The specific fire history of the Newaukum Creek basin is poorly documented. A large fire occurred in the upper Green River Watershed in 1701 (U.S. Forest Service 1996). It is unclear whether that fire penetrated the Upper Basin. Notes taken during General Land Office (GLO) surveys during 1872 in the area of the Plateau mention that, “The large timber except a narrow belt along the bank of the White River has been entirely destroyed by fire.” Another large fire event occurred in 1899, in the portion of the Green River watershed that is in the Snoqualmie National Forest (Peter 1993). Whether these fires penetrated into the Newaukum Creek basin is unknown.

Most historical fires in the western hemlock zone are attributed to lightning, but some may have been ignited by Native Americans to attract large herbivores by stimulating browse (see Agee 1993). The likelihood of fire ignition in this zone is highest from July through August, and is linked to the occurrence of long-term drought, minor rainfall, thunderstorms, and easterly winds (Agee 1993).

Fires in the western Hemlock zone of the Washington Cascades are episodic – rather than cyclic – and intense. Whereas fire-return intervals[12] are approximately 230 years for Douglas-fir zones, limited evidence suggests that fire-return intervals for western hemlock forests are 750 years – or more (Agee 1993). However, few of these forests have sufficient fire records to ascertain the regularity of a ‘fire cycle’. Burned stands often suffer massive mortality, either from incineration of the crown, or severe scorching from fires in the shrub layer.

In general, forests within this area naturally originate from and are maintained by very infrequent, but massive fires (Agee 1993). However, fires have been actively suppressed for many decades. A continued policy of fire suppression is expected to diminish the prevalence of Douglas-fir in the general western hemlock zone in natural areas. However, this has relatively little bearing on the Newaukum Creek basin, where the most of the upper basin has been converted from natural forests to a high-yield forestry plantation.

6.2. EXTREME FLOWS

Flooding is an important natural disturbance process in streams and riparian areas of the Newaukum Creek basin, and in the Westside Riparian-Wetlands wildlife-habitat type in general (Chappell et al. 2001). This process affects bank erosion, bar formation, soil deposition, and

[12] The fire-return interval indicates the number of years that typically pass between fires at a specific location or in an area of a given size. Essentially, it describes how commonly fire occurs in a particular landscape.

biological activity in riparian forests (nitrogen cycling, decomposition, and seed germination, for example). Human infrastructure is also affected by flooding, such as the incidence and frequency of over-the-road events. We aimed to characterize flood flows, the magnitude, timing, frequency, and duration of base flows and low flows (Poff et al. 1997) are also essential components of the flow regime in Newaukum Creek. Droughts can also have strong impacts on stream organisms.

Flow analyses presented here rely on a combination of observed and simulated data (e.g., for historical comparisons). When appropriate, empirical observations of daily flows from a United States Geological Survey (USGS) gauge near the stream mouth are used for analyses and interpretations. Data from this station extend from the mid-1940's to present.

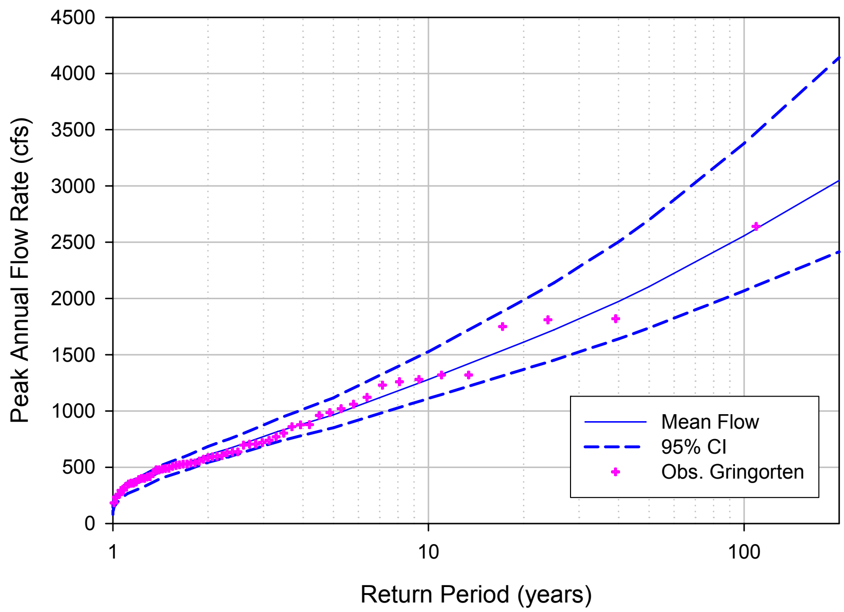
6.2.1. Peak flows

Our analyses indicate peak flow magnitude for 10-yr floods are approximately 1,300 cfs, whereas the 50-yr floods reach 2,100 cfs, and the 100-yr floods may exceed 2,560 cfs (Fig. 13). We quantified flood frequency using the USGS Bulletin 17B (USGS 1981) method, which estimates the magnitude of flows for a given probability of occurrence. Observed data are then plotted with positions based on the number of years of data and their ranking in magnitudes. Comparisons between estimated values and observed peak annual flow rates are useful for evaluating the level of confidence in the estimates (see Appendix A). Flood events are independent among years. Simply stated, there is an equal probability that in any given year a 100-year event (p = 1/100) could occur. However, the probability of 100-year events occurring in two consecutive (i.e., back to back) years is only 1 in 1000 (i.e. = $P_1 * P_2$). Estimating these flow frequencies integrates long-term changes in climate and land cover, allowing us to perform trend analyses and provide insight into how stream flows may be changing over time.

Floods of November 2006

As shown in the Fig. 16, during water year 2006 (10/1/2005 – 9/30/2006) two sets of opposite extreme conditions occurred within the same season. An historical daily high flow occurred in June 2006, and an historical low flow occurred at the end of summer (i.e., early September). Nearly zero precipitation fell from the first week of June though mid-September. If stream flows were not so far above normal in June, stream flows could have very likely been at unprecedented low levels. Note that the response time for stream flows to return to summertime base flow conditions was 10 to 14 days. This implies that flows will typically recover to pre-storm levels (for moderate to large storms) within two weeks.

Figure 13. Flood frequencies at the mouth of Newaukum Creek under historical and current conditions (USGS Station 12108500, 1945-2005).

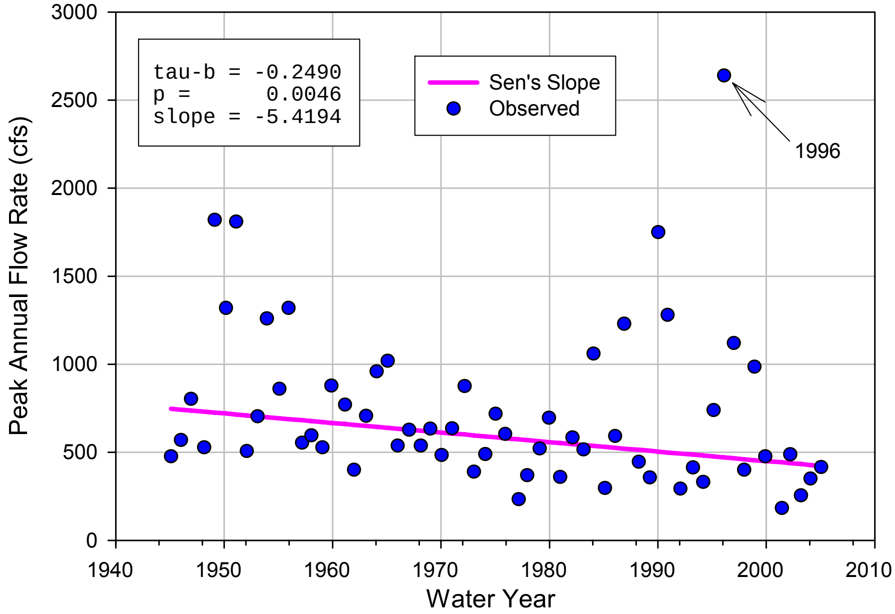


*Observed flow rates are plotted using Gringorten methodology (Gringorten 1963), fitted using 17B with 95-percent confidence intervals. To further elucidate the level of accuracy in estimating flood frequencies, interpreting the range of flows that could be considered the 100-year flood with 95-percent confidence could range from 2070 cfs to 3380 cfs. Stated another way, the estimated 100-year flow rate could range in return periods from the 45-year to 250-year event. This range of uncertainty dramatically reduces as the length of data increases relative to the estimated flood frequency.

Peak annual flow rates in Newaukum Creek exhibit a distinct and significant ($p < 0.01$) downward trend over the period of record (i.e., sixty years of measured data at the USGS gauge 12108500), based on the results of a Mann-Kendall Tau-b trend test (Fig. 14). This test determines the direction and magnitude of the trend in peak annual flows over time, and is non-parametric, meaning that it does not require the data to be normally distributed. This downward trend includes the record high flow observed in 1996.

Peak annual flows are declining by an estimated 5.4 cfs $year^{-1}$, on average, according to our analyses. We used Sen's method to compute the slope of the fitted linear regression function (i.e., magnitude of the annual decline). This finding is somewhat unexpected because impervious surface area has increased and forest cover has decreased over the period of record. Open meadows and wetlands have also become less abundant. These changes typically exacerbate peak annual flows, especially where storm water retention/detention facilities are lacking (e.g., outside Enumclaw city limits). The cause of the decline in peak flows is unknown, but we suspect climate variation is at least partly responsible.

Figure 14. Trend in observed peak annual flow rates in Newaukum Creek using Mann-Kendall Tau-b methodology.



6.2.2 Daily flows

Mean daily flows near the stream mouth ranged from lows of 20-30 cfs in late summer (September) to 100 cfs during winter (see Fig. 15). Average minimum daily flows in summer are consistently near 10 cfs, while mean maximum daily flows during this period range roughly from 30-100 cfs. Flow magnitude appears more variable during winter. The mean annual flow for any given year is equal to a daily average flow rate of 59 cfs. The mean daily flow rate is 42 cfs, while 50-percent of the flows are equal to or less than 40 cfs (i.e. the median). Each one of these can be correctly construed as an average flow rate for the basin, and which one is chosen depends on the question. We summarized current daily mean flow rates using a simple method devised by the USGS[13]; current flows are plotted relative to their respective historical flows for each specific day. Conditions are grouped into seven categories, ranging from the historical daily low (1), dry (2 and 3), normal (4), wet (5 and 6), and the historical high for that day (7). As an example of this technique, water year 2006 is illustrated in Fig. 16.

[13] http://water.usgs.gov/waterwatch/?m=real&w=plot&r=wa

Figure 15. Comparison of monthly precipitation volumes (upper panel) and the actual mean daily flow rate for the period of record (gray), mean daily flow per day (blue), and the maximum and minimum mean daily flow rate (fuchsia) for the period of record. The precipitation box plots (light blue) represent the 25/50/75 percentiles of monthly volumes based on seven years of data measured at KC Gauge 44U. The box-plot on the right (dark blue) illustrates the non-parametric summary of the main chart with whiskers of 10/90th percentiles, box of 25/75 percentiles (with the median line), and representative outliers as 5/95th percentiles points.

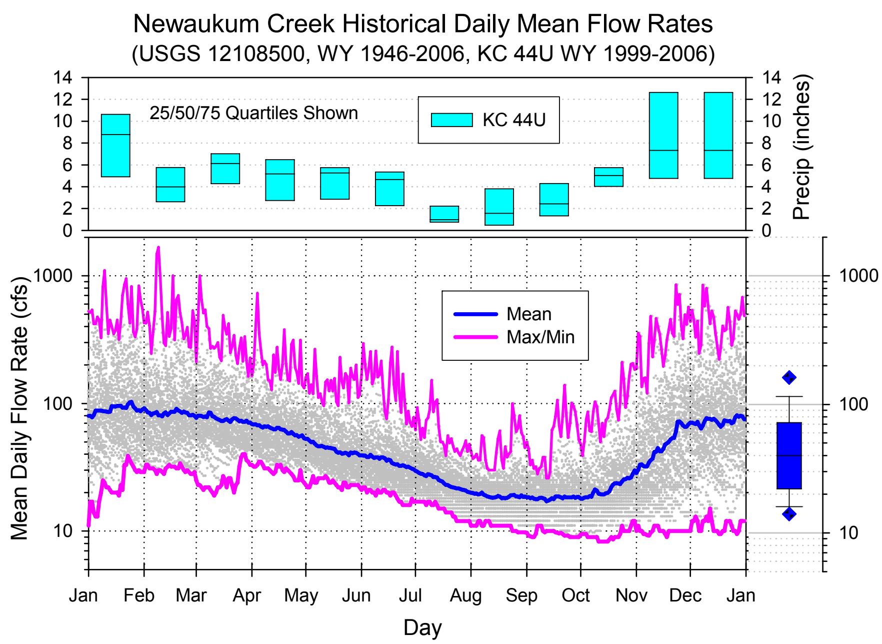
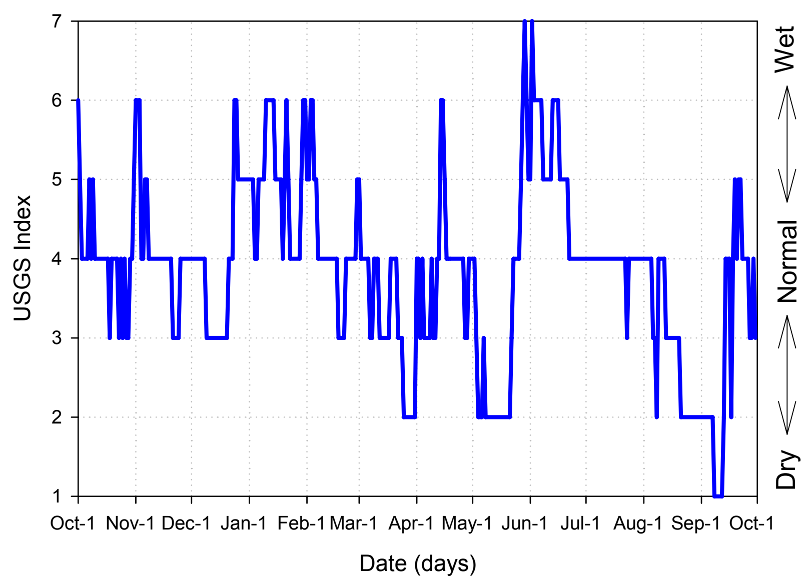


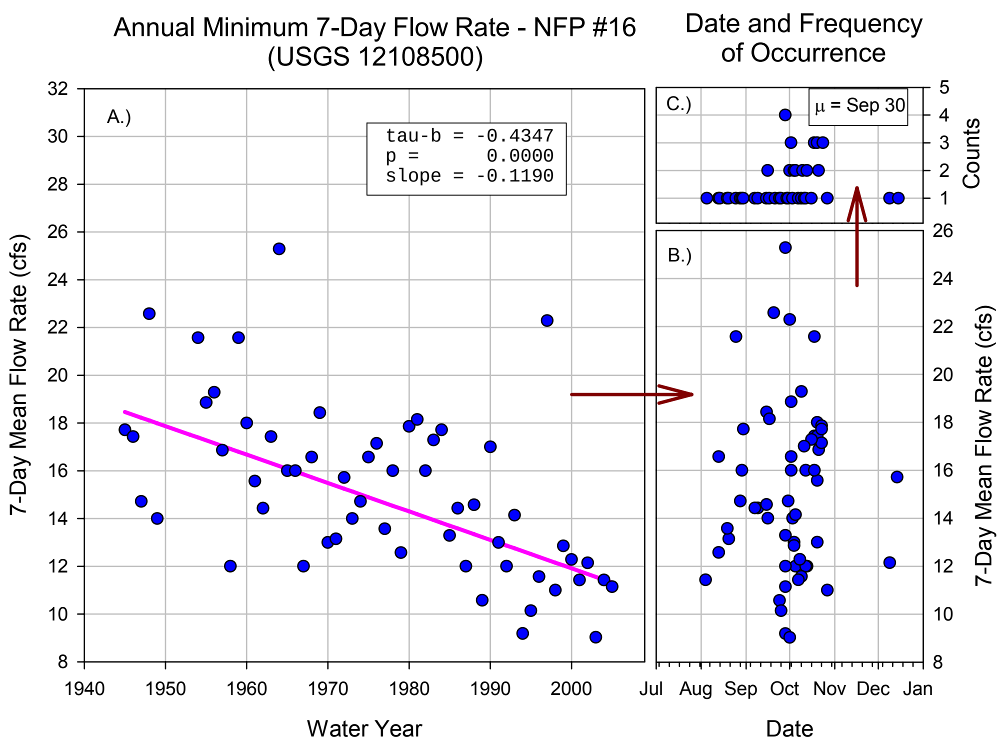
Figure 16. Index of daily flows in Newaukum Creek in Water Year 2006, based on USGS method. The index codes are defined as follows, relative to the long-term average (1948-2006; USGS Station 12108500): 1) historical low flow; 2) < 10%; 3) 10-25%; 4) 25-75%; 5) 75-90%; 6)>90%; and 7) historical high flow.



6.2.3 Droughts

We detected a surprisingly strong and significant (tau-b = -0.4347; p < 0.0001) downward trend (Fig. 17) in observed low flow rates (as indicated by the annual minimum 7-day mean flow), Sen's slope was estimated to be -0.12, meaning that the annual minimum 7-day flow rate is declining at a rate of 0.12 cfs per year. This period tends to occur near September 30 each year. Timing of extreme flow conditions is similar to most stream systems in the lower Puget Sound. Additionally, minimum flows in Newaukum Creek were likely slightly later (September - October) and lower (i.e., just below 10 cfs), according to simulations of historical conditions. Drought conditions have lasted through the end of the calendar year, evidenced by a relatively flat historical minimum flow rate continuing from October to December. While these are not frequent, they are potentially stressful for in-stream organisms, such as salmonids.

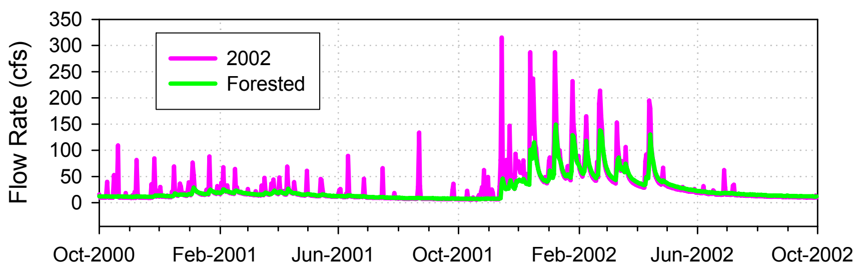
Figure 17. Estimated (A) magnitude, (B) frequency, and (C) date of occurrence of the 7-day low flow. Arrows indicate that data from chart A are projected into chart B using date of occurrence and those data in chart B are projected into chart C for frequency of occurrence.



6.2.4 Effects of land use change and precipitation variability on extreme flows

We developed numerical hydrological models to evaluate the influence of land use change and long-term precipitation variation on observed flow trends (Fig. 12). These models allow us to evaluate the outcome of contrasting land use scenarios and are especially useful for analyses spanning multiple decades. For the purpose of illustration, Fig. 18 depicts two landscape conditions; 1) a forested state hypothesized to represent historical conditions, and 2) land cover as estimated in 2002. Two contrasting water years are displayed: 2001 (dry) and 2002 (wet). All else being equal, it is clear that land cover change results in obvious hydrological changes, namely storm peaks with elevated magnitude and frequency. An illustration of model validation is shown in Fig. 19 and details on model accuracy are in Appendix A.. Maps of surficial geology (Fig. A1) and slope distributions (Fig. A2) are found in Appendix A. Figure A3 in Appendix A includes a map of 'current' (2002) and 'future' landcover conditions. Current land cover estimates are based on classified imagery from 2002. Estimated future landcover conditions are simply based on based on zoning. These classifications are used for developing scenarios and the comparative analyses.

Figure 18. Example hydrographs for 2002 (magenta; surrogate for current conditions) and expected historic (green; forested) conditions.

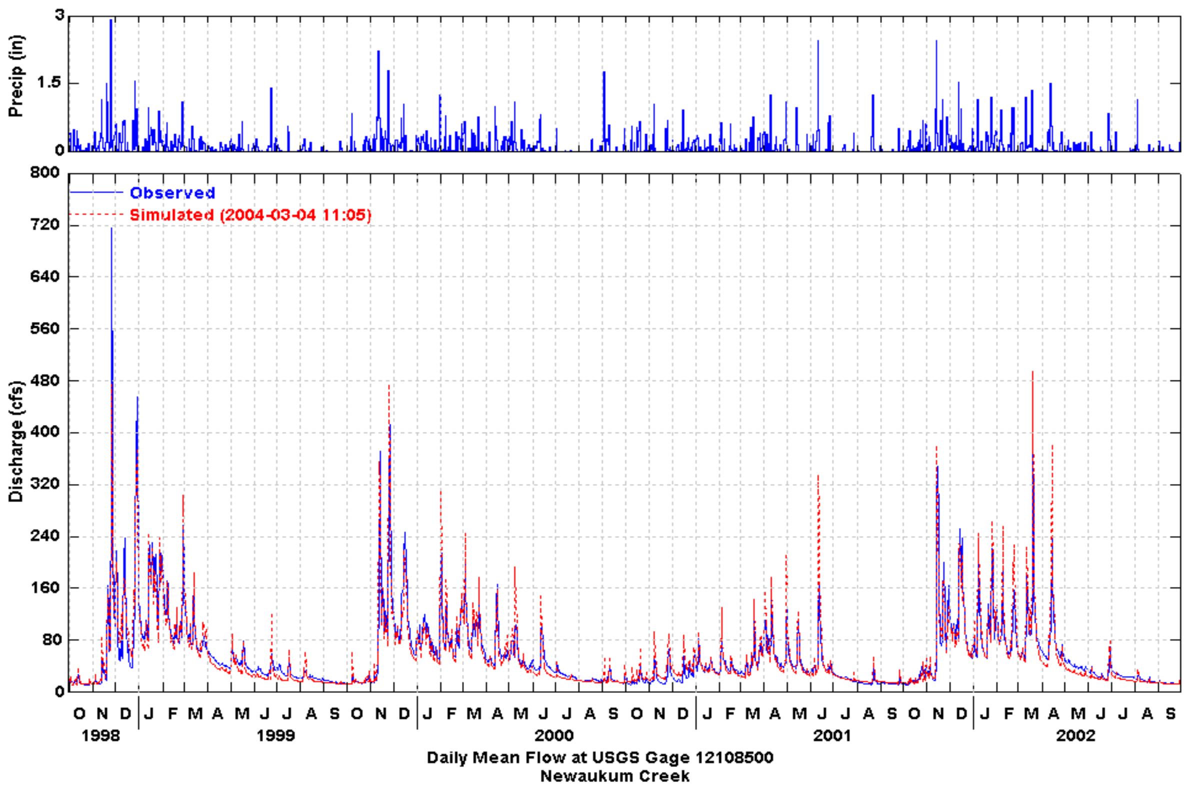


Models of land use change suggest that, if Newaukum Creek was completely forested, the 10-yr flood (i.e. 1 in 10 y) would approximately be 800 cfs, whereas under more current conditions (e.g. 2002), the same flow rate occurs more frequently (i.e., once every three years). Flows are not anticipated to change drastically due to land use change, alone, under the future development scenarios. For example, flow frequencies estimated for future conditions lie within the 95% confidence interval estimated for 2002 conditions (Fig. 20). This is due, in part, to the fact that agricultural land will continue to be the dominant land cover type through the anticipated future. However, net changes under this scenario are based on the simplifying assumptions that remaining forest patches within the agricultural district will be converted to cropland (recognizing that this may not be the actual outcome), and remaining residential zonings will be in-filled to capacity (see Appendix A for model assumptions).

We cannot unequivocally attribute the downward trend in summer base flow rates to urbanization. Recent research in the region suggests urbanization does not significantly reduce summer time base flow conditions (Konrad 2005). Losses in infiltration due to the expansion of impervious surfaces and concomitant reductions in water storage capacity in the basin may be somewhat offset by summertime water subsidies (irrigation, lawn watering, and septic systems, for example). These practices augment summer time low flows, potentially off-setting lost natural groundwater contributions. However, in a closed system (i.e. all sources of consumed water originate within the basin) this explanation is invalid. Further investigations into the role of climatic variation are warranted to help establish a causal mechanism for observed declines in baseflow.

In addition to land use change, we also modeled the influence of long-term precipitation variation on the hydrology of Newaukum Creek. We assumed a static land cover and then ran the historical record of precipitation on the land surfaces. We rely on meteorological data collected outside of the basin because long-term weather data from Newaukum Creek are unavailable. Long-term records from the Sea-Tac station were scaled to approximate average daily precipitation volumes in Newaukum Creek basin. Resulting flood frequencies should be used with appropriate caution, especially for when planning at small-scales[14]. Estimates presented here should be used only for general planning purposes. We also suggest using upper 95% confidence intervals rather than mean values as guides, to reduce risk.

Figure 19. Comparison of observed precipitation (upper panel) and simulated (red) and observed (blue) discharge in the Newaukum Creek ecosystem. Precipitation was measured at KC gauge 44U. Flows were measured at USGS stream gauge 12108500. Further details on model accuracy are in Appendix A.



Annual precipitation measured at Sea-Tac shows no significant trend, but there is some evidence for significant declines in early winter precipitation over time (i.e., 10/1/1948 – 12/31/2006) (Fig. 21). Recall that low flows in Newaukum Creek are most pronounced in late September (Figs. 15, 16).While tau-b is not as strong as in the 7-day flow, it is still statistically significant with an average decline in volume equal to 0.05 inches per year. These findings

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[14] Several factors introduce substantial uncertainty in modeled estimates of hydrologic responses; 1) Precipitation levels vary across the basin, and this within-basin variation is generally nonlinear and 2) the use of surrogate data from Sea-Tac in place of observations from within Newaukum Cr. Additionally, 3) no large flood events occurred during the model calibration period, which would have been useful in adjusting channel hydraulics assumptions. The accuracy of channel hydraulics plays a critical role in estimating stream channel capacity and over-bank flood routing. If flood flows overtop banks and inundate adjacent low lying areas across the Enumclaw Plateau, this would detain flood flows and reduce downstream flow magnitude. Future efforts could improve these parameters with a more complex approach, applicable at the level of individual sites.

suggest – but do not conclusive demonstrate –that declining 7-day low flows are not a consequence of anthropogenic actions within the basin, rather changes in climate.

Figure 20. Results of flood frequency simulations for Newaukum Creek at the mouth (1948-2004, Sub-basin NEW291, see Appendix A).

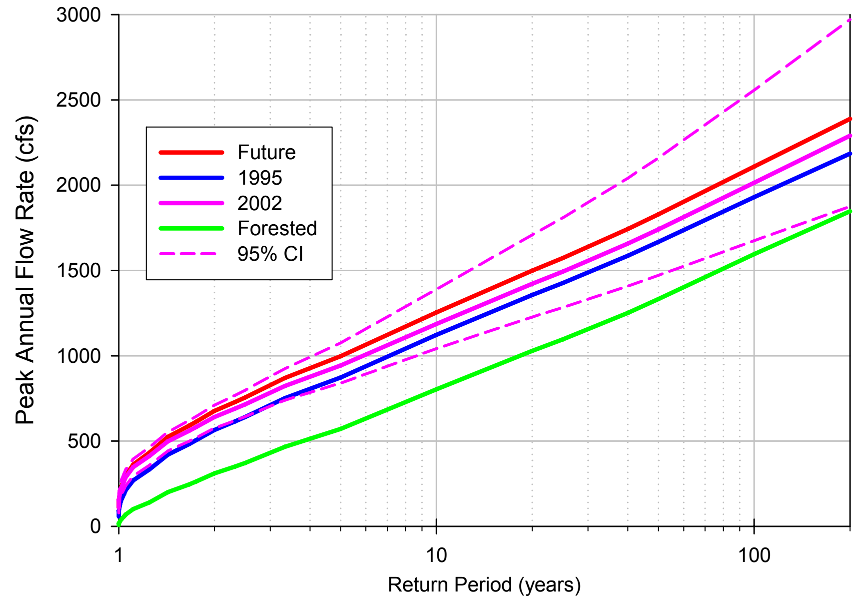
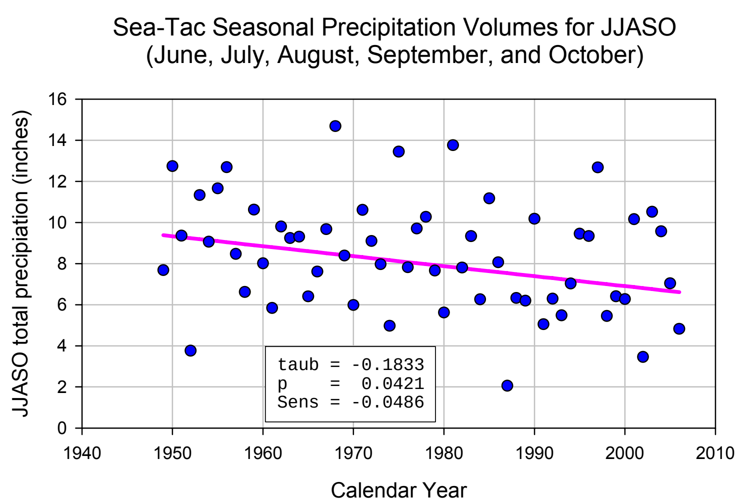


Figure 21. Illustration of seasonal declines in annual seasonal precipitation volume at Sea-Tac from June through October, from the late 1940's to present. The annual magnitude of the decline is indicated by tau-b (-0.1833).



6.3. MASS-WASTING, INCLUDING LANDSLIDES AND DEBRIS FLOWS

Mass-wasting refers to the downslope movement of soil and rock under the direct influence of gravity (not being moved by wind, water or glacial ice for example). Typically mass-wasting processes are most active in areas of steep topography. Two areas of the Newaukum basin have sufficiently steep topography so that mass-wasting processes are active. These two areas are on Boise Ridge, and in the Newaukum Ravine. Different geologic substrates in these two areas lead to lead to two different styles of mass-wasting.

Boise Ridge is characterized by steep slopes and shallow soils on top of bedrock. Under these conditions shallow landslides occur when the thin soil layer becomes saturated with water and slides on the underlying bedrock surface. Often, as the soil layer moves it disaggregates and transforms into a thick mass that flows downslope as a fast-moving fluid. On steep slopes this fluid mass can be highly erosive and can grow to many times its original volume as it moves downhill. This type of mass-wastage is called a debris flow. Debris flows often originate as hillside failures but then drain into and flow down steep headwater channels. In addition to incorporating sediment by erosion debris flows typically pick up and move a large number trees and other organic material. They are often energetic enough to move large boulders. Debris flows occur more frequently in areas under timber harvest (Sidle et. al. 1985) but they are a natural process in areas with steep topography and humid climates. Debris flows are often responsible for blocking or washing out forest roads and they can cause catastrophic disturbance to the receiving stream channels, but they also deliver gravel and woody debris to channels that is ultimately critical to creation of functional stream habitats. Aerial photographs and field observations show a history of debris flows on the steep, west-facing slopes of Boise Ridge.

A different type of mass-wastage is pervasive in the lower part of the Newaukum Ravine. This portion of the Newaukum basin is underlain by thick glacial deposits. As Newaukum Creek incised into these deposits it created steep unstable slopes which then failed as massive, deep-seated slumps. Slumps are large, slow-moving landslides which move on curved failure surfaces far underground. Distinctive topography indicates a history of massive landsliding along almost two miles of the Newaukum Creek ravine (Fig. 11). The original movement in this landslide was prehistoric and probably occurred thousands of years ago. Geotechnical monitoring of the landslide has demonstrated that that it remains unstable and continues to shift downslope (Alan Corwin, 2007). Instrumentation installed in geotechnical borings has documented landslide movement at a depth of up to 150 feet below the ground surface in this ravine. Movement in this landslide complex has damaged 212th Ave SE, but this landslide moment also supplies coarse sediment and woody debris to Newaukum Creek through this reach.

6.4. WIND

Wind is a common disturbance in the Newaukum Creek basin, toppling trees in upland and riparian forests. Major windstorms in the area occurred as recently as 2006. Other major events around Washington occurred in 1921 (Great Olympic blow-down), 1962 (Columbus Day storm) and 1993 (Inauguration Day storm). However, windstorms are relatively common, with notable events occurring in 1891, 1894, 1964, 1965, 1966, 1967, 1969, 1971, 1973, and 1974 (Kruckeberg 1991). These events can add substantial quantities of wood to streams and blow down snags and live trees. The consequences of windstorms may vary in intensity among sites with different topography. However, no site-specific information was available to characterize the impacts of these events on Newaukum Creek.

6.5. INSECT INFESTATIONS

We do not explain this disturbance process in detail, but consider it worth mentioning that insects, such as the Spruce budworm (epidemic beginning in 1975; Kruckeburg), may act as important disturbances that potentially shape the structure of upland and riparian forests for decades or centuries by altering natural patterns of tree mortality and thus, fuel loading on the forest floor.

7.0. AQUATIC RESOURCES

We describe the historical and current physical attributes of the channel network (streams, creeks, and ditches) and wetlands (as well as bogs and ponds), which are the most recognizable aquatic elements of the basin. Within each category, we attempt to characterize the factors that are vital to the growth and maintenance needs of organisms: water resources, sediment resources, light availability, nutrient availability, oxygen, and riparian sources of energy such as leaves from the forest (organic matter) and prey for fish.

7.1. CHANNEL NETWORK STRUCTURE

This section explains the basic layout and dimensions of the stream channel network within Newaukum Creek basin (Fig. 2). We estimate that the Newaukum Creek basin (26 square miles) is a 3rd to 4th order stream containing approximately 130 miles of channels[15], including constructed drainage ditches and natural water courses. Drainage density – which refers to the length of stream channel per unit basin area – is 3.0 miles per square mile (or 2.0 miles per square mile, excluding constructed ditches). The Newaukum Creek mainstem is 16 miles long, composing 12% of the total; 5.7 miles lie within the Ravine, 5.3 miles in the Plateau, and 5 miles in the Upper Basin. Humans have increased drainage density and basic channel branching patterns in the system through decades of dredging, diking, and ditching. These activities have increased channel length, particularly across the Plateau (Fig. 2). Much of the network consists of unnamed 1st and 2nd order tributaries, though 77 miles (59% of channel length) are comprised of ditches (primarily in the Ravine and Plateau). Of those 77 miles, we were unable to accurately distinguish between newly excavated versus channelized 'streams'; most of these channels drain arable lands that likely once contained wetlands[16]. These figures may underestimate the true channel network because many road-side ditches, some of which have wetland vegetation growing in them, are not included in current stream maps layer.

The tree-like branching pattern of the Upper basin is predicted to result in more physical and biological diversity at stream confluences than would be expected at confluences in the Plateau or in the Ravine, where tributary streams are small relative to the mainstem (see Benda et al. 2004). The Newaukum Creek mainstem is intersected by roughly 20 natural channels and at

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[15] King County's watercourse data layer ("wtrcrs") was used to calculate the total stream miles present, including agricultural ditches and channels.

[16] It may be possible to estimate which channels were once free-flowing streams using the following criteria: (1) the channel connects two non-channelized stream reaches; (2) the channel drains directly into Newaukum Creek; (3) the channel does not lie within the boundaries of the GLO-mapped wetlands, excluding the mainstem; and (4) the channel does not flow in north-south or east-west straight lines, such as along a roadside, but rather angles towards Newaukum Creek in a more natural meander. This latter criteria will exclude any tributaries that have been fully channelized to run alongside a road. Using those criteria, we estimate that 11 miles of natural stream reaches have been channelized, and their ecological functioning can be considered impaired.

least 13 drainage ditches. Confluence density along the mainstem – counting only ‘natural channels’ - is approximately 1.3 km^{-1}, though channel geomorphology does not change appreciably at all of these confluences.

Prior surveys report the channel is widest in the Ravine (20 feet in summer; 30 feet in winter), narrowing to 12 feet (in summer; 17 feet in winter) across the Plateau. The North Fork of Newaukum Creek, hereafter ‘North Fork’ measures four feet wide (in summer; 8 feet in winter) (Goldstein, 1982). Note that data for the mainstem in the Upper Basin, Stonequarry Creek, Watercress and Big Spring Creek are unavailable. Multiplying mean channel width by reach length yields rough estimates of stream area; 16 acres in the Ravine; 11 acres on the Plateau; 3 acres in the North Fork. These figures suggest that most of the stream area available to support aquatic primary production lies within the Ravine, followed by the Plateau.

7.2. CHANNEL MORPHOLOGY

This section explains the geomorphology of five reaches composing Newaukum Creek. This section further subdivides the Upper Basin into 1) the Boise Ridge reach and the 2) Alluvial fan reach. The Plateau corresponds to the 3) Plateau reach. The Ravine is subdivided into the 4) Ravine reach and 5) Confluence reach (Fig. 22). Sediment sources and calibers are also characterized. We provide summaries from previous studies, where available.

We speculate current levels of channel complexity are below historic levels, though it has not been formally quantified. Surveys conducted in the early 1980’s in conjunction with field visits and current oblique airphotos provide a qualitative perspective on the distribution of reach types, channel morphology, and stream sediments.

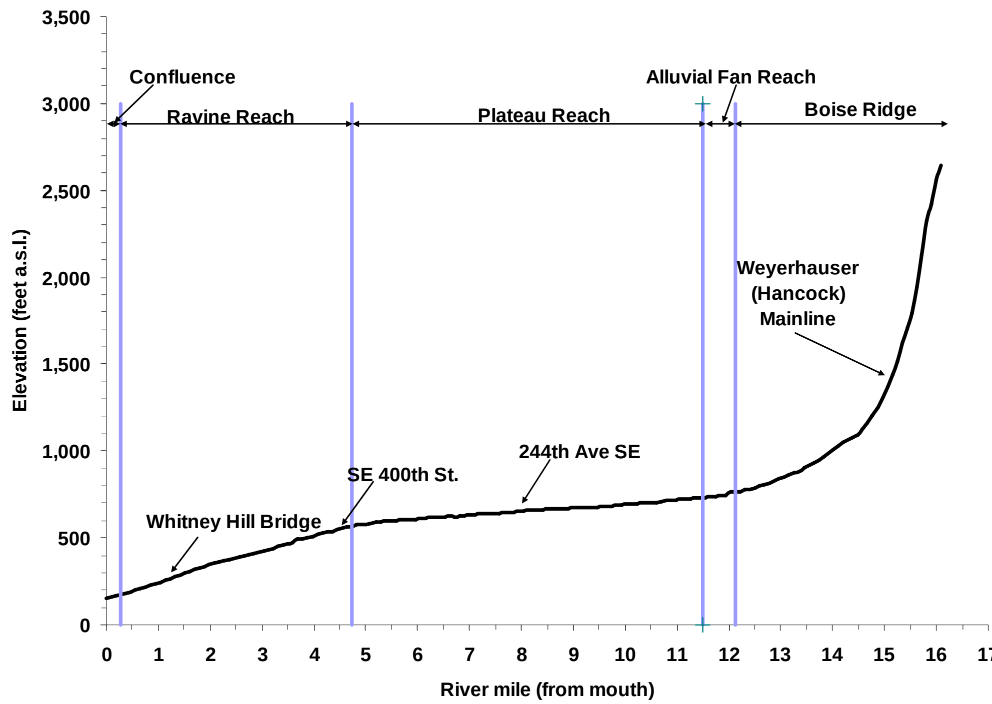
7.2.1. Boise Ridge Reach (RM 12.1-16.0)

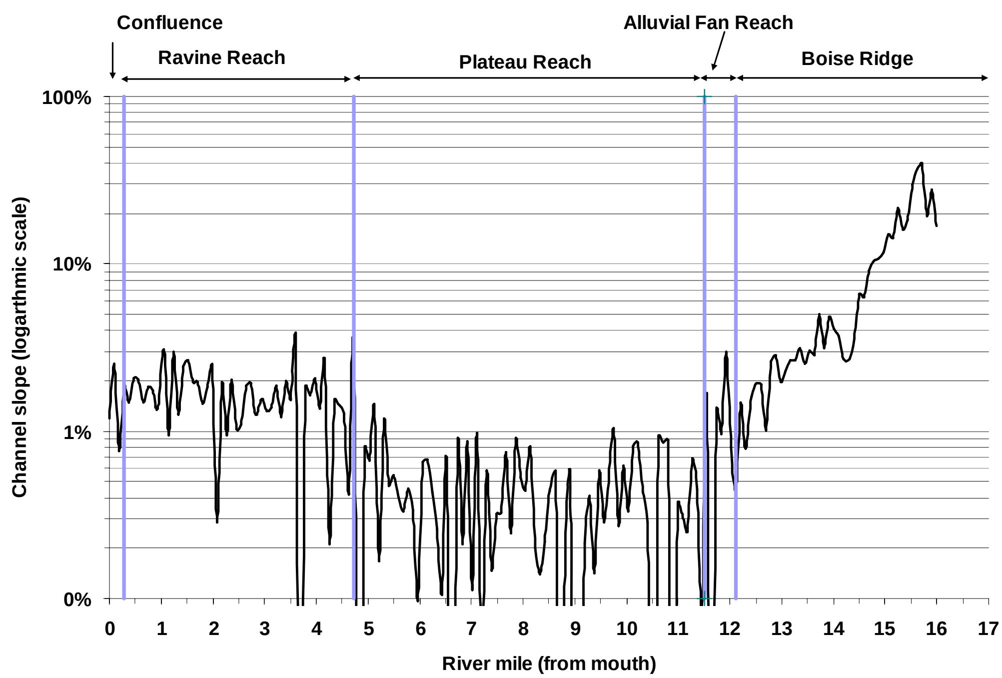
Newaukum Creek is formed by the confluence of several tributaries that originate near the crest of Boise Ridge. These channels have slopes of up to 40% in their upper reaches, decreasing to 4% near the base of Boise Ridge. These channels include a reaches of both cascade and step-pool morphology (Montgomery and Buffington, 1993), with the relative percentage of step-pool channel increasing with decreasing gradient. In their upper reaches these streams have cobble-boulder beds with local bedrock exposures. The bedrock sections often form cascades that are natural barriers to upstream fish passage. The elevation range of these headwater channels suggest that the largest flow events in these channels are likely a result of “rain on snow” events associated with the passage of strong warm fronts during the fall and winter.

Boise Ridge is underlain by volcanic bedrock covered with a thin, discontinuous soil layer. Processes including chemical weathering, freeze-thaw, wetting and drying, root growth, and fluvial abrasion break down this bedrock. Resulting sediment is transported downslope and delivered to headwater channels via soil creep, tree-throw, and landsliding. Historical timber harvest activities in the basin increase the sediment supply through erosion of road cuts and fills, washing of fines from road surfaces, failures of road fill prisms and logging landings, and scour at culvert outfalls. In the steepest zero and first order channels this sediment may be moved downslope by periodic debris flows (Benda and Dunn 1997). In the less precipitous channels downstream this sediment load carried by more conventional fluvial transport, with most of the sediment transport occurring during a few high flow events each year.

Prior surveys were not conducted in this reach, but the North Fork may be loosely comparable. Previous surveys suggest the North Fork is co-dominated by rubble (40.2%) and gravel (37.9%), with some sand (17.9%) and boulders (4.7%) (Goldstein 1982). Pools were primarily formed by wood and boulders, and averaged two feet deep, using reach length as the weighting factor (adapted from Goldstein 1982). Cover types in the North Fork were primarily grasses and bank overhangs, which was present in 43% of the reach (Goldstein 1982).

Figure 22. Channel profile (upper) and channel slope (lower panel) in Newaukum Creek. Locations of major road crossings are indicated. Note that the y-axis in the lower graph is on a log scale to better represent low to moderate gradient reaches.





7.2.2. Alluvial Fan Reach (RM 11.5-12.1)

Along the mapped main mainstem of Newaukum Creek the fan reach extends from RM 11.5 to RM 12.1. Where Newaukum Creek tributary channels cross alluvial fans they typically exhibit plane-bed channel morphology (Montgomery and Buffington, 1993). These fans have formed in the time since deglaciation, and the depositional process that created them continues. Specifically, at the base of Boise Ridge the tributaries of Newaukum Creek flow from an area of high relief, underlain by bedrock to an area of much lower relief underlain by glacial sediments. In this area channel gradients decrease rapidly downslope (Fig. 22). As a result average *basal shear stress* (the force exerted by flowing water on the stream bed), and therefore the ability of these channels to convey coarse sediment also decreases. This is an area of natural sediment deposition. As a result, each of the major tributaries has formed prominent alluvial fans in this reach (Fig. 10).

Plate 7.2.1. Deposition of riverine sediments resulting from out-of-channel flow.

The tributary channels in this reach are likely to be sediment rich with common gravel bars. These channels are inherently subject to flooding and avulsion as a result of progressive sediment accumulation. Plate 7.2.1. shows evidence of out-of-channel flow and sediment deposition in this alluvial fan reach. This likely occurred during storms during the 2006/2007wet season. Virtually all human disturbance in steep terrain like that of Boise Ridge is likely to increase sediment discharge to the stream system. Any such increase in upstream sediment supply would result in an increase in channel aggradation, flooding, and channel migration. These are natural processes on an alluvial fan, but an increased sediment discharge will cause an increase in their frequency and magnitude.

7.2.3. Enumclaw Plateau Reach (RM 4.7-11.5)

After leaving the alluvial fans that border Boise Ridge the major Newaukum tributaries flow out across the broad level expanse of the Enumclaw Plateau. Newaukum Creek flows over the surface of the Enumclaw plateau from RM 4.7 to RM 11.5. As described previously this Plateau is largely the upper surface of the Osceola mudflow. The average stream gradient across the plateau is 0.4%. Prior to European settlement large expanses of the Plateau were wetlands (Section 7.3). In an effort to increase the arable land early farmers dredged channels and dug ditches to reduce the extent of soil saturation. As a result much of the stream channel length across the Plateau consists of constructed ditches and straightened channels. On the eastern portion of the plateau the channel locally exhibits pool-riffle morphology with gravelly riffles indicating some gravel supply and movement (Plate 7.2.2.). Further west riffle sections become increasing scarce.

A prior study (Goldstein 1982) suggests the streambed in the Plateau (in 1980) was dominated by gravel (62.3%), lesser areas of sand (20.8%) and rubble (15.6%). Boulder substrate was very scarce, covering only 1.3% of the streambed. Average weighted pool depth was two feet; similar to the North Fork. Cover was present in only 28% of the reach.

Newaukum Creek is typically deep and relatively narrow with steep channel banks as it runs across the Plateau. This morphology probably reflects some dredging history, but it persists and in some areas may be entirely a result of a combination of competent streambanks and limited bedload sediment supply. The channel banks are composed of cohesive sediments (mudflow deposits) and are reinforced by a dense vegetative root mat (largely due to the pervasive growth of a dense monoculture of reed canary grass in the riparian zone). This allows the steep channel banks to persist and be stable. The paucity of coarse sediment supply prevents the channel bed from aggrading. In reaches where it has not been artificially straightened, the channel exhibits a meandering character.

Plate 7.2.2. Gravelly riffle in Newaukum Creek mainstem.

Because of the low gradient and low confinement of Newaukum Creek in this reach, it has a limited ability to move coarse sediment from the headwater reaches far out onto the plateau. No steep tributaries join the mainstem on the plateau to introduce additional sediment. As a result, for much of its length across the Plateau, Newaukum Creek appears to move little bedload. The widespread occurrence of aquatic plants growing from the streambed is consistent with infrequent movement of streambed sediment. A large flow event occurred on Newaukum Creek in early November 2006. Limited field observations following this event showed common indications of out-of-channel flow, but no evidence of out-of-channel sediment deposition across the Plateau reach.

Historical analyses based on aerial photos from 1936 and 2005 confirm that lateral channel movement has been very limited across the Plateau (see photo comparisons in Appendix B). Much of Stonequarry Creek, the North Fork, and Watercress Creek had already been channelized by 1936, though even unmodified streams changed little over the period of observation. We selected several reaches exhibiting the most dynamic changes to illustrate this point (see 10 paired images depicting channels and landscapes in 1936 versus 2005 in Appendix B). We also orthorectified General Land Office maps from the late 1800's, however stream channels were over generalized, and the mapped stream positions were often implausible.

7.2.4. Ravine Reach (RM 0.3-4.7)

Newaukum Creek descends from the Enumclaw Plateau to the Green River Valley through a four mile long ravine (RM 0.3 to RM 4.7) (Fig. 22). The Ravine is an important part of the Newaukum Creek basin because of its broad, largely intact riparian buffers, its supply of sediment and LWD, and its unrestricted proximity to the Green River. The Ravine section can be conveniently divided into three subsections based on the topography and dominant geomorphic processes; Upper, Middle, and Lower Ravine reaches. The Upper Ravine section exhibits increasing slope and confinement as the channel transitions from a pool-riffle character at the upstream end of this upper reach to a plane-bed character moving downstream. The Middle Ravine section (upstream of Whitney Hill Bridge, RM 1.1) has an average gradient of 1.7% and exhibits a step-pool character. The Lower Ravine section exhibits both a step-pool and a meandering character.

A prior survey (Goldstein, 1982) suggests that the Ravine, in 1980, was dominated by rubble (44.4%) and gravel (39.2%), with scarce sand (8.4%) and boulder (8% substrate). Pools averaged just less than two feet deep. Cover types in the Ravine were primarily overhanging branches, undercut banks and logjams; cover was present in 66% of the reach (Goldstein 1982).

Plate 7.2.3. Example of bank armoring in the Upper Ravine.

TetraTech, Inc. conducted more recent surveys (in 2005 and 2006) comparing the channel characteristics, riparian forests, and fish use among two stream reaches. They refer to the site of a future restoration project as the 'impact' reach and an upstream site as the 'control' reach[17]. Each was approximately 984 feet (300 m) long. In 2005, the control reach averaged 34.7 feet (10.6 m) wide, approximately 1% slope, and contained 102 square feet (9.5 m^2) of residual pool area per 328 feet (100 m) of stream. Large wood volume averaged only 35 cubic feet (1 m^3) per 328 feet (100 meters). The impact reach was 26.9 feet (8.2 m) wide, with less than half as much pool area (4.7 m^2 of residual pool area per 100 m) and large wood volume (14.1 cubic feet per 328 feet or 0.4 m^3 per 100 meters). Channel avulsion occurred in the control reach in 2006. Channel width in the control reach now measures 32.5 feet (9.9 m; ± 4.0 SD) and 27.6 feet (8.4 m; 1.4 ± SD) in the treatment reach. Maximum stream depths were similar in the control and treatment reaches (i.e., 1.8 feet or 54 cm and 1.3 feet or 41 cm, respectively). Gravel substrates (fine and coarse) composed 60% of the streambed in the control reach, compared to 56% in the treatment reach. Substrates were 100% embedded in 15% of the sampling points in the control reach, and 11% in the treatment reach.

In the Upper Ravine section (RM 4.7 to RM 1.8) near the south edge of the Green River Valley, the channel gradient increases as the channel begins to incise through the mudflow deposits and into the underlying glacial till. With a steeper gradient the channel has more erosive power than it has immediately upstream on the Plateau. At high flows the channel is able to recruit new

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[17] The control reach runs from 47˚ 16 44.2 N 122˚ 03 48.6 W to 47˚ 16 50.6 N 122˚ 03 57.6 W. The treatment reach is immediately downstream, at 47˚ 16 51.5 N 122˚ 04 1.6 W to 47˚ 17 2.1 N 122˚ 04 1.6 W.

sediment through bed and bank erosion. One of the few instances of bank armoring noted in this study was observed in this section. (Plate 7.2.3.) Erosion provides bedload sediment in this section so the channel exhibits a mobile channel bed. At the upper end of this section, the limited depth of incision and relatively stable ravine sideslopes are conducive to residential and agricultural development in proximity to the channel. As the ravine sideslopes become steeper and less hospitable for development forested riparian reaches become more common. Although locally subject to erosion, there is no evidence of large-scale slope instability.

In the Middle Ravine section (RM 1.8 to RM 1.0), where the creek leaves the Plateau and flows over the Green River Valley wall, the ravine deepens and the channel gradient increases. Large erosions scars are present along the channel through the Middle Ravine (Plate 7.2.4.). These scars indicate areas where the toe of the active landslide is encroaching on the channel and being trimmed back by channel erosion. These erosion scars, along with likely channel incision, provide large volumes of sediment to the channel through this reach. The common occurrence of active bank erosion also delivers large wood (trees) to the channel. As a result wood loading is high and complex woody debris jams are relatively common through this reach. Because of the steep, unstable ravine sideslopes these has been little development adjacent to the channel.

Plate 7.2.4. Erosion scars in the Middle Ravine of Newaukum Creek Basin.

The character of the channel and of the ravine changes in the Lower Ravine section (downstream from Whitney Hill Bridge). The channel flows between a massive landslide block on the right (north) side of the ravine and the Green River Valley wall on the left (south). Although still flowing through a landscape dominated by landsliding, the character of the valley bottom and ravine sideslopes suggest that there is little active, deep-seated landslide movement along this reach. The gradient through the lower ravine is less than in the middle section and the ravine floor is wider than above (i.e., less confined), causing reach morphology to transition to a meandering character. The steep slopes on either side still preclude streamside development. Aside from a history of logging the riparian buffer through this reach is little affected by development of the land. In some locations the channel still impinges on the adjacent valley walls. The resulting erosion provides additional sediment and large wood to the channel through this reach.

7.2.5. Confluence Reach (RM 0.0-0.3)

The lowest 1200 feet of Newaukum Creek cuts across the geomorphic floodplain of the Green River. The channel through this reach is largely plane-bed, although steps in the profile form where large wood forms spanning log jams (Plate 7.2.5.). Channel confinement decreases through this reach, reducing the ability of the channel to transport coarse sediment (Fig. 11). The channel's capacity to move sediment is further reduced by the backwater effect created during high flows in the Green River, as evidenced by the persistent gravel bar present at the mouth of Newaukum Creek on the Green River (Plate 7.2.6.). During periods of low flow the lowest section of Newaukum Creek becomes steep and shallow as it flows over this bar and into the Green River. Although this bar formation is a natural phenomenon (perhaps exacerbated by flow regulation of Green River), conditions on the bar have been identified as a problem for adult fish passage during low flow (see Chinook salmon in Section 9.1). The gentle topography of the Green River floodplain allow for access and development adjacent to the channel in this lowest reach of Newaukum Creek. As a result the channel has been locally straightened, armored and confined by berms. Flooding and channel migration have threatened the one residence located near the channel in this reach.

Plate 7.2.5. Large wood jam in Newaukum Creek.

Prior surveys of this reach observed substantial sediment loading and bed movement, concluding substrates were moderately embedded (Boehm 1999). Spawning gravels were scarce in the 480 m of stream nearest the confluence, but plentiful upstream**.** Within 70 m of the confluence, small gravels (<25 mm; 35% by area), large gravels (25-100 mm; 35%) and sand (30%) dominated the streambed**.** Upstream reaches were mostly cobble (100-256 mm) with interspersed rip-rap (i.e., from 200-320 m) and boulder-dominated units. Fast-water units contained mostly large gravel (35%) and cobble (30%). Small gravels (20%) and sand (15%) were present, but relatively scarce. In contrast, slow-water areas

Plate 7.2.6. Gravel bar at mouth of Newaukum Creek (left). The large river is the Green River mainstem.

were dominated by sand (45%), small gravel (35%), and large gravel (20%). Within the lower portion of the ravine, mean maximum and residual pool depths were estimated to be 0.54 m and 0.41 m respectively (Boehm 1999).

Portions of the mainstem in the Ravine near the confluence with the Green River have been extensively modified. Recent surveys indicate that – even in the relatively undeveloped ravine - large wood (exceeding 9.8 inches or 0.25 m in diameter and 9.8 feet or 3 m in length, by their definition) abundance was only 5 pieces per 328 feet (100 m) and logjam density was only 0.35 per 328 feet (100 m) in the lower mile (1.73 km) (Boehm 1999). This may be partly attributable to activities during 1984-1990, when a landowner straightened and channelized roughly 1,150 feet (350 m) of meandering mainstem channel with heavy machinery. In response to this disturbance, another downstream landowner built a bank revetment. Also, large wood was once regularly removed wood from the mainstem stream near the confluence with the Green River. The aim was to avoid damage to a now-absent logging bridge (Boehm 1999).

7.3. WETLAND DISTRIBUTION AND CHARACTERISTICS

Wetlands play a critical role in the functioning of the Newaukum Creek basin[18] (Fig. 24). These areas perform many important functions at the local and basin-wide scales:

> "Wetlands potentially perform a number of different and often critical environmental and ecological functions benefiting humans (Kusler and Opheim 1996; NRC 1992, 2001). These include flood storage and retention, groundwater discharge/recharge, maintaining and protecting water quality and providing abundant and clean potable water. Some maintain base flow, and may enhance the water quality within streams and lakes with important fish and wildlife species. Correspondingly, some provide habitat for Federally and State threatened and endangered species, as well as for a wide diversity of important invertebrates, amphibians, birds, furbearers and small mammals. In fact, the diversity of birds (Richter

Table 3. Wetland habitat types in Newaukum Creek basin.

Wetland Habitat Type	Area (acres)	% of total wetland area
wet field	975	70
forested	237	17
scrub-shrub	89	6
riparian - forested	26	2
open water	26	2
riparian - shrub	22	2
riparian - ag field	9	1
emergent	7	1
bare ground	4	0
ditch	<1	0
Total	1,395	100

[18] Historic wetlands were delineated from Government Land Office (GLO) land survey maps dated 1877 and 1883. These maps are often inaccurate, incomplete, and biased toward certain map elements such as larger, permanently flooded wetlands. At the time of the initial survey, wetlands were not legally defined. Even if every "cranberry marsh" and "alder swamp" had been mapped, different mapping techniques are in use today. For example, wet meadows (which by today's standards are considered jurisdictional wetlands) may not have been mapped historically. Despite these limitations, it is clear that large areas of wetland covered much of the Plateau. The GLO-mapped wetlands totaled approximately 3,460 acres.

and Azous 2001b) and small mammals (Richter and Azous 2001c) in wetlands may exceed that found in upland habitats" (King County 2004).

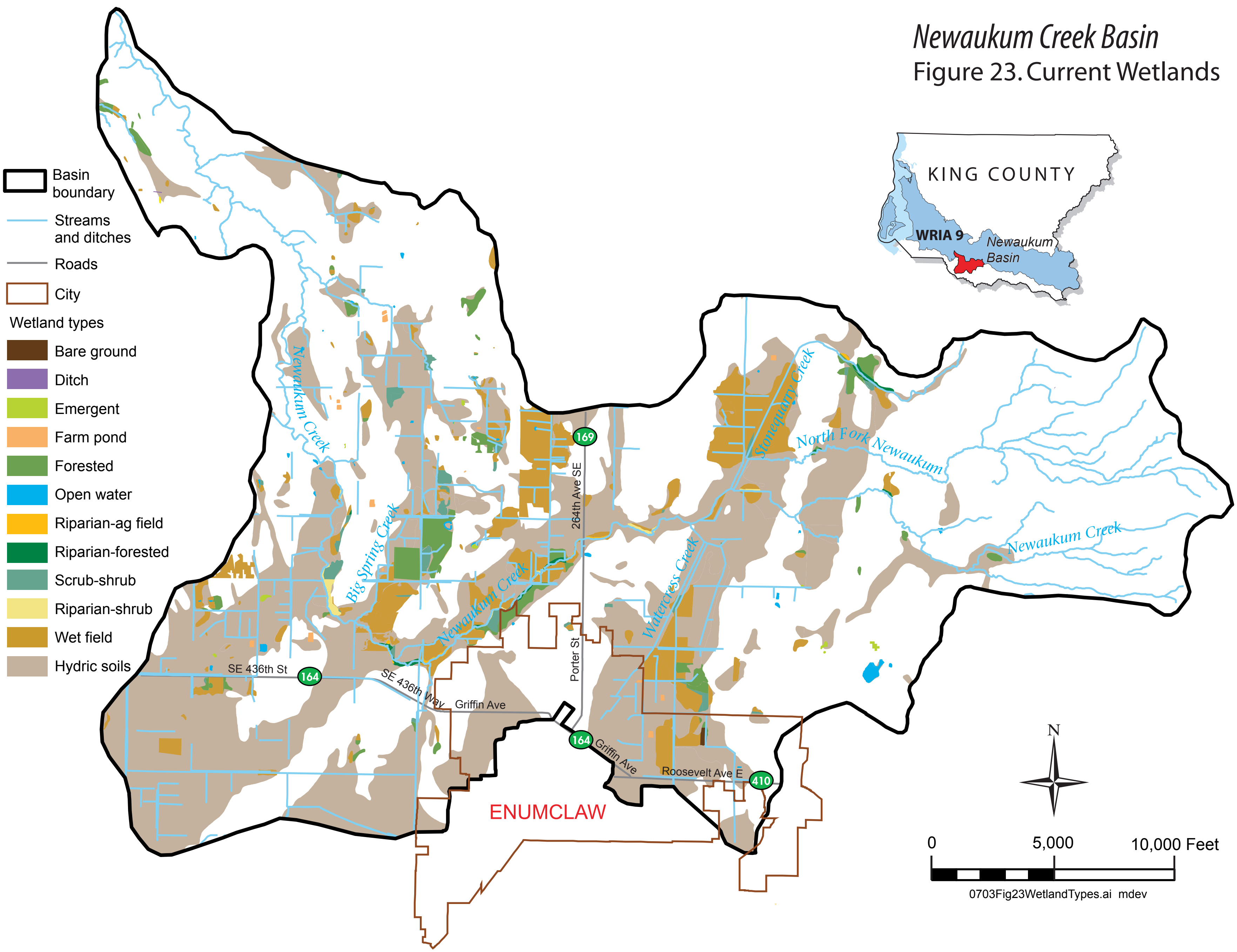
We estimate wetlands historically occupied between 6,445 and 7,843 acres, which corresponds to between 38 and 41% of the total basin area (Fig. 24)[19]. Newaukum Creek apparently contained a huge wetland complex on the Plateau, in the vicinity of the City of Enumclaw. This and other wetland complexes may have been connected by numerous tributary streams, though Newaukum Creek was the only stream recorded on GLO maps (dated 1877 and 1883).

Beavers apparently played an important role in forming wetlands across the Plateau. According to the GLO survey notes, historic wetlands in the Newaukum Creek basin were often formed by beaver dams. One surveyor in September 1872 reported: "This Township [containing the Plateau] so far as our observation extended contained a large area of fine rate land, most of which however is quite wet caused by numerous beaver dams across the small streams and therefore requires drainage to be made available for the purpose of agriculture." Likely, these wetlands varied considerably, including forested, scrub-shrub, emergent, herbaceous, and open-water types. Extensive wetland complexes would have provided the varying types of breeding habitats required by different frogs and salamanders, and salmonid rearing habitat would have been accessible (see Section 9.6 for details on wildlife).

[19] These figures are based on the assumption that existing hydric soils were originally wetlands. We mapped hydric soils from Natural Resources Conservation Service (NRCS) soils data. Hydric soils cover approximately 6,445 acres. Assuming these were, indeed wetlands, a total of 7,843 acres of wetlands were present in the Newaukum Creek Ecosystem (including wetlands on the GLO maps).

Newaukum Creek Basin

Figure 23. Current Wetlands



The impacts of logging, agriculture, residential development and other aspects of Euro-American settlement on wetlands are extensive in Newaukum Creek Basin. Today, most wetlands on the Plateau have been modified with ditches or have been drained and filled (Fig. 23, 24). Some are used as grazing areas for livestock (C. Dyckman, *pers. comm.*). Current wetland data indicates only 1,252 acres (1.9 square miles) are present in the basin (Table 3)[20]. Declines in wetland area are largely attributable to the practices of ditching, channelizing, and the introduction of reed canarygrass to improve the arability of land for agricultural crops (see detailed explanation in Section 9.4.5). To prepare an area containing wetlands for agriculture, a common practice was to dig ditches to drain wetlands. The ditches dry out the land to varying degrees and thus extend the growing season for agricultural crops and make the land more arable overall. An extensive network of these drainage ditches is located throughout Newaukum Creek basin. Another common practice has been to channelize streams by using rip-rap, culverts, and bulkheads to eliminate a stream's ability to meander, and thus freeing up more land to farm or otherwise develop. Another former practice of preparing lands for agriculture was the planting of reed canarygrass, which is now extremely prevalent. The ecological implications associated with invasive species are discussed later (Section 9.4.5). Briefly, this species becomes a monoculture, which prevents the establishment of native vegetation and is extremely difficult to eradicate once established.

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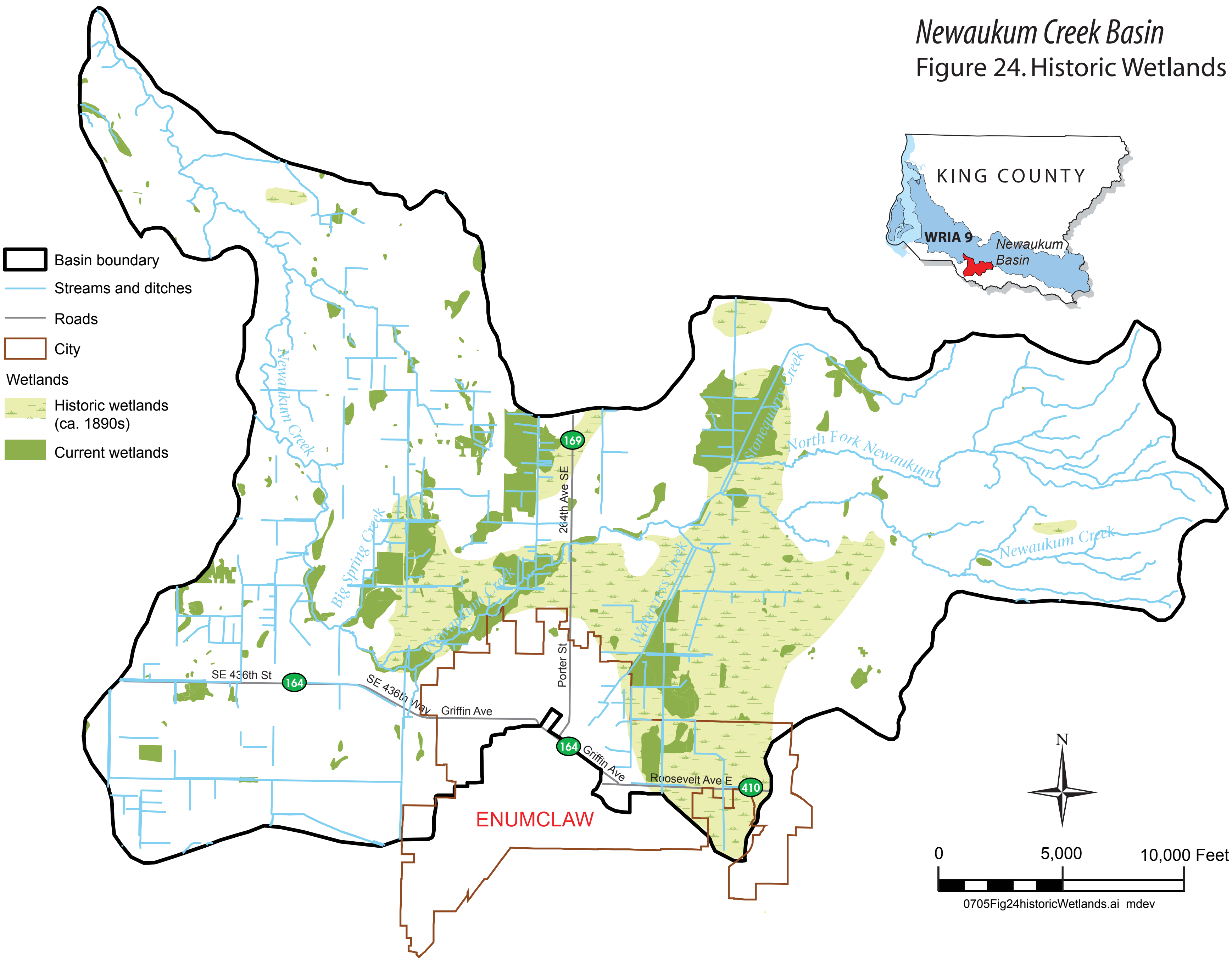
[20] We mapped current wetlands by creating a map of all available wetland related data in a GIS to produce a map, which was verified with field reconnaissance. No delineations were conducted, so these mapped wetlands do not indicate jurisdictional boundaries. The resulting data layer, depicted in Figure 23, thus represents the current best available wetland map for Newaukum Creek Ecosystem. Wetland data included: National Wetlands Inventory; King County Sensitive Areas Ordinance wetland folio; 2002 landcover data from University of Washington; wetlands in WDFW PHS data; "wetsoils" in U.S. Geological Survey "surfgeol" layer; and muck soils in University of Washington soils data. We noted errors of commission; where wetlands were mapped but apparently not present. Sizes or shapes of mapped wetlands were updated from field notes. Finally, errors of omission were recorded; where wetlands were present but not previously mapped, they were corrected. These wetlands were sketched and manually digitized. Finally, all open water ponds that were visible on aerial photos were added to the wetland layer if they were not already included. Each wetland polygon was viewed individually in GIS using color and infrared aerial images to assign wetland habitat types (Appendix B, Table B2). Farm ponds (man-made structures) were not included as wetlands; however, they are included in the landcover map. Sources of potential errors include partial or complete lack of verification because an entire wetland could not be accessed or a portion of a wetland encompassed an area too large to be viewed from the roadside. Sources of error when assigning wetland category from aerial images include, but are not limited to an: (1) inability to differentiate wetland vegetation from other field grasses and shrubs; (2) underestimation of emergent wetlands because they may be categorized as wet fields or scrub-shrub instead; (3) inability to detect wetland hydrology from aerial imagery in many cases, such as forested wetlands.

Newaukum Creek Basin
Figure 24. Historic Wetlands



7.4. SURFACE HYDROLOGY

This section explains some of the historical changes in the hydrology of Newaukum Creek. Please refer to 'Extreme Flows' in Section 6.2. for further details on the flow regime in Newaukum Creek, as well as summary statistics for mean daily, annual, and extreme flows.

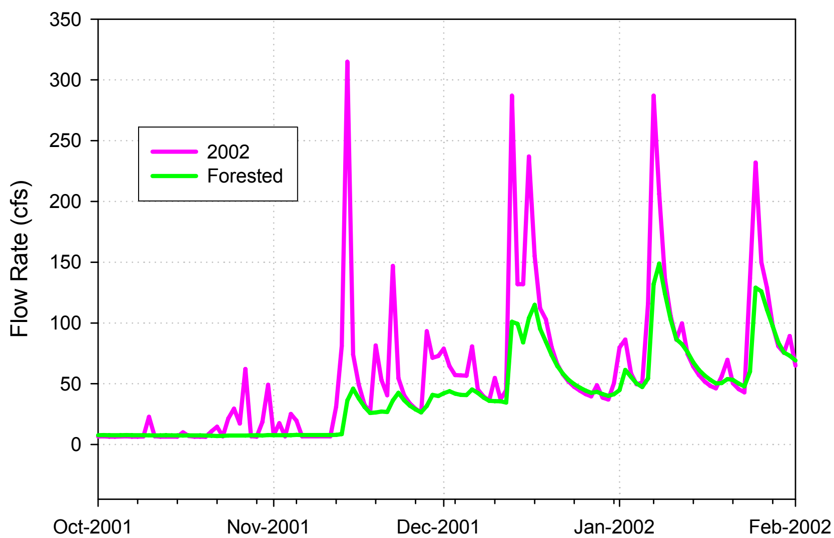
Humans alter the surface hydrology of Newaukum Creek basin through several pathways. For example, humans reduce flows by withdrawing water for irrigation, livestock watering, and domestic use. Recent figures are not available, but as of 1982, 11 water rights permits were issued in the basin, granting a maximum instantaneous withdrawal rate of 2.30 cfs (Goldstein 1982). Most of this (2.14 cfs) was for irrigation of 241 acres (97.5 ha), whereas 0.15 was for 'fish propagation' and 0.01 cfs was appropriated for domestic use (1 user). The creek was subsequently closed to further water rights applications. In addition to these direct alterations, humans influence the hydrology of the basin primarily by transforming forests and wetlands into agricultural areas and residential developments, which alters flow paths for runoff and increases the density of channels in the basin.

State and local policy (e.g., Washington State Department of Ecology, King County Department of Natural Resources and Parks) mandates the mitigation of hydrological impacts due to human activity. One standard practice is to estimate stream hydrology as it would have existed when watersheds were undisturbed by humans (commonly referred to as 'forested conditions). Any changes to that hydrologic regime would require construction of engineered facilities to better mimic natural conditions (e.g., see Fig. 25). For example, increased runoff during storms is readily apparent after development (Wigmosta and Burges 2001). Other changes are more subtle. For example, storm run-off events occur more frequently as soil conditions reach a threshold and become saturated, commonly in fall and spring. Hydrological impacts by human development vary within a basin, based on differences in land cover, geology, slope, and climate. However, with an estimated 74% of the basin underlain with low permeability soils (i.e. Osceola and bedrock), geology-related differences in hydrology are limited to areas near the base of the foothills. There, soils have a much higher permeability, and areas with these types of soils help mitigate hydrologic changes resulting from conversion of forested lands.

Human-induced changes to the hydrologic regime can be evaluated with direct methods using satellite imagery, numerical computer models, and continuing research; allowing specific conditions to be characterized without confounding external factors (e.g. climate). Using these techniques to numerically represent changes in the landscape provides the ability to quantify and thus prioritize where and how resources should be focused. In this report, we only address the former— quantification of basin hydrology. Unless specified otherwise, the reference condition for analytical comparisons is an entirely forested basin (i.e., hypothetical forested condition). We use 2002 land cover as a surrogate for 'current' conditions, and future land use zoning maps as a rough estimate of 'future' conditions.

The extent and distribution of forest cover and impervious surface strongly influences basin hydrology. [21]Amounts of impervious surfaces can be visualized in Fig. 26. A table of these estimates can be found in Appendix A, Table A3. The three sub-basins with the highest amount of impervious surface include parts of the City of Enumclaw. Sub-basin NEW261 contains the least impervious area (Fig. 27); this sub-basin is not in the FPD, rather it is located where Newaukum creek descends to the Green River valley floor. We estimate 11% of the Newaukum Creek basin is covered by impervious surfaces (or 9% if sub-basins dominated by residential and commercial areas are excluded), ranging from 2 to 59% among sub-basins. Clearly, impervious surfaces are not limited to urban areas.

Figure 25. Illustration of the estimated hydrology for Newaukum Creek (top) under forested conditions and as observed in 2002.



[21] In 2001, King County captured low altitude, high resolution multispectral imagery (i.e., using multiple light spectrums from infrared to near ultraviolet) of the landscape using an airplane platform. This yields a highly accurate estimation of impervious surfaces, excluding areas where topological or vegetative shading was significant—those areas were manually refined to improve accuracy (Fig. 26). Using a binary summarization of the data, land surfaces were classified as either impervious or non-impervious. The impervious classification includes existing asphalt/concrete roads, buildings, logging roads, or other highly impacted soils. Non impervious surfaces may include; forest, pastures, grass, wetlands, etc. Errors in the data set are primarily omission type errors not commission. An example of an omission error would be where impervious surface exists but is not classified as such. Commission errors occur where a non-impervious surface is misclassified as impervious. Consequently, the minimal error bias in the data set tends to under represent the true total impervious surface within the basin.

Newaukum Creek Basin

Figure 26. Impervious Surfaces

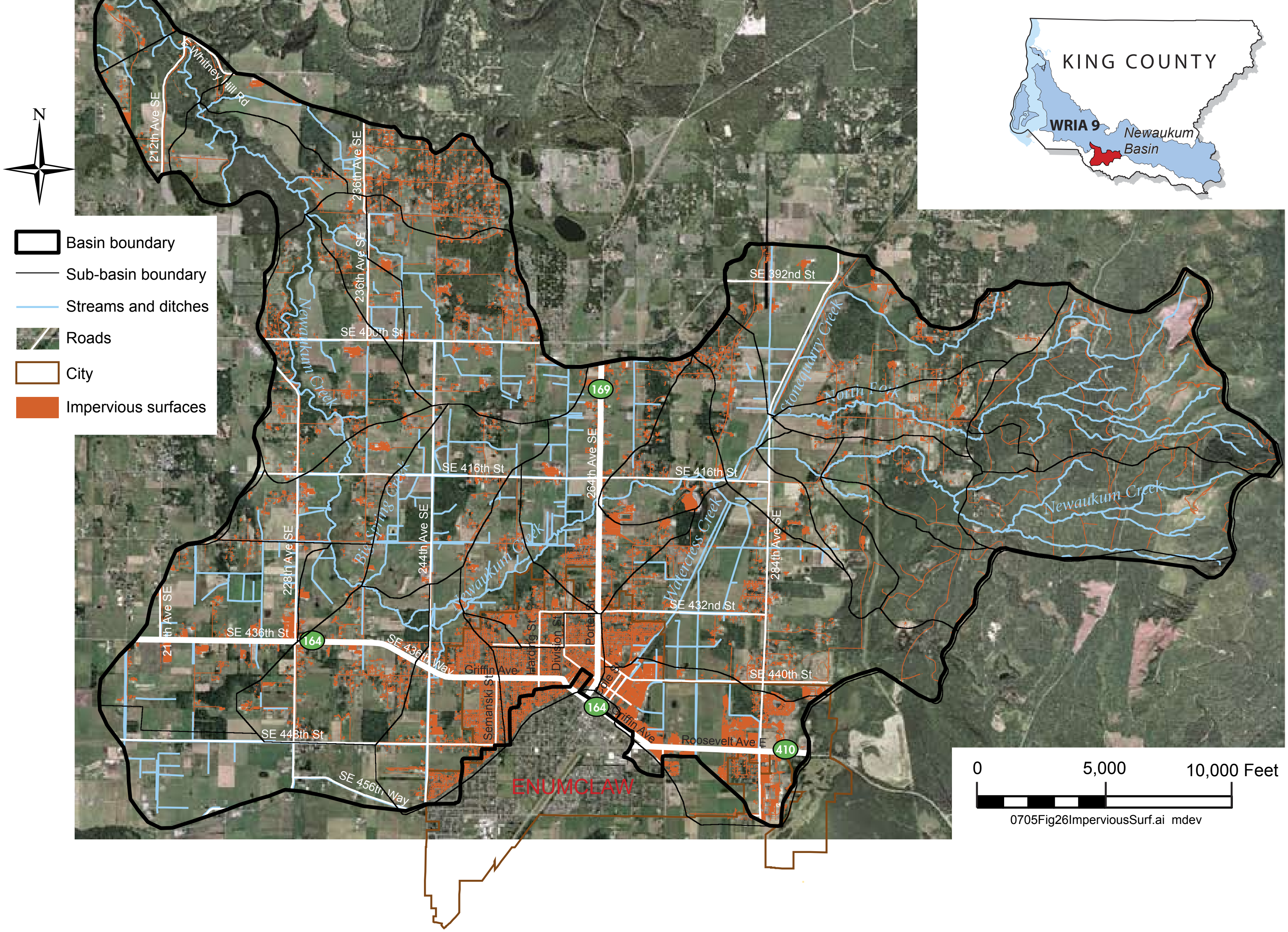
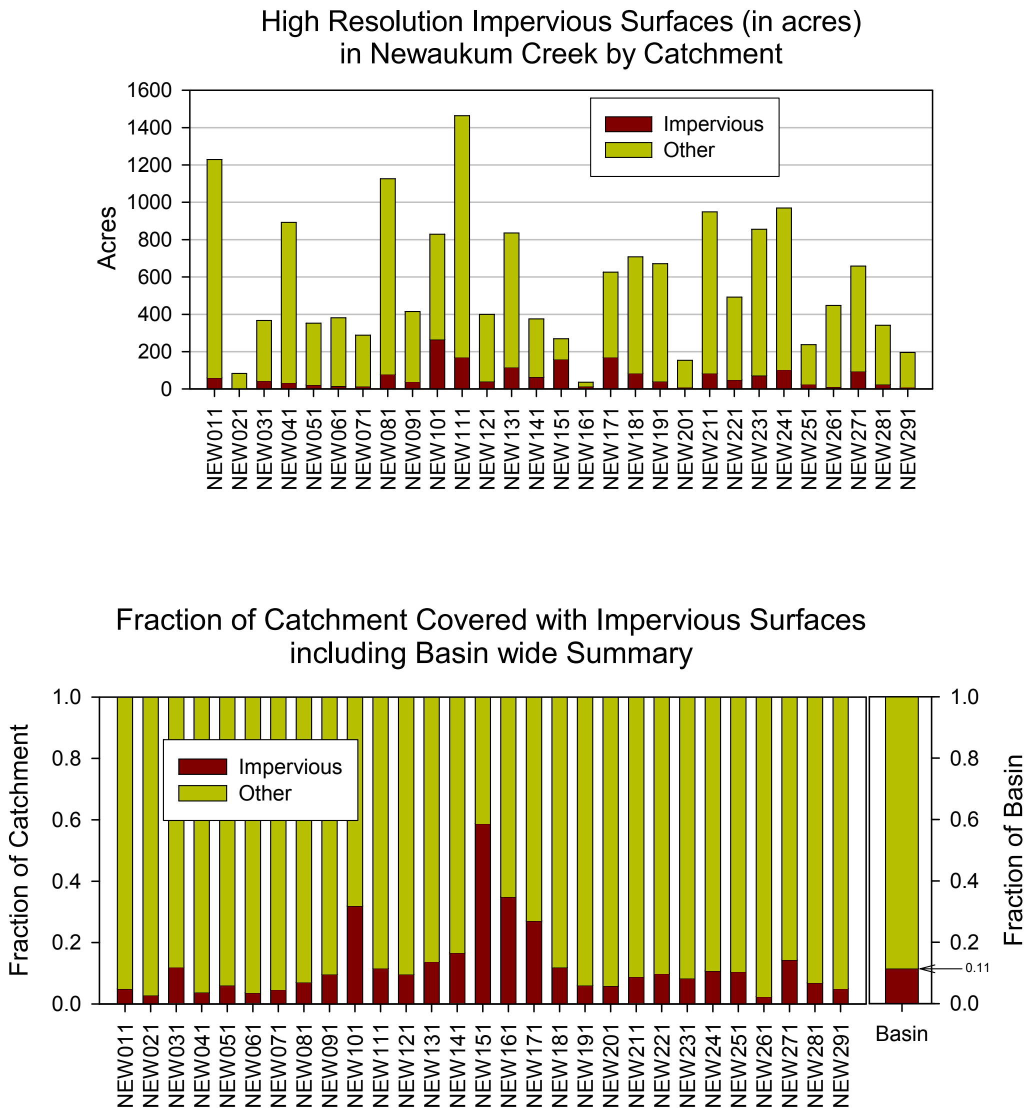


Figure 27. Bar graphs of impervious surface area by sub-basin. The upper panel shows the number of acres of impervious surfaces, while the lower panel illustrates the percent of the sub-basins (and basin overall) covered with impervious surfaces.



Human-induced changes in flood frequencies can be approximated for any location in the channel network by contrasting model estimates generated under different land cover conditions, in this case ‘forested conditions’ and ‘current conditions’. A complete list of flood frequencies can be found in Appendix A, Table A4. For example, we illustrate the predicted magnitude of hydrologic change across the basin using a moderately frequent flood event (10-year flood frequency), with estimates normalized to forested conditions. This analysis indicates where the greatest hydrological changes in the basin have likely occurred (Fig. 28). Not surprisingly, areas that remain largely forested show the least amount of change, while areas with highest amount of impervious surfaces show the greatest degree of change. Increases in the frequency of 10-year floods range from <10-percent (green) to > 200% (dark red) across the basin. Analyses of other flood frequencies yield similar results. One exception is that the divergence from forested conditions declines with storm magnitude (i.e. 100 yr storms), suggesting extreme events are severe under any land cover scenario. Moreover, differences between current and future conditions are minimal, presumably because the existing landscape is mostly 'built out' within zones, and forecasted changes in impervious area (for example) are expected to occur in zones that are already impacted by development.

Efforts to quantify relationships between stream hydrology and ecology are ongoing, but identifying a statistically significant link between flow metrics and biological parameters is challenging. A widely accepted, yet costly method of quantifying stream health is the Benthic Index of Biotic Integrity (B-IBI technique (see explanation in Section 9.2). Significant efforts have been made to directly link stream hydrology and ecology. These efforts have largely advanced using metrics requiring less costly data, such as development of Indicators of Hydrologic Alteration (The Nature Conservancy[22]), and the King County Normative Flow Program or NFP[23]. The NFP evaluated more than 100 different flow statistics in an effort to tease out significant correlations between aspects of the flow regime and stream health. Currently, a couple of dozen metrics have been shown to correlate well with B-IBI (Cassin et al. 2005). Generally, these identified metrics can be grouped into rates of change, durations, and magnitudes. The strongest correlation found was with the "high pulse range" (NFP metric #48). This high pulse range is defined as the number of days between the start of the first high flow pulse (i.e., where 'pulse' is defined as a flow exceeding the mean annual flow rate under a forested condition by a factor of two) and the end of the last high flow pulse during a water year.

We estimated the high pulse range for each sub-basin, which yielded results consistent to previous examples (Fig. 29); the more developed the landscape is, the more degraded the stream system is expected to become. This and similar metrics, accentuate the measured disturbance more than using storm and base flows. The divergence from forested conditions is obvious and pronounced. Predicted high pulse range is most sensitive to the extent of urbanization and agriculture, whereas predicted values between forested conditions and current forest production zones (FPD) are highly similar[24]. See Fig. 30 for an illustration of how predicted values for the high pulse range vary across the basin.

[22] http://www.nature.org/initiatives/freshwater/conservationtools/art17004.html

[23] http://dnr.metrokc.gov/wlr/BASINS/flows/index.htm

[24] Note that this similarity is likely influenced by the fact that model calibrations for forested conditions are based on the observed hydrology generated from the current Forest Production Zone. Further efforts are needed to specifically evaluate impacts of the Forest Production Zone on stream hydrology, relative to historic conditions.

Newaukum Creek Basin

Figure 28. Change in 10-Year Flood Frequency in Current and "Future" Landcover Scenarios

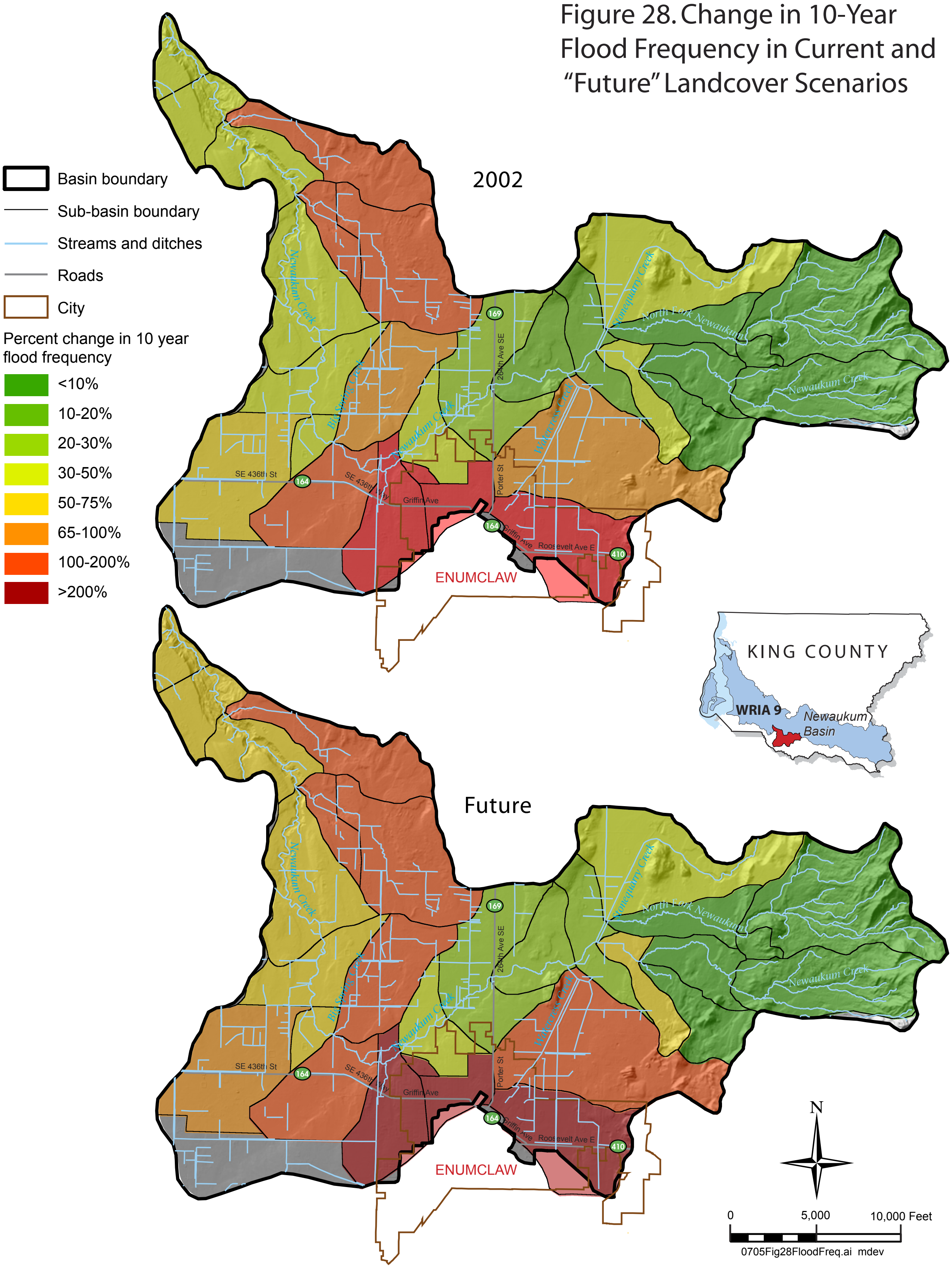
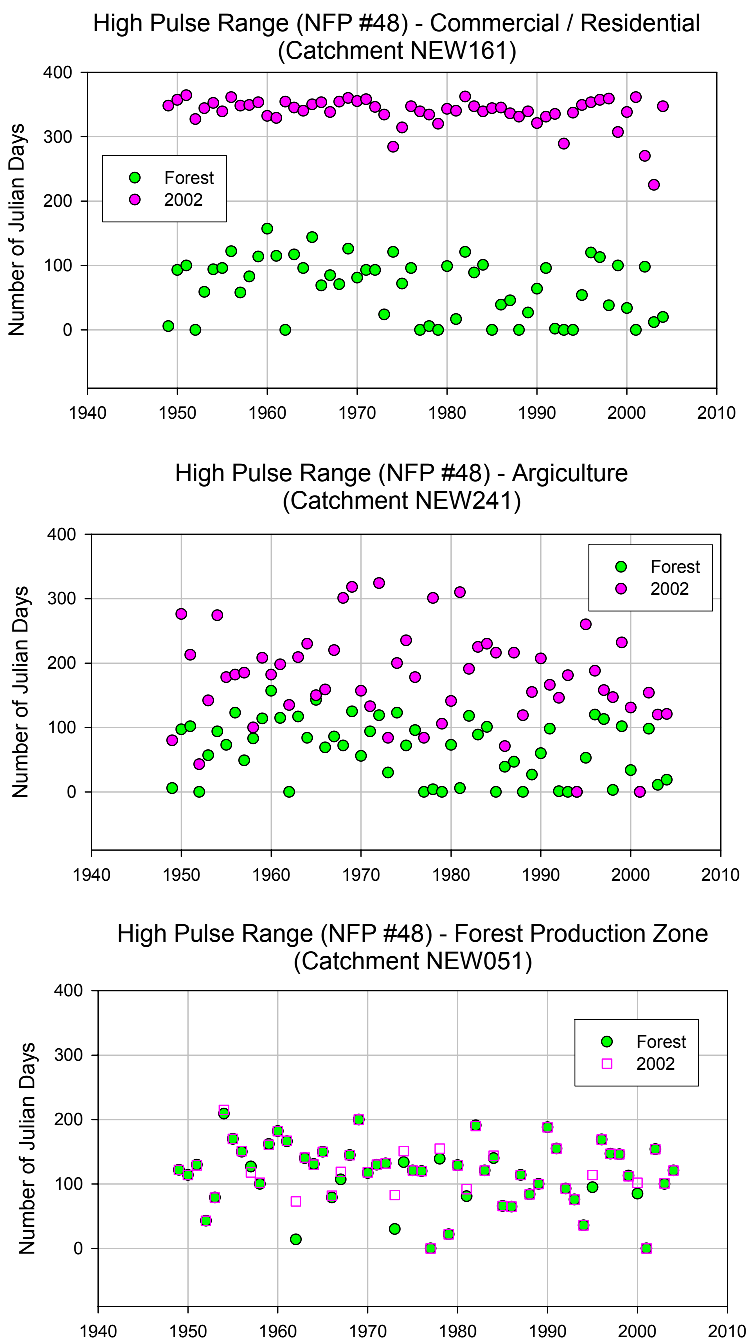
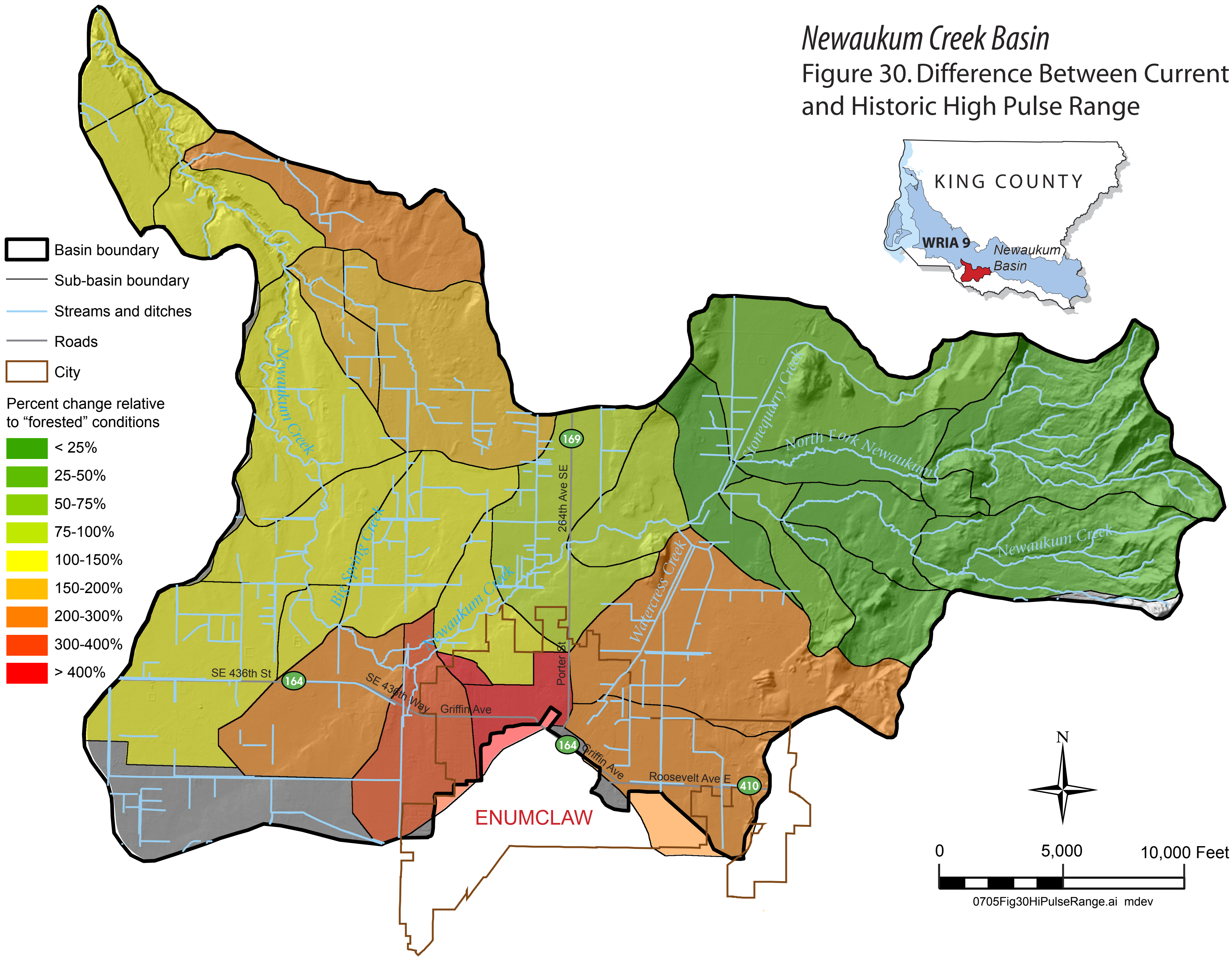


Figure 29. Comparison of 'high pulse range' among sub-basins with contrasting land uses: commercial/residential (top); agriculture (middle); and forest production (bottom). The high pulse range is measured in days between the start of the first high flow pulse and the end of the last high flow pulse during a water year. A 'pulse' is defined as twice the mean annual flow rate under forested conditions.



Newaukum Creek Basin

Figure 30. Difference Between Current and Historic High Pulse Range



7.5. GROUNDWATER HYDROLOGY

7.5.1. Hydrostratigraphy

Groundwater recharge into the lower zones of the Newaukum Creek basin is limited by the fine-grained material deposited in the Osceola mud flow (Qom). This material overlays the surficial geology and covers existing topography. Only a few earlier sculpted hills, such as higher-lying till drumlins and bedrock peaks, remain at the surface in the areas inundated by the mudflow (see Ch. 3.1.). See Table 4 for a summary of hydrogeologic units[25] beneath the Newaukum Basin.

The aquifers (Table 4) were mostly deposited by massive outwash floods carrying coarse materials from glacial melting to the north of the area when the only outlet for the floods was to the south. These major water-bearing hydrogeologic units are (from shallow, i.e., more recent, to deeper, older): (a) Vashon Recessional Outwash (Qvr); (b) Vashon Advance Outwash (Qva); and (c) Deeper coarse grained units (QAc, QBc).

In general, the aquifers receive inflow from recharge at the surface, to the extent water can penetrate the Qom overlying materials. The deeper units receive water from shallower ones, and carry it out to adjacent surface water systems (Newaukum Creek, the Green River, and the White River) where the river systems have eroded down to an elevation to intercept the aquifers. This is the normal hydrogeologic system in the Puget Sound Lowland region.

Groundwater recharge is higher along the eastern portion of the basin (though west of the bedrock hills), because the coarse material composing the Qvr aquifer is exposed at the ground surface. The paleotopography of this location was higher than the mudflow flood level during the Osceola mudflow event. As a result of the high groundwater flows in the Qvr in some nearby areas (such as in the Coal Creek basin to the north of the Newaukum basin) there are surface water systems that do not have surface water outlets. However, the Qvr unit is often underlain by bedrock at a shallow depth (in some areas as high as 700' elevation) and thus is not thick enough to convey all the water out to the margins. This may explain the presence of some springs that occur in the basin, particularly along the margins of the Osceola mudflow where coarser materials may not have been covered entirely. The deeper aquifers occur along the western portions of the Newaukum basin, where bedrock is much deeper.

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[25] Hydrogeologic and geologic units may differ because geologic nomenclature emphasizes depositional history whereas hydrogeology is concerned more about hydraulic continuity even when the history cannot be determined.

Table 4. Hydrostratigraphy of the Newaukum Basin. Aquifers are *italicized*.

Unit name	Unit abbrev	Aquifer / Aquitard	Elevation: top of unit	Receives water from	Discharges water to	Depositional process
Young Alluvium	Qyal	intermed., usually aquifer	175 - 585	adjacent units (e.g., Qva)	to Newaukum (or other) Creeks	Recent, deposited by Newaukum (and other) streams from materials eroded from adjacent materials
Mass Wasting deposits	Qmw	intermed.	255 - 455	adjacent units	to adjacent units	Recent, landslide debris
Wetland Deposits	Qw	intermed., usually aquitard	620 - 675	Runoff from adjacent areas	to underlying layers (Qva, Qvr)	Recent, developed through wetland biological processes
Osceola Mudflow	Qom	aquitard	560 - 750	Precipitation on surface	to underlying (Qva, Qvr)	Recent, mudflow (lahar) from Mt Rainier, about 5600 years ago
Vashon Recessional Outwash	*Qvr*	*aquifer*	*750 - 1070 (where at surface)*	*Precipitation on surface*	*to surface water or deeper units*	*Pleistocene, during melt-off of most recent glaciation, about 13,000 years ago*
Vashon Ice-contact Deposits	Qvi	intermed. usually aquitard	620 - 915 (where at surface)	Precipitation on surface	to underlying layers (Qva, Qvr)	Pleistocene, direct from ice-carried materials, during most recent glaciation, about 15,000 to 13,000 years ago
Vashon Till	Qvt	aquitard	545-740 (where at surface)	Precipitation on surface	to deeper layers (Qva) or runoff	Pleistocene, during most recent glaciation, about 15,000 to 13,000 years ago
Vashon Advance Outwash	*Qva*	*aquifer*	*uncertain, perhaps 450 - 620*	*From higher layers (Qvr, Qom)*	*to Newaukum Creek or to White or Green River*	*Pleistocene, from melt waters during advance of most recent glaciation, about 15,000 years ago*
pre-Fraser non-glacial unit	Qpf	intermed., usually aquitard	uncertain,perhaps 390-550	from shallower layers (Qva)	to deeper layers (QAc)	Pleistocene, probably during Olympia Interglacial period, approx 60,000 - 15,000 years ago
First older coarse unit	*QAc*	*aquifer*	*uncertain, perhaps 310 - 500*	*from shallower layers*	*to shallower units or to Newaukum Creek or White or Green Rivers*	*Pleistocene [probably during Possession glaciation, approx 80,000 - 60,000 years ago, but not studied so age is uncertain]*
Second older fine-grained unit	QBf	aquitard	uncertain, perhaps 200 - 470	from shallower layers	to deeper units (QBc) or back to shallower units (QAc)	Pleistocene [probably during Whidbey interglacial period, approx 125,000 - 80,000 years ago, but not studied so age is uncertain]
Second older coarse unit	*QBc*	*aquifer*	*uncertain, perhaps lower than 250*	*from shallower layers*	*to shallower units or to White or Green Rivers*	*Pleistocene [probably during Double Bluff glaciation, approx 190,000 - 125,000 years ago, but not studied so age is uncertain]*
Third Older undifferent-iated units	QCu	intermed-iate	uncertain	from shallower layers	to shallower units	Pleistocene, during older periods (glacial or non-glacial, uncertain ages)
Bedrock	Tf, Ti, To, Tp	aquitard	varies from below sea level in west to >2500 in east	from precipitation or unconsolidated units	to unconsolidated units	Miocene, Oligocene, and Eocene Epochs, mostly from volcanic events

7.5.2. Water Use

There are three large public water systems in the Newaukum Creek basin, as listed in Table 5. It is notable that Enumclaw gets much of its water from two spring sources, Boise Springs and Watercress Springs. There are also approximately 82 smaller public water systems (Group B systems) in the basin, serving between 2 and 14 connections each. All but one is supplied by wells; that one (F. Gunter Water System, ID 38096, in 20/06-14) obtains water from a spring. In addition, many residences obtain water from individual wells. Some individual wells are designated for use as irrigation sources; others are likely used for irrigation and livestock watering as well as domestic water supply.

Table 5. Large (GroupA) Public Water Systems in Newaukum Creek.

Water System Name	Dept of Health Id no.	Number of Users (Con-nections)	Sources	Location: township, range, section, depth
City of Enumclaw	23600	4,903	Boise Springs Watercress springs 2 wells intertie with Tacoma	T20 R07-29 T20 R07-19 T20 R07-18: 229’
Walczak Water, Inc	92350	67	1 Well	T21 R06-34 224’
Evergreen Sky Ranch Community Water	24165	22	3 Wells	T21 R06-32 83’ T21 R06-29 78’ T21 R06-32 68’

Washington State Department of Ecology lists many (but an uncertain number of) groundwater rights certificates and claims in the area of the Newaukum basin. The uncertainty comes from the imprecision of the location in the data available (only to township, range, and section) and from the likelihood that many claims have lapsed over the years from lack of use. Some of the more prominent groundwater rights in the area are those for municipal supply by the City of Enumclaw, with priority dates 1960, 1968, 1980, and 1986. There are several certificates for multiple domestic water supply systems, which may be identified to Group B systems. Many of the others are for irrigation purposes, and these may be difficult to link to a specific current owner. Ecology is in the process of mapping the water rights locations more precisely (including points of withdrawal, e.g., wells, and areas of application) but have not completed (or provided to King County) these GIS coverages for the Newaukum basin.

7.6. WATER QUALITY

Water quality strongly affects organisms living in Newaukum Creek, much of which is designated supplemental spawning and incubation habitat, as well as core summer salmonid habitat for salmon and trout (Payne 2006). Clean water –especially clean groundwater - is also vital to the health of people and livestock in the basin. Historically, Newaukum Creek probably ran cool and clear, exhibiting low acid-neutralizing capacity, and was nutrient-poor (i.e., oligotrophic), similar to most streams of the Pacific coastal ecoregion (Welch et al. 1998). Total suspended solids would have likely been relatively low, except during flooding events. However, water quality concerns related to manure disposal by dairy farms began to be addressed in the 1970’s. Since then, water quality degradation from land use change has been a growing concern. Many stream sampling locations have been established (Fig. 31). More recently, water quality in Newaukum Creek was rated as being of ‘moderate concern’ in 2003-2004 (based on Water Quality Index rating: Washington Department of Ecology), signaling a general improvement in conditions during the last three decades.

This section first characterizes the quality of drinking water supplies, the status of sewage treatment, and then focuses on four aspects of water quality known to have been problematic in Newaukum Creek: (1) temperature; (2) dissolved oxygen[26]; (3) nutrients; and (4) bacterial contamination. For example, Newaukum Creek was listed under Section 303(d) of the federal Clean Water Act as an impaired water body in 2004 (Listing # 12708) because portions of the stream did not meet water quality standards for dissolved oxygen between June and October (see Roberts and Jack 2006). Please refer to Appendix C, Table C1 for comprehensive information on long-term average values for these and other water quality characteristics.

7.6.1. Drinking water supplies and sewage treatment

Groundwater provides high-quality drinking water to the residents of the Newaukum Creek basin (also note details in Section 7.5.). The major (3 Group A; Table 5) systems have only minor water quality problems with coliform bacteria (usually in the distribution system), and iron and manganese in the well water. The iron and manganese are of secondary concern because their impact is mainly only on esthetics (taste and color) rather than human health. Both Group A and B systems must analyze for nitrate on a regular basis, and the results of these analyses (although none exceed the Drinking Water Standard of 10 mg/l nitrate as N) are used to address concerns about nutrients entering into the groundwater system.

Sanitary sewers and wastewater treatment plants handle human wastes within the city limits of Enumclaw but otherwise the population is on septic systems. Many of these systems are antiquated, often installed contemporaneously with the houses they serve, and probably do not adequately treat the nitrate from the waste.

Some nitrate emitted from these sources near the ground surface is taken up by plant roots, while much of the rest is denitrified by bacteria in the aquifer. However, some nutrients can be carried horizontally a considerable distance. A check of nitrate concentrations in compliance samples taken by Group A and B public water systems in the basin indicates a median concentration of about 0.3 - 0.4 mg/l (N), with a tendency for higher concentrations in shallower wells (less than 100’ depth), as would be expected from the transport pathways described above.

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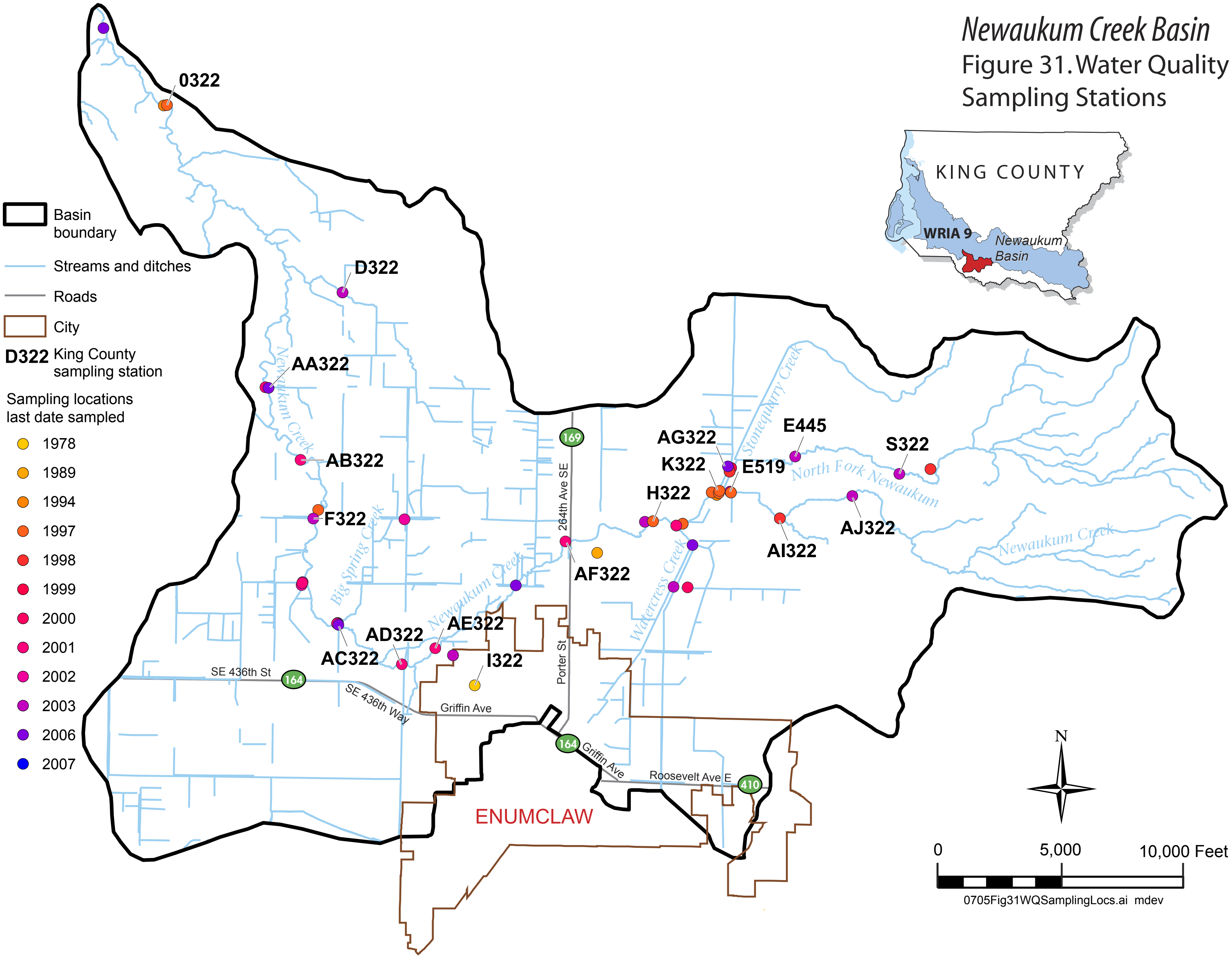
[26] Temperature and dissolved oxygen are currently being investigated and addressed by a cooperative effort between the Washington Department of Ecology, King County, the Muckleshoot Indian Tribe, and others (details in Roberts and Jack 2006).

Newaukum Creek Basin

Figure 31. Water Quality Sampling Stations



7.6.2. Temperature

Stream temperature is critically important to aquatic organisms because it regulates their survival, metabolism, reproduction, growth, and behavior (Welch et al. 1998). Permanent shifts in temperature can cause stream organisms to abandon habitat that would otherwise be suitable (Holtby 1988). Accordingly, stream temperature is closely regulated[27]; heat is considered a pollutant under Section 502(6)d of the Clean Water Act. Newaukum Creek is designated core summer salmonid habitat for salmon and trout which means the seven-day average daily maximum (7-DADM) water temperature must not exceed 16°C (60.8°F) during July 1 to September 15. Newaukum Creek from the mouth to approximately RM 12 and portions of the North Fork[28] are also protected as supplemental spawning and incubation habitat for salmonids (Payne 2006). This means that water temperatures must not exceed 13˚C (55.4°F) from September 15 to July 1 (Plate 7.6.2).

Heat load and stream discharge are inseparable determinants of stream temperature, and both must be considered when seeking management solutions to alleviating high stream temperatures (see Poole and Berman 2001 for a synthesis). In effect, stream temperature is influenced by the heat load (heat energy added to a stream) divided by the discharge (volume of water flowing in the channel). This means that any human activities that change either the heat load to the channel or the discharge in the channel will influence stream temperature. For example, diversion of water from the stream will result in increased stream temperatures unless the heat load is also reduced. Likewise, increasing discharge, without altering heat load, will decrease stream temperatures. Stream temperatures are affected by many factors across a number of spatial scales and may be highly variable, even among locations only several meters apart (Haeur and Hill 2006). This means that point-values must be interpreted within the broader context of entire stream reaches.

Internal drivers of stream temperature include:

- Channel morphology: Deep, narrow, placid channels absorb less heat from the atmosphere and are more easily shaded than wide, shallow, turbulent channels. Temperatures in channels with complex, uneven streambeds are generally less variable because of buffering effect of exchanges between surface waters and the hyporheic zone (subsurface mixing zone beneath the streambed).
- Riparian vegetation: Trees and shrubs insulate the stream from solar radiation, reducing the heat load; allowing cool streams to stay cool. Trees also reduce windspeed and increase humidity, which reduces advective and conductive heat transfer from the atmosphere to the stream but also decreases evaporative cooling. Long-term studies from Oregon revealed that removal of riparian forests along small streams increased maximum stream temperatures by 7˚C and the daily temperature swings in June to increase by 6˚C (Johnson and Jones 2000). Fifteen years passed before stream temperatures recovered to pre-impact levels. While relatively narrow forested buffers provide shade (insulation from solar

[27] See www.ecy.wa.gov/programs/wq/swqs and http://www.ecy.wa.gov/pubs/0610091.pdf for more information on revisions to existing standards.

[28] See map at http://yosemite.epa.gov/r10/water.NSF/34090d07b77d50bd88256b79006529e8/99190491021573f788256f87005f503a/$FILE/wria09_spawning.pdf

radiation), maintaining riparian microclimates (which affects advective and convective heat flux) requires buffers at least tens of meters wide (see Brosofske et al. 1997).

- Alluvial aquifer layering: The depth and layering of aquifers determines the extent and patterns of fluxes between surface and subsurface flows. These exchanges do not add or remove heat, but rather buffer changes in temperature.

Other external drivers of stream temperature control the rate at which heat and water are delivered to the stream, and can be affected by human activities. These (natural) external drivers include: topographic shade; precipitation; air temperature; windspeed; solar angle; cloud cover; relative humidity; groundwater temperature and discharge into the stream; and tributary temperature and discharge (Poole and Berman 2001).

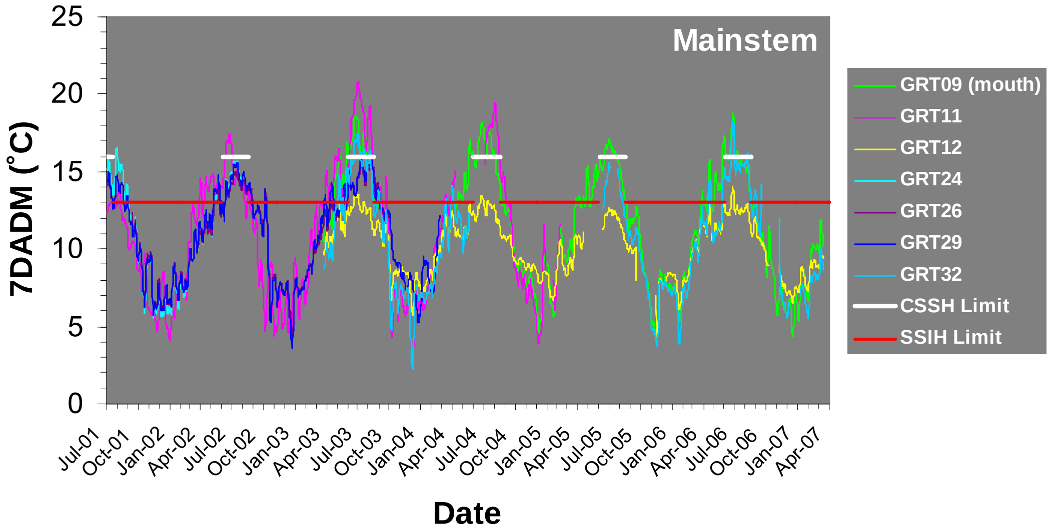
In a relatively small stream, such as Newaukum Creek, the thermal stability of a stream is strongly influenced by riparian shade and groundwater inputs. The factors likely influencing stream temperatures in the system can be ranked in order from most important to least important (adapted from Poole and Berman 2001):

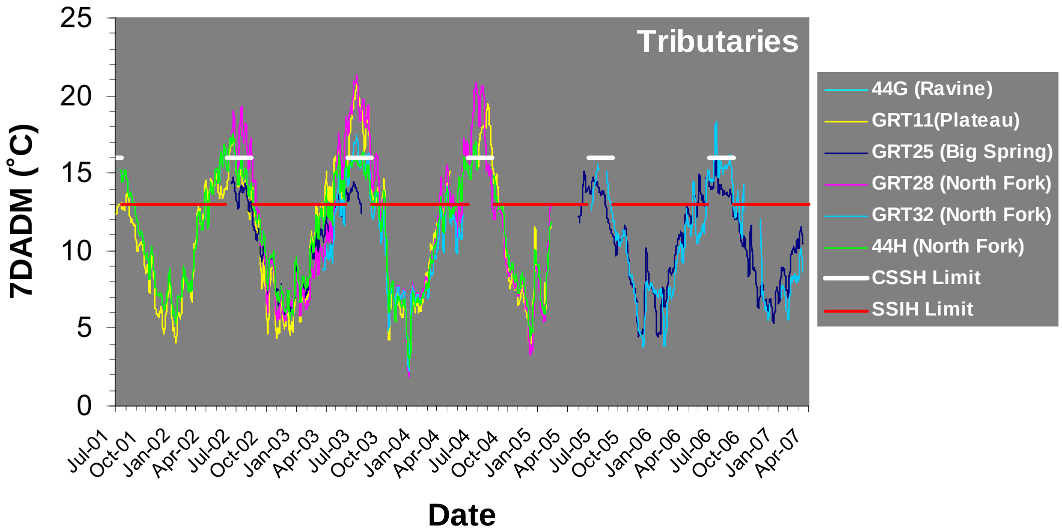
1. Riparian shade (High)
2. Groundwater (High)
3. Tributaries (Moderate)
4. Stream discharge (Low-Moderate)
5. Hyporheic groundwater (Moderate in Ravine, Low in the Upper Basin and Plateau)

Humans have shaped many of these drivers, but the most important mechanisms by which human activities may affect stream temperatures in Newaukum Creek likely include (after Poole and Berman 2001):

- Reductions in stream shading due to forest clearing across the Plateau have likely increased the heat load to the stream;
- Increases in impervious surfaces, clearing of forest cover, and groundwater pumping may have reduced stream discharge during the summer (see Section 6.2). This reduces the stream's ability to withstand a given heat load without exhibiting increased stream temperature. Simultaneously, landcover changes may cause more surface runoff, which tends to carry a greater heat load, than if it were to percolate through aquifers.
- Drain tiles and ditches cause groundwater to enter surface channels where it is subject to warming, rather than be directly delivered to the stream via subsurface pathways. This increases the overall heat load to the channel network and may be contribute to increased stream temperatures.

Plate 7.6.2. Seasonal and interannual patterns in the seven day average daily maximum temperature (7DADM) at monitoring stations in the mainstem (upper panel) and tributaries (lower panel)[29]. Temperature limits for core summer salmonid habitat (CSSH) and supplemental spawning and incubation habitat (SSIH) are shown.





- Many other changes have occurred, including simplification of the stream channel through diking and wood removal. These actions may reduce hyporheic flow (a subsurface mixture

[29] See maps of water temperature monitoring locations at ftp://dnr.metrokc.gov/dnr/library/2004/kcr1609/0401_05greenTEMPmgrsites.pdf and http://dnrp.metrokc.gov/WLR/Waterres/hydrology/GaugeMap.aspx?TabDefault=Map

of groundwater and riverwater) – particularly in the Ravine, whereas relatively little hyporheic exchange is expected to occur across the Plateau due to the fine-grained substrate from the Osceola mudflow.

Water temperatures– specifically, 7DADM – in the mainstem of Newaukum Creek consistently exceeded Washington state standards for streams designated as spawning and incubation habitat (SSIH limit, Plate 7.6.2) at five of six sampling locations in recent years. The site nearest the forested headwaters was a notable exception (GRT12). The 7DADM typically rises above 16˚C beginning in early May and largely remains at that level until October. The 7DADM has also exceeded core summer salmonid habitat standards (CSSH limit, Plate 7.6.2) at the mouth of Newaukum Creek each year since 2003, and also at monitoring stations along the Ravine and Plateau.

Similar patterns have been observed in water temperatures in tributaries to the Newaukum Creek mainstem. The 7DADM has typically exceeded the SSIH limits in five of six tributary streams in recent years – especially in springtime. CSSH limits were also exceeded throughout much of the basin, with the largest exceedances being observed in portions of the North Fork and in an unnamed tributary stream along the Plateau. The most notable exception to these patterns was Big Spring Creek, in which the 7DADM only slightly exceeded SSIH limits in spring, and has not exceeded within CSSH limits, at least in recent years.

Stream temperatures were simulated under three scenarios for Newaukum Creek (an agriculturally dominated sub-basin) to evaluate the potential benefit of riparian reforestation and the potential outcome of hydrological changes resulting from pending landcover change[30]. Scenarios included: (1) current land cover, (2) future land cover, and (3) future land cover with added mature riparian vegetation. Scenarios 1 and 2 assumed existing shade equivalent to 20% of the stream surface, and scenario 3 assumed 65% equivalent shade. For context, Scenarios 1 and 2 are representative of conditions in the Plateau in 1980, when 15% of the stream length was shaded (Goldstein 1982). Scenario 3 is more representative of conditions in the Ravine in 1980, where 62% of the stream was shaded. Results suggest future stream temperatures are likely to increase as a result of diminished groundwater base flows. Conversely, summer time stream temperatures could be improved beyond existing conditions by increasing the riparian shade (e.g., in a forested stream system). However, we caution that further model development and accuracy assessment is warranted[31]. This simulation did not consider the effect of increased soil and air temperatures resulting from anticipated climate change.

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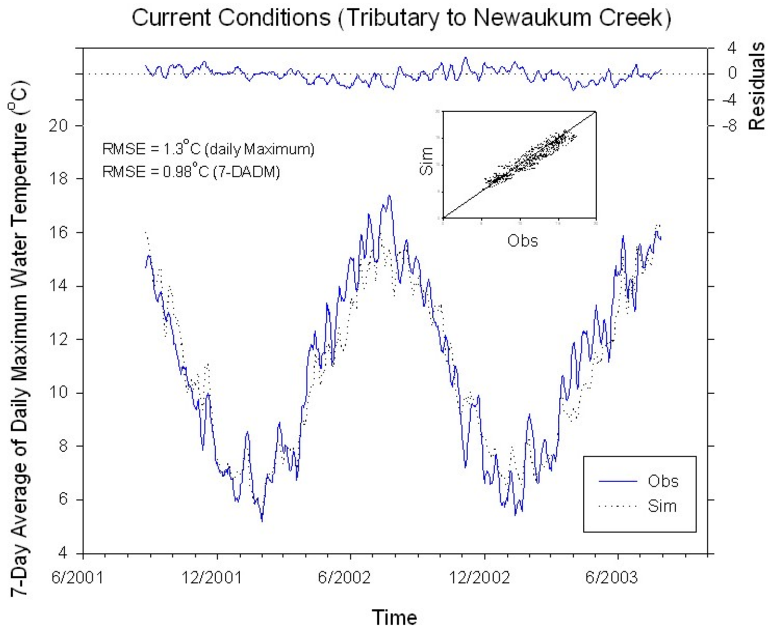
[30] See Section 7.6.6. Note that more comprehensive and sophisticated modeling efforts are underway (Roberts and Jack 2006, Swanson et al. 2006). Accordingly, simulation results presented here should be integrated with information from ongoing studies.

[31] For example, calibrating for water temperature requires comparing simulated and observed data throughout the seasons. However, to apply these models for supporting Total Maximum Daily Load (TMDL) development, it would be prudent to test the models for accuracy with criteria used in TMDLs. In this case, water temperatures would be evaluated on a sliding 7-day average of daily maximum water temperatures. Using this statistic, Fig. 32 illustrates some comparisons (e.g., a time series plot, scatter plot, and a residual plot) of simulated versus continuous observed stream temperatures for a tributary to Newaukum Creek. Focusing only on summer months (June-September), the root-mean-square-errors (RMSE) for daily maximum water temperatures and the 7-Day Average of Daily Maximums (7-DADM) RMSE equal 1.3^{o}C and 0.98^{o}C, respectively.

Figure 32. Comparisons of simulated versus continuous observed stream temperatures for a tributary to Newaukum Creek.



7.6.3. Dissolved Oxygen

Dissolved oxygen (DO) is vital for the survival of aquatic animals, such as fish, amphibians, and invertebrates. Oxygen is added to the stream through mixing with the atmosphere, and absorbed across the air-water interface, but also is produced by photosynthetic aquatic plants. Low oxygen conditions result when the plant material dies and decomposes or result from diel shifts in plant metabolism. In this way, nutrient pollution and DO are linked (see Section 7.6.4).

Newaukum Creek is designated core summer salmonid habitat for salmon and trout (Payne 2006) which means the lowest 1-day minimum DO level must not fall below 9.5 mg L^{-1}. during July 1 to September 15. Newaukum Creek from the mouth to approximately RM 12 and portions of the North Fork[32] are also protected as supplemental spawning and incubation habitat for salmonids. This designation means the lowest 1-day minimum DO level must not fall below from September 15 to July 1. Essentially, DO levels must exceed 9.5 mg L^{-1} year-round in Newaukum Creek.

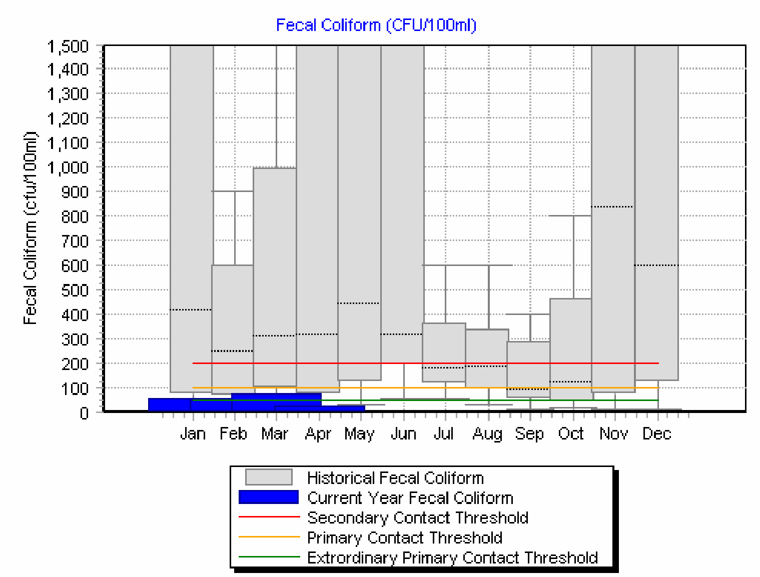
DO levels have not significantly changed from 1979-2004 at the mouth (Station 0322), but have significantly declined at Station F322 near 416th. Newaukum Creek was on the 2004 303(d) list of impaired waters for dissolved oxygen.

[32] See map at http://yosemite.epa.gov/r10/water.NSF/34090d07b77d50bd88256b79006529e8/99190491021573f788256f87005f503a/$FILE/wria09_spawning.pdf

7.6.4. Nutrients

Nutrients, such as nitrogen (N), phosphorous (P) are essential for living organisms and in supporting instream primary production, but in excess, nutrients become pollutants. In natural streams of the Cascades, N or P (or both) are typically in scarce and therefore limit primary production in streams (Welch 1992). The N:P ratios in the Newaukum Creek mainstem is roughly 16:1, which is in the normal range for this region and suggests that phosphorus is the nutrient limiting instream primary productivity (i.e., assuming periphyton uses N and P at ratios of 7:1; Welch 1998). In contrast, N is often assumed to be limiting to plant production in riparian areas. An excessive supply of nutrients can promote algal blooms and associated declines in dissolved oxygen (see 7.6.3).

Plate 7.6.4. Comparison of historical (from 1979) and current (2007) fecal coliform levels in Newaukum Creek.



The box contains the middle 50% of the data. The upper edge (hinge) of the box indicates the 75th percentile of the data set, the lower hinge indicates the 25th percentile. The difference between the values of the hinges is called the interquartile range. The line in the box indicates the median value of the data set. The ends of the vertical lines (whiskers) extend to 1.5 times the interquartile range. Values that lie out side of the whiskers are termed outliers. Outliers have been omitted from our graphs for clarity.

Ammonia and total N in Newaukum Creek have apparently declined from 1979-2004, though total N, ortho-phosphorus, total P concentrations are still high relative to the rest of the greater Green River basin. Levels are particularly high near areas where agriculture is prevalent (Herrera 2005), and in stormwater near the mouth of Watercress Creek (Wachter 1999). Studies are ongoing; Swanson et al. (2006) reported average NH_3 concentrations of 0.01 mg L^{-1} in Newaukum Creek mainstem and 0.039 mg L^{-1} in the tributaries (± 0.026 SD, range 0.01-0.06). Nitrate plus nitrite concentrations averaged 1.06 mg L^{-1}in Newaukum Creek mainstem (± 0.5 SD, range 1.42-1.95) and 1.4 mg L^{-1} in the tributaries (± 0.08 SD, range 0.56-2.1). Total P averaged 0.054 mg L^{-1}in Newaukum Creek mainstem (± 0.021 SD, range 0.03-0.06) and 0.071 mg L^{-1} in the tributaries (± 0.025 SD, range 0.03-0.08). Orthophosphate concentrations averaged 0.033 mg L^{-1}in Newaukum Creek mainstem (± 0.020 SD, range 0.016-0.044) and 0.045 mg L^{-1} in the tributaries (± 0.028 SD, range 0.03-0.08).

Nutrients originate from many sources. Both human-related and ecological sources are briefly considered here (but see McClain et al. 1998 for more detail). We focus on N because it is relatively sensitive to human and biological activities. Whereas naturally-occurring P largely originates from geologic sources, such as bedrock weathering, N enters streams through many pathways, such as organisms that capture it from the atmosphere (e.g., N-fixing bacteria) or from the oceans (e.g., Pacific salmon). Substantial N also enters the stream and surrounding landscape through atmospheric deposition[33]. N also naturally originates in water upwelling from subsurface aquifers, including the hyporheic zone, but this source and others are not considered here. In oxygenated streams, N most commonly occurs as nitrate-nitrogen, but also as ammonium-nitrogen, both of which support the growth of aquatic primary producers (Welch et al. 1998).

Red alder forests naturally deliver N to streams. Their roots are 'infected' with microbial symbionts (*Frankia* bacteria) that 'fix' N_2 gas from the atmosphere. This contributes substantial amounts to soils each year via leaf litter and belowground processes. For example, 40 yr-old alder stands produce roughly five metric tons of leaf litter annually, resulting in the deposition of approximately 100 kg of N to riparian soils (O'Keefe and Naiman 2006). Most alder-derived N originates from stands along recently disturbed reaches in the Upper Basin or Ravine, though few persist across the Plateau.

Marine-derived N enters the stream via salmon carcasses, and is mostly restricted to the limits of anadromous fish spawning; primarily the Ravine and Plateau (see Section 9). The carcasses of spawning salmon support the productivity of other organisms in the stream (Bilby et al. 1996, 1998; Wipfli et al. 1998). Deposition rates vary annually, depending on the number of dead salmon in the system. For example, a 7.25 kg spawned-out salmon contains 0.18 kg of N and 0.031 kg of P (Gende et al. 2004). Salmon-derived N inputs to riparian areas are patchy and short-lived, and mostly used by riparian trees (Drake et al. 2006). Nutrient retention is enhanced by large wood – both directly by physical capture and indirectly through biological uptake (Valett et al. 2002).

Of course, humans add N to streams and groundwater via many activities. Groundwater receives nutrients (usually nitrate) from a variety of sources, such as: fertilizers applied to crops and lawns, decay of plant material after land clearing, manure from livestock management (dairies, beef cattle) and human waste disposal via on-site sewage systems (OSS). Nitrate leaching from agricultural fields to subsurface aquifers can produces productivity hotspots (manifested as algal blooms) in areas where N-rich water is upwelling into stream channels. Surface waters also likely receive nutrients in runoff from forestlands (e.g., biosolids or urea application) and residential landscapes, as well as atmospheric deposition. Also, human impacts on beavers alter nutrient cycling in Newaukum Creek by reducing their influence on river form and hydrology.

7.6.5 Bacterial Contamination

Fecal coliform bacteria originate from the feces of warm-blooded animals. They enter streams through many pathways, including livestock, application of manure as fertilizer, manure lagoons, and failing residential septic systems (Wachter 1999). Bacterial pollution during high flow events has been a major concern in Newaukum Creek for a more than a decade, and continues to represent a significant management challenge. As a result, seventeen bacteriological sampling

[33] Inkpen and Embry (1998) estimate that Puget Sound annually receives from rivers 15,000 tons of N from animal manure, 9,300 tons from agricultural fertilizers, and 7,800 tons from atmospheric deposition.

stations were established in the Newaukum Basin[34]. Bacteria are regulated to protect water contact recreation:

Earlier studies (1995-1997) found that fecal coliform levels exceeded water quality standards during storms in most sampling locations outside of the forested Upper Basin (Wachter 1999). These early studies found extreme contamination near the mouths of Watercress Creek, the Veazie Valley conveyance, and in the mainstem (the latter being attributed to cumulative impacts of land use, including manure lagoons on dairy farms). Fecal coliform bacteria loading measured at the river mouth improved from 1979-2004 (Herrera 2005), but 12 stations violated water quality standards in 2000, and violations were also observed in 2004, according to the Washington Department of Ecology.

7.6.6 Other Water Quality Parameters

The biological condition of streams in King County (i.e., as indicated by B-IBI) declines with increasing average low-flow conductivity[35], alkalinity[36], turbidity, total suspended solids, total phosphorus, zinc, and copper concentrations (McElligott 2005). Increases in conductivity and alkalinity – in particular – are strongly linked to urbanization of watersheds (McElligott 2005). Further work is needed to establish cause-and-effect relationships.

Trend analysis of water quality data from 1979-2004 (at Stations F322 and O022) reveals mixed results (Herrera 2005). Significant improvements were observed in turbidity[37] at both stations. Significant worsening trends were detected in conductivity (0322) and pH (O322). Studies from 1995-1997 concluded that concentrations of total suspended solids were elevated near the mouth of the Veazie Valley conveyance, though loading rates were not quantified (Wachter 1999). Total suspended solids measured at the river mouth improved from 1979-2004, though turbidity and TSS remain elevated during storms (Herrera 2005).

Earlier studies concluded that Watercress Creek is an important source of metals (Cu, Pb, Zn) to the mainstem and contributes to the degradation of water quality (Wachter 1999). In 2003,

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[34] Map and site codes at ftp://dnr.metrokc.gov/dnr/library/2000/kcr728/ADDENDA/fig2-bacteria-sample.pdf.

[35] Measurements of stream conductivity, which is the capacity to transmit an electrical current, are useful in tracking changes in water quality and in tracing the movement of both natural constituents and pollutants through the channel network (Welch et al. 1998). Conductivity is determined by the quantity and type of ions (i.e., electrically charged) present in the water. Measurements of total dissolved solids (TDS) – essentially a measure of salts dissolved in the water - are used in much the same way.

[36] Acid Neutralizing Capacity (ANC) or alkalinity indicates the ability of the stream to resist changes in pH (Welch et al. 1998). Levels of ANC and pH are largely determined by the type of bedrock in the headwaters, which affects the quantity of bicarbonate and carbonate ions (Welch et al. 1998). Both ANC and pH are relatively low in Cascade streams.

[37] Water clarity is typically measured as turbidity or from the concentration of suspended solids (e.g., fine sediments), expressed in nephelometric turbidity units (NTU's; Welch et al. 1998). The concentration of fine sediments in stream water is naturally quite variable, but is sensitive to human impacts; development activities tend to reduce the clarity of the stream. Murky (turbid) water can inhibit the ability of fish to locate prey and deposition of fine sediments can reduce the survival of incubating eggs. Generally, turbidity should not exceed 25 NTU's (EPA 1986).

total aluminum concentrations[38] reached chronic levels in baseflow and acute levels during storm events, based on U.S. EPA guidelines (Herrera 2005). Average dissolved copper concentrations are below the maximum acceptable thresholds for acute and chronic levels (EPA 1986).

7.6.7. Water Quality Patterns in the Green River Watershed

Water quality modeling efforts at the scale of the greater Green River watershed provide some context for understanding patterns in water quality in Newaukum Creek. Modeling efforts, in general, can inform management actions by helping to identify major contributors to water quality degradation.

For example, an observational study (2001-2003) focusing on non-point sources - primarily generated from land use practices - was conducted by King County, Department of Natural Resources and Parks, Science section[39]. This generated loading estimates for nutrients and bacteria for the Green River watershed based on an intense sampling water quality monitoring program. Non-point source pollutant loadings are generated from various types of land use (e.g. dairy farms, residential lawns, etc.), so classified land cover maps were re-categorized to better fit the level of data and associated certainty. The categories used were: 1) bare ground, 2) commercial and industrial, 3) grasses, 4) crops/pastures, shrubs, 5) forests, 6) high density residential, 7) low density residential, 8) roads, 9) wetlands, and 10) open bodies of water.

Pollutant loading rates were estimated for individual sub-basins across a variety of land use types by quantifying landcover across the entire Green River watershed and using calibrated numerical models to create a rich data set. A data reduction technique was used to accommodate the large number of variables and variability across sub-basins. Specifically, we used Principle Component Analysis (PCA), which identifies the significant variables influencing the variance observed in the data, while maintaining the full characteristics of the data.

Principal Components Analysis results suggest that 61.6% of the variance in the water quality data can be explained by the first two principal components (Fig. 33). Component 1, explaining 45.5% of the total variance, is primarily controlled by the high concentrations of constituents which are found in urban and agricultural areas. All measured constituents – except for DO, pH, and the conductivity, hardness, and alkalinity covariates – cluster on the left side of the Component 1 axis. This cluster is dominated by agricultural and urban areas (Fig. 34), whereas the right side is dominated by forested sites with some low/medium development sites. Thus it can be inferred that the variability in water quality between these land use types explains 45.5% of the variation in the dataset.

The second principal component explains 16.1% of the variance in the data and is strongly controlled by conductivity, hardness, and alkalinity. These constituents are higher in groundwater than stormwater so the second principal component can be interpreted as a baseflow vs. stormflow component. This component also captures some of the variance between agricultural water quality and urban water quality with metals grouping in the northwest quadrant and nutrients grouping in the southwest quadrant, which are mostly agricultural sites

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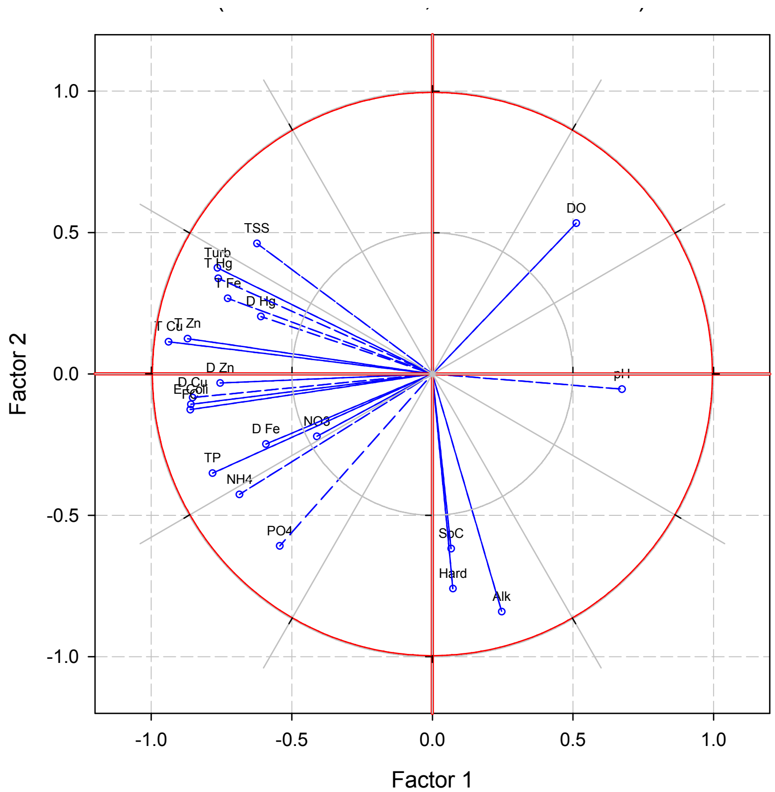
[38] Aluminum is often associated with the effects of acid precipitation or industrial discharges (Welch et al. 1998).

[39] http://dnr.metrokc.gov/wlr/watersheds/green/water-quality-assessment.htm; ftp://dnr.metrokc.gov/dnr/library/2004/KCR1636/8-newaukumcrk.pdf

(Fig. 34). Urban sites group with the metals in the northwest quadrant and with the nutrients in the southwest.

Seasonal patterns were evident in both simulated nutrient and bacteria concentrations. Nitrogen (species) concentrations are elevated in the wet season, whereas phosphorous (species) concentrations are elevated during summer, due to the relative contribution of groundwater to streamflows. However, drainages dominated by agricultural land uses had elevated phosphorus concentrations, likely from surface runoff from pastures during storms. Observed concentrations of bacteria are the most variable constituent, spanning up to several orders of magnitude (e.g. 1 to 10,000 cfu) at the same location. This variability is primarily the result of a non-point source acting like a point source (e.g. animal excrement deposited directly in the stream, versus on land where more dispersion will occur).

Figure 33. Results of principal components analysis evaluating observed water quality within the greater Green River watershed (Factor 1 = 45%, Factor 2 = 16.1%).



Next, we present simulated values for monthly and annual pollutant loadings from each of the 10 land use types (listed above) for the Green River watershed including Newaukum Creek. Simulations are based on calibrated watershed-scale water quality models (Hydrological Simulation Program – Fortran; HSPF[40]).

[40] http://www.epa.gov/ceampubl/swater/hspf/

Seasonal patterns are similarly evident in both bacteria and nutrient concentrations, in model simulations. Simulated monthly bacteria loadings generated from agricultural land uses show seasonal patterns of variability reflective of storm runoff, likely due to differences in the magnitude and frequency of storm events (Fig. 35). Simulated bacterial concentrations are higher in spring and fall when storms are large and infrequent, allowing fecal matter to accumulate on the landscape between storms. Concentrations are lower (but range widely) in summer time when storms are small and infrequent - likely to due high animal activity with low potential runoff. Conversely, winter conditions are more variable with bacterial concentrations generally higher at the beginning, then tapering off towards the end of winter and beginning of spring. Simulated nitrate and nitrite concentrations also show stronger, consistent seasonal patterns (Fig. 36). Concentrations are low in summer due to the lack of storm runoff, increasing as the wet season progresses. As storms grow less frequent, simulated concentrations become less variable.

Figure 34. Results of principal components analysis of water quality data from the greater Green River watershed, grouped by land use.

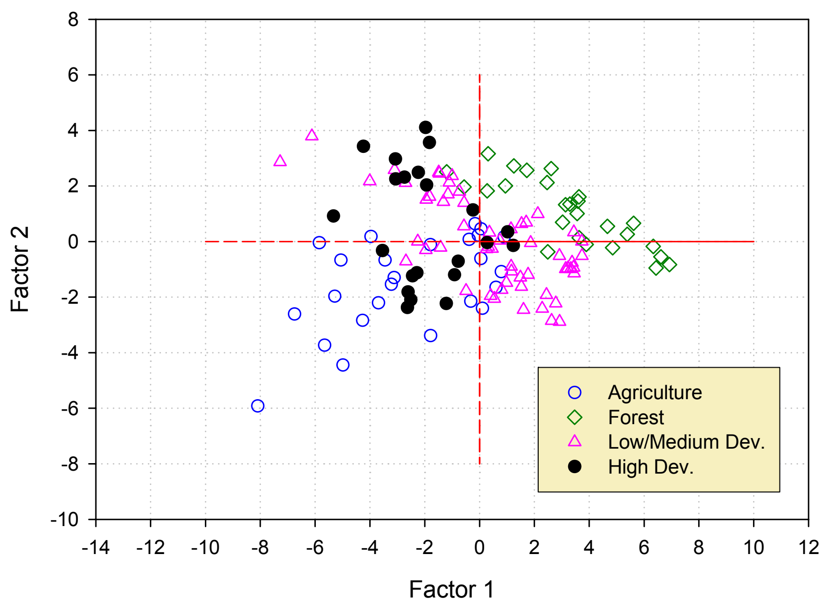


Figure 35. Simulated loadings of fecal coliform bacteria by season (Water Years 1991-2004, agricultural).

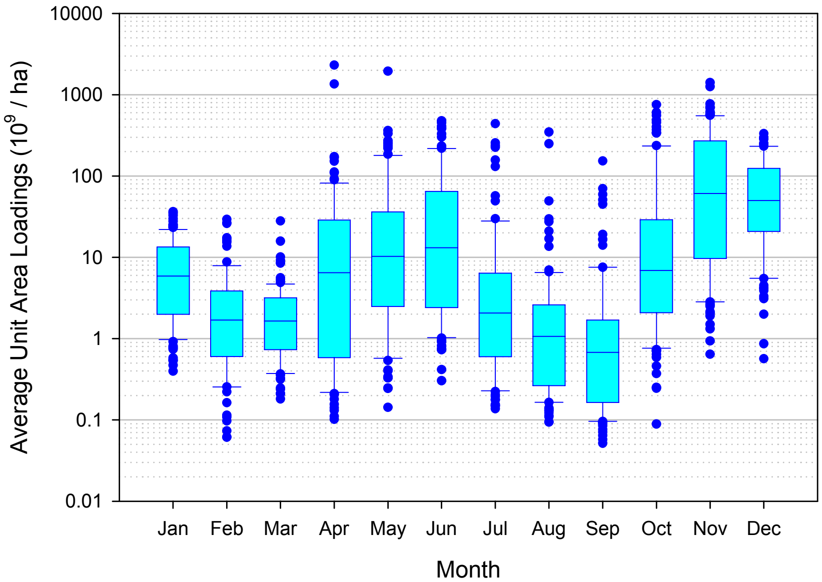
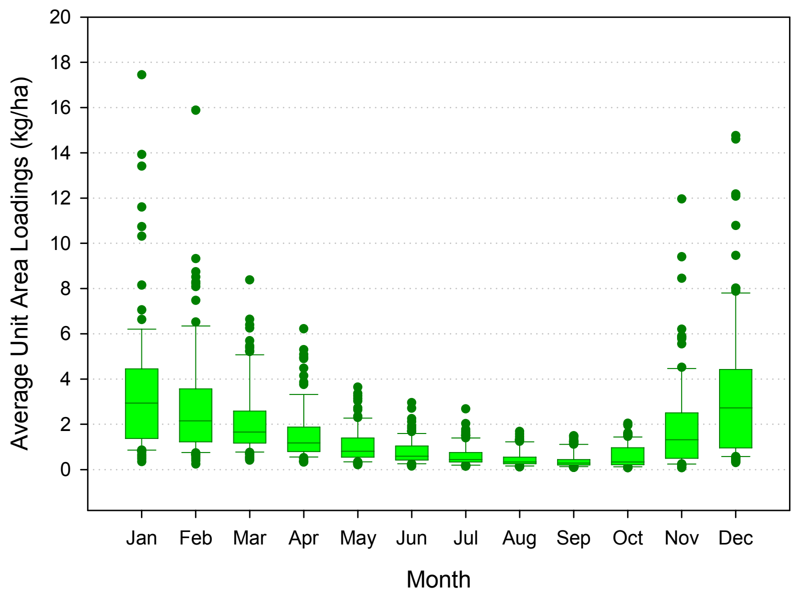


Figure 36. Simulated loadings of nitrites and nitrates by season (NO_2 and NO_3) (Water Year 1991-2004, agricultural).



8.0. SOIL RESOURCES

This section briefly explains the soil resources supporting biological production in riparian and upland areas throughout Newaukum Creek basin. Basic soil properties are relevant to habitats and key ecological processes throughout the basin. Detailed soil maps are available, but exceed the scope of this report.

Soil develops at the surface of the earth as a result of complex and interrelated processes that occur at the interface between the land and atmosphere. These processes include weathering and breakdown of the geologic parent material, formation of secondary minerals, incorporation of organic matter, and movement of soil constituents by water moving through the soil column. In the Newaukum Creek watershed, soil development has been largely controlled by two factors; the parent material (geologic substrate) and soil drainage (surface and shallow subsurface hydrology). Elevation also affects soil development because it exerts the primary control on temperature and precipitation variations across the watershed.

Most of the soils in the Newaukum basin are formed from three types of parent material. These are: volcanic bedrock, glacial deposits, and the Osceola mudflow. In areas with persistent sanding water (see drainage discussion below) sufficient vegetative matter can accumulate so that soil develop entirely in this surficial organic material. Specific soil series are associated with each of these parent materials are presented in Table 6.

Table 6. Parent materials and associated soil types in the Newaukum Creek basin.

Parent Material	Soil Name	Cumulative Percentage
Glacial Deposits	Indianola loamy fine sand Scamman silt loam Everett gravelly sandy loam Barneston gravelly coarse sandy loam Ragnar fine sandy loam Neilton very gravelly loamy sand Winston Loam Alderwood Gravelly Sandy Loam Norma loam	44.9%
Osceola Mudflow	Buckley silt loam Lemlo silt loam	31.7%
Volcanic Bedrock	Pitcher sandy loam Nagrom Sandy Loam Ovall gravelly loam Christoff sandy loam Littlejohn gravelly sandy loam Ogarty gravelly loam Kanaskat gravelly sandy loam	12.5%
Organic Material	Shalcar muck Seattle muck Tukwila muck	4.1%

Much of the Newaukum Creek watershed is located on the broad, low gradient surface of the Enumclaw plateau. Much of soil parent material on the Plateau is fine-grained and very compact so that it is relatively impervious. This low permeability, combined with the almost level topography combined to create broad areas where (prior to construction of the current drainage system) standing water or soil saturation is present for much of the year. These areas formed the extensive wetlands that characterized the pre-development Plateau (Fig. 24). As a result the SCS classified 49% percent of the soils in the basin as either poorly drained or very poorly drained (SCS, 1973, 1992). Soil development in these areas was strongly affected by the extended periods of soil saturation and associated anaerobic (low oxygen) conditions. Decomposition of plant matter was inhibited by the lack of oxygen so thick organic layers often accumulated above mineral soil. The low gradient and common areas of standing water also locally lead to deposition of fine-grained mineral sediments above the in-place parent material. With the installation of extensive drainage systems many areas that had wet or saturated soils under natural conditions are now in agricultural production.

The texture of the Osceola is somewhat finer than typical till deposits. The mudflow has some clay component which originated as a product of chemical alteration of volcanic rocks in-place on the mountain. A high clay content typically means lower permeability, higher water-holding capacity, and higher cation exchange capacity (CEC). Soil developed on the mudflow deposits tend to be wet both due to the low permeability of the soil and the flat topography on the surface of the mudflow.

Till is generally gravelly silty sand. Where weathered and disaggregated (nearer the top of the soil horizon) soil developed on till tends to be well drained. The C horizon of till soils however becomes very impermeable due to the due to compaction by glacial loading and maybe some post-glacial chemical cementation. As a result there is often a seasonal water table perched on top of the intact till. With little clay or organic content till soils tend to have a relatively low CEC.

9.0. PLANTS AND ANIMALS – THE BIOTIC COMMUNITY

In this section, we characterize the basic structure, composition and distribution of key organisms that dominate aquatic, riparian, and terrestrial (upland) communities of the Newaukum basin. Biotic communities can strongly influence ecosystem processes. Their influence depends on the types of species present, their functional characteristics, relative abundances, and the nature of their interactions (Chapin et al. 2003). After characterizing special status species (Section 9.1, we provide a broader perspective of the plants and animals that compose the Newaukum Creek basin (Sections 9.2-9.6). We use a community-based approach to describe important groups of plants and animals, and explain their individual taxonomy, life history, trophic position (in other words, their place in the food web) or ecological attributes.

9.1. SPECIAL STATUS WILDLIFE SPECIES

This section summarizes the basic life history characteristics, distribution, and population abundance (if known) of 16 ‘special status’ wildlife species occurring in the Newaukum Creek basin (Table 7). Our rationale was that these species play a pivotal role in management actions, so a basic understanding of their life history, status, distribution, and biological context is warranted. We include species with special designation at the federal, Washington State, and/or King County level. Most special status species are fish and birds. None of the rare plant species that occur in King County are known to be present in the Newaukum Creek Basin (WNHP 2006). We describe the life history requirements of the 16 individual species for simplicity and practicality. However, we emphasize that efforts to assist individual species must be firmly embedded in an understanding of their context in the broader ecosystem, including population and community-scale interactions. Characterizations of fish species address most (or all) of the factors explained in Table 8. Please note that many additional species are described in Sections 9.2-9.6. and that Newaukum Creek basin also contains Special Status Lands (Fig. 37)

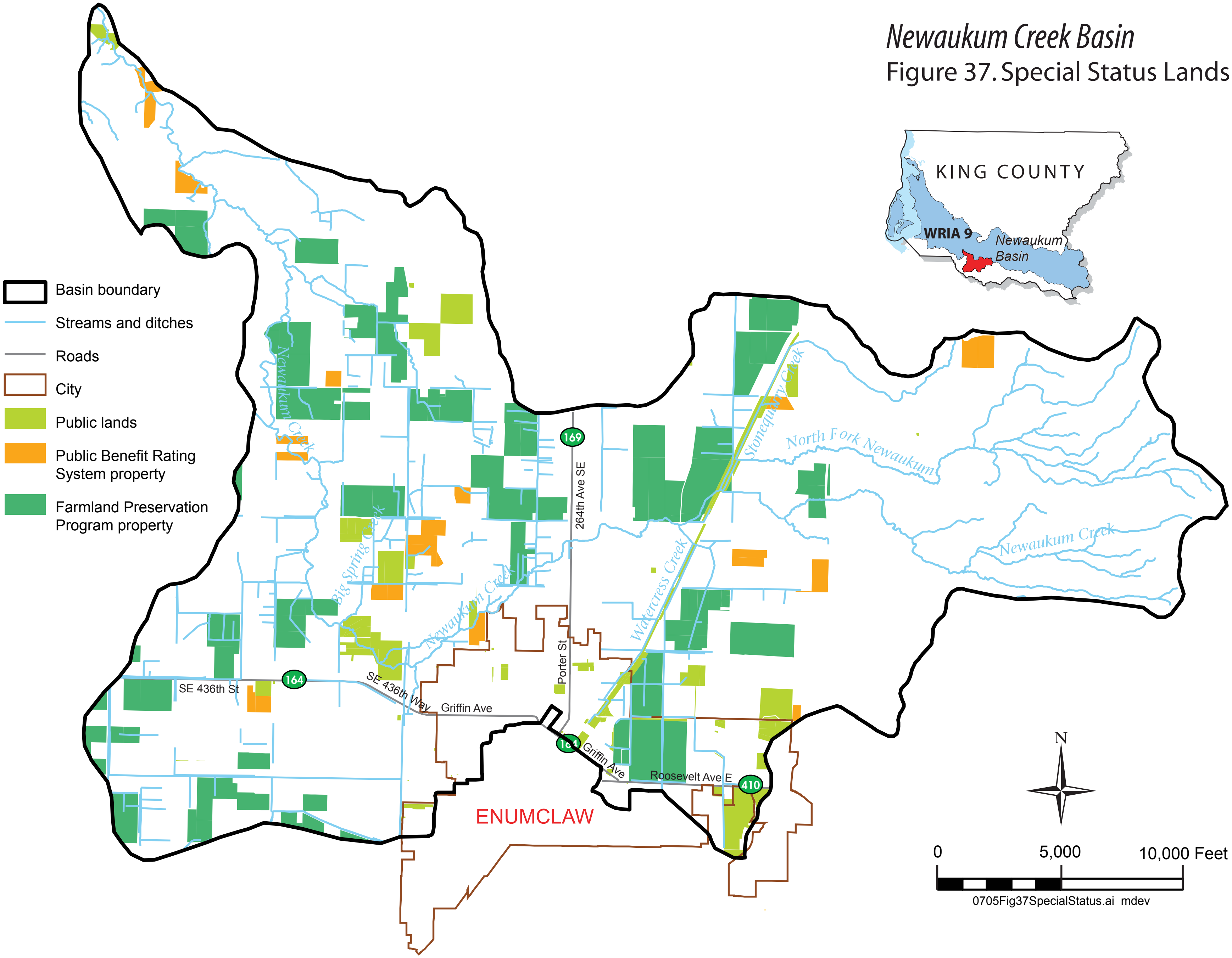
Table 7. Special Status Wildlife Species that may be using breeding or foraging habitat in Newaukum Creek basin or have likely been extirpated.

Common Name	Scientific Name	Status[†]
Chinook (king) salmon	*Oncorhynchus tshawytscha*	FT
Bull trout	*Salvelinus confluentus*	FT
Rainbow (steelhead) trout	*O. mykiss*	Pending FT
Bald eagle	*Haliaeetus leucocephalus*	FT, ST, KCC
Spotted owl	*Strix occidentalis*	FT (extirpated)
Marbled murrelet	*Brachyramphus marmoratus*	FT (extirpated)
Vaux's swift	*Chaetura vauxi*	SC, KCC
Pileated woodpecker	*Dryocopus pileatus*	SC, KCC
Osprey	*Pandion haliaetus*	KCC
Great blue heron	*Ardea herodius*	KCC
Red-tailed hawk	*Buteo jamaicensis*	KCC
Western toad	*Bufo boreas*	FCo, SC, KCC
Tailed frog	*Ascaphus truei*	FCo
Long-eared myotis	*Myotis evotis*	FCo
Long-legged myotis	*Myotis volans*	FCo
Pacific Townsend's big-eared bat	*Corynorhinus townsendii townsendii*	FCo, SC, KCC

[†] FT = Federal Threatened; ST = State Threatened; FCo = Federal Species of Concern; SC = State Candidate; SS = State Sensitive; KCC = Protected under King County Code

Newaukum Creek Basin

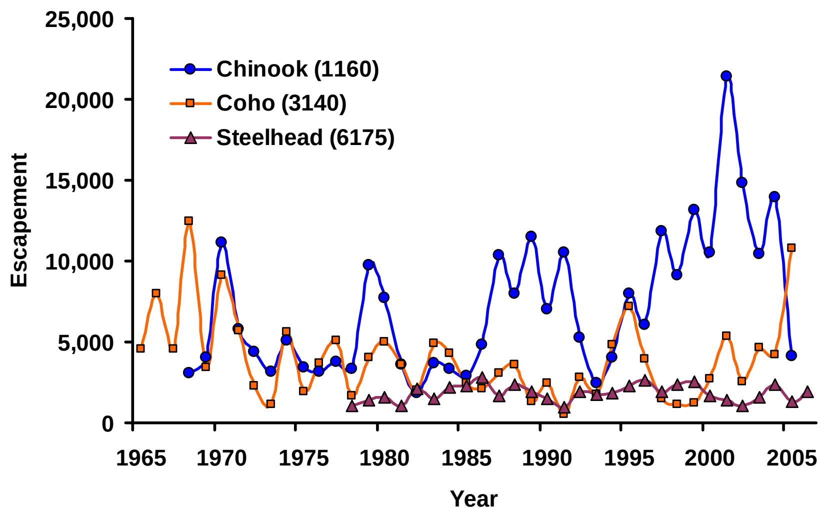
Figure 37. Special Status Lands



9.1.1. Chinook salmon

Chinook salmon are protected as a threatened species under the Endangered Species Act, and are a primary focus of basin recovery plans (WRIA 9 Steering Committee, 2005). The Duwamish/Green River Chinook salmon population is a native stock (# 1160) with composite production, with total escapement ranging from 2,476 to 21,402 (Fig.37). This is managed as a 'integrated' stock by the Washington Department of Fish and Wildlife. Historical run sizes apparently peaked upwards of 37,000 individuals (WRIA 9 Steering Committee, 2005). Roughly 1,700 chinook now spawn naturally in the river (e.g., ~5% of the estimated historical maximum run size).

Figure 38. Escapement estimates for Green River chinook†, coho salmon †† and steelhead ††† (Washington Department of Fish and Wildlife 2007; stock identities are indicated in parentheses)

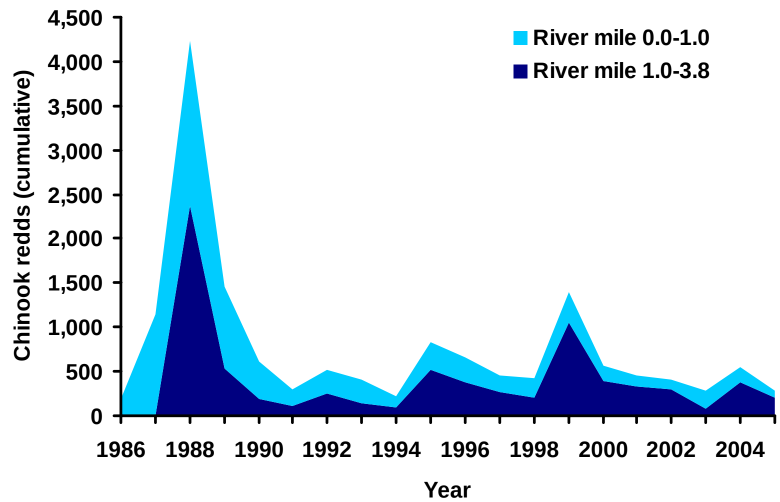


† Total escapement estimates for chinook are based on redd counts in the mainstem Green River from RM 35.0 to 41.5 and from RM 41.5 to 43.0, and in Newaukum Creek from RM 0.0 to 3.9. Estimates from 1997 on are based on results from WDFW mark-recapture studies conducted from 2000 to 2002.
†† Escapement estimates for coho are the sums of cumulative fish*days values for Hill (WRIA 09.0051), Newaukum (09.0114), Spring (09.0119), Cress (09.0121A), and North Fork.Newaukum (09.0122) creeks indices.
††† Total escapement estimates for steelhead are based on cumulative redd counts in all mainstem spawning areas (RM 26.4 to 59.9) and in index reaches in Soos and Newaukum creeks totaling 12 miles.

The established spawning aggregation in Newaukum Creek is thought to represent a valuable component of the Duwamish/Green River population. It diversifies the larger population and receives many of the naturally spawning Chinook adults entering the Green River (WRIA 9 Steering Committee, 2005). On average, 45% of the spawning Chinook adults in Newuakum Creek are of known hatchery origin (ranging from 15 to 79% from 1989-1997; Kerwin and Nelson 2005). As a result, the system is thought to contribute substantially to the productivity of the Duwamish/Green River stock (WRIA 9 Steering Committee, 2005). Genetic analysis indicates natural spawners in Newaukum Creek are indistinguishable from those in Soos Creek Hatchery. This is attributable to significant gene flow between naturally spawning fish and those originating from the hatchery.

Spawning occurs in the fall, primarily in the Ravine. In general, adults salmon forage at sea for 2-4+ years prior to returning to spawn in natal streams (Quinn 2005). Duwamish/Green River mature adults begin migrating upstream in September and quickly commence spawning, which lasts through the end of November. Peak returns now occurs in early October rather than late October, presumably due to hatchery practices (WRIA 9 Steering Committee, 2005). Most spawning is thought to take place in the lower two to four miles of Newaukum Creek, but extends at least eight miles from the confluence with the Green River to the 244th St. intersection (Goldstein 1982; Boehm 1999). Redd densities vary among locations and years (Fig. 39)[41]. Eggs incubate in spawning gravels through the winter and hatch in the spring.

Figure 39. Cumulative number of chinook redds counted in two index reaches in Newaukum Creek (Washington Department of Fish and Wildlife). This is a stacked area graph. Note that redd counts in RM 1.0-3.8 begin in 1988.



Juvenile Chinook inhabiting Newaukum Creek are presumed to exhibit similar life histories to those in the greater population, though this has not been verified. Five juvenile life history trajectories are presumed to have existed in the Duwamish/Green River system prior to extensive development; their loss may have coincided with steep declines in productive estuarine habitats and construction of the Howard Hanson dam. Only 'estuarine-reared fry' and 'marine-direct fingerlings', which originate from 'fall' Chinook salmon, are now common (WRIA 9 Steering Committee, 2005). Resulting juveniles are 'ocean-type', migrating downstream to estuaries shortly after emergence. 'Estuarine-reared fry' primarily originate from naturally spawning fish and occupy mainstem and side channel habitats, migrating to the estuary or nearshore after a few days to weeks in freshwater or at 45-70 mm in length. They are present in estuary from April to May and move offshore in May and June, exhibiting the longest estuary residence time of any life history type remaining in the system. In contrast, 'marine-direct fingerlings' apparently originate from both natural and hatchery-spawning fish. These fingerlings

[41] Note that continuous surveys are necessary for accurate evaluations of the distribution of spawning in space and time. Observations from fixed index reaches do not necessarily reflect temporal trends in redd abundance at the basin-scale, as fish may be spawning in different locations (outside the index reaches, for example).

are likely more reliant on freshwater habitats than estuary-rearing fry. Fingerlings linger in natal streams for weeks or months until migrating to the estuary and nearshore at roughly 70 mm in length, presumably *en masse*. They remain in the estuary for roughly two weeks.

Existing juvenile life history types probably rely more heavily on the availability of oversummering habitats than overwintering habitat, because they leave Newaukum Creek prior to winter. Summer feeding (rearing) habitat for juvenile Chinook in Newaukum Creek now exists primarily downstream from RM 10, near where Newaukum Creek crosses 416th. Chinook juveniles have been observed rearing between RM 8-10; though spawning in this section is uncommon (R. Fritz, *pers. comm.*). Juvenile Chinook originating from the Green River mainstem could plausibly move into Newaukum Creek and rear during the summer, as well. A single chinook salmon juvenile was caught in a smolt trap in Big Spring Creek in the spring of 2005[42].

Optimum stream temperatures for Chinook salmon vary among life stages (see Richter and Kolmes 2005 for review and primary references). Daily maximum temperatures exceeding 20˚C represent thermal barriers to migrating spawners. Spawning generally occurs only when temperatures are below 14.5˚C. Incubating embryos and alevins survive best at temperatures below 9˚C whereas temperatures of 13.9 to 19.4˚C result in severe mortality. Optimal temperatures for juvenile rearing are approximately 15˚C, ranging from 12-17˚C depending on food availability. High juvenile mortality results when daily maximum temperatures exceed 24-26˚C. Smoltification is impaired at temperatures above 17˚C, but this varies widely among studies.

Recent surveys estimated the density of juvenile Chinook in the lower Ravine to range from 0.002 to 0.008 fish m^{-2} among reaches in mid-June (TetraTech, Inc., 2005). In late July of 2006, Chinook represented 1-8% of the total fish abundance (among reaches), ranging from 30 to 120 mm (not including a 180 mm outlier) in total length. Whereas 83% used slow water habitats in one reach, only 33% were in slow water in another reach; the rest (67%) were in fast water.

Habitat connectivity is a potential obstacle for spawning migrations near the mouth of Newaukum Creek[43]. Specifically, upstream migrations by spawning salmon are sometimes blocked or restricted where Newaukum Creek runs across an alluvial fan at the confluence with the Green River mainstem. This potential passage barrier is usually attributed to 1) downcutting by the Green River mainstem; 2) increased downwelling through the alluvial fan in response to the enhanced hydraulic gradient; and 3) deposition of transported sediment several sources through Newaukum Creek. Upstream migration is presumed to be limited by a steep cascade in the Boise Ridge Reach (Fig. 22) (Williams et al. 1975).

9.1.2. Bull trout

Bull trout is under federal protection as a threatened species (Table 7). No bull trout have been detected in Newaukum Creek, despite numerous surveys (See Washington State Salmonid Stock Inventory – Bull Trout/Dolly Varden, October 2004).

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[42] http://www.midsoundfisheries.org/smolttrap.html

[43] Mid-Sound Fisheries Enhancement Group is conducting a comprehensive assessment of fish passage barriers in Newaukum Creek (T. Fields, *pers. comm.*). It is expected that juvenile barriers are more common than barriers to spawning adults.

9.1.3. Steelhead trout

Newaukum Creek contains a native winter (ocean-maturing) steelhead trout stock (# 6175) (Table 7), which are used in hatchery programs at Soos Creek and Icy Creek. Naturally-spawned Puget Sound steelhead (both summer and winter runs) are protected as threatened species under the ESA. However, Green River steelhead are thought to have a low risk of extinction, relative to other populations throughout Puget Sound. Winter steelhead of hatchery origin (mostly from Chambers Creek) are also present, but are assumed to contribute little gene flow to the native stocks because they spawn at different times[44]. Winter steelhead are closely related to those from the Cedar, White, Puyallup, and Snohomish basins (Phelps et al. 1997). A total of 558 spawners were passed above Howard Hanson dam from 1992-2000, ranging in number from seven fish in 1997 to 133 fish in 1996 (WDFW, 2007). Average escapement estimates for the Green River were 2,249 fish from 1994 to 1998 and 1,827 fish from 1999-2004.

Newaukum Creek provides valuable spawning areas for winter steelhead, including Big Spring Creek and most of the mainstem – but especially between RM 10 and 11 (Rob Fritz, *pers. comm.*). They may also spawn in portions of Watercress Creek. Surveys in 2005 found 17 steelhead redds across four reaches (totaling 5.4 miles) downstream from RM 8.7; 16 of 17 redds were found from RM 1-3.8 (WDFW, 2007).

In general, steelhead return to spawn in natal streams (potentially more than once) after foraging at sea for 1-3 years (Quinn 2005). Winter steelhead vary from Pacific salmon in that they reach an advanced stage of maturity when they enter streams early in the year and quickly commence spawning (Quinn 2005). This occurs roughly from February through June in the Green River system. They bury relatively small eggs in gravels while stream temperatures are climbing. Fry emerge in late spring and earlier summer (Quinn 2005).

The steelhead trout is currently considered the same species as rainbow trout (*O. mykiss*); the steelhead is the anadromous form, whereas the rainbow trout is the freshwater form (Quinn 2005). However, the distinction between the two is the subject of ongoing investigation. Newaukum Creek hosts rainbow trout (and juvenile steelhead) throughout the year. Steelhead spend 1-3 years feeding and growing in freshwater. Over-summering habitats are distributed throughout the basin, especially the North Fork, South Fork, Big Spring Creek, and Watercress Creek. Overwintering habitats are more narrowly distributed due to the limited availability of complex refugia.

Optimum stream temperatures range widely among steelhead life stages (see review by Richter and Kolmes 2005). Spawning migrations are blocked by temperatures over 21˚C. Spawning occurs when daily temperatures average roughly 10-13˚C. During incubation, optimal temperatures are below 9˚C and the daily maximum should never exceed 14.5˚C. Juvenile steelhead grow fastest at 14-15˚C, but 16-17˚C also appears acceptable. The 7-day annual maximum temperature should not exceed 20.5˚C.

Recent surveys estimated the density of juvenile steelhead in the lower Ravine to range from 0.013 to 0.021 fish m^{-2} among reaches (mid-June 2005, TetraTech, Inc.). In late July 2006, rainbow trout represented 49-67% of total fish abundance (among reaches), ranging from 20-

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[44] A non-native, severely depressed hatchery stock (Skamania; since 1965) of summer steelhead (# 6168) is present in the Green River, but thought to be absent from Newaukum Creek. A self-sustaining population may exist, but this is undetermined (K. Lakey, WDFW, *pers. comm.*).

280 mm in total length. Most occurred in 'fast' (i.e., from 43 to 50%) and 'slow' water units (i.e., 25-50% among reaches), rather than in backwaters, side channels, or near wood (though these are relatively scarce).

9.1.4. Bald eagle

Bald eagles nest in large, open-limb trees within one mile of large bodies of water or on cliffs and feed primarily on fish (Scott 1987) (Table 7). Priority Habitats and Species (PHS) data from Washington Department of Fish and Wildlife (see WDFW 2006) reports that a bald eagle nest site was located in the Buckley quadrant in 2000, but not thereafter. The nest was in a small grove of black cottonwoods adjacent to Newaukum Creek in an area surrounded by agricultural fields. No other bald eagle nests are known in the Newaukum Creek basin, presumably because of the lack of mature forest stands near large water bodies.

9.1.5. Spotted owl

The lack of old-growth forest in Newaukum Creek basin precludes old-growth-dependent birds such as spotted owls from nesting here (Table 7). However, this species may be nesting in the upper Green River Watershed and could potentially use the Forest Production District (FPD) in Newaukum Creek basin as part of their travel corridor. If so, their use of this forest as a stop-over during daily and annual migrations is expected to be extremely limited because of a general lack of mature forest in the region.

9.1.6. Marbled murrelet

The upland forests of the Newaukum Creek would have provided habitat for Marbled murrelets, but this species is thought to be extirpated basin by the loss of old-growth forests (Table 7). As with the spotted owl, this species may be nesting in the upper Green River Watershed and may use the Forest Production District (FPD) in Newaukum Creek Basin as part of its travel corridor.

9.1.7. Vaux's Swift

Vaux's Swift nests in mature forest within hollow trees and cavities created by woodpeckers and they forage over open areas and water (Table 7). This species is a confirmed breeder in the basin near Enumclaw. Vaux's Swifts are positively associated with old-growth forest (Bull and Hohmann 1993) and may be the only diurnal bird that depends on old-growth for its continued survival (Manuwal 1991). Nest sites are likely to be a critical limiting resource for this species, which are colony nesters (Manuwal 1991). Only large-diameter hollow trees can accommodate swifts (Bull and Blumton 1997). Suitable roost trees are most likely to occur in old-growth stands (Bull 1991). The species occasionally nests in chimneys, though populations cannot be maintained without mature forests for nesting. The small amount of open water (i.e., foraging habitat) in this basin is likely a secondary limiting factor for Vaux's swifts.

9.1.8. Pileated Woodpecker

The Pileated Woodpecker is the largest woodpecker species in Washington (Scott 1987), and nests and forages in mature and second-growth forests (Table 7). The optimal habitat for Pileated Woodpeckers is conifer forest with at least two canopy layers, the uppermost being 80 to 100 feet in height (Bull 1987). Snags, down logs, and stumps are key components of nesting and foraging habitat (in which woodpeckers feed on carpenter ants [*Camponotus*]; Scott 1987) for this species, which annually excavates a new nesting cavity in large snags or partially decayed live trees (Mellen et al. 1992, Bull and Jackson 1995, Aubry and Raley 2002b). Other species depend on these woodpeckers for the creation of nesting cavities. Pileated Woodpeckers may thus be considered "ecological engineers" (Jones et al. 1994) because they are the only species able to excavate large cavities in hard snags and decadent live trees, and a wide array of other bird and mammals species use their cavities. This species is possibly nesting in the basin near the Green River.

9.1.9. Osprey

Osprey are not known to nest in the Newaukum Creek basin (Table 7). Osprey are closely associated with rivers, estuaries, lakes, and other large bodies of water, and they feed over open water almost exclusively on fish. Osprey tend to select dead snags or dead-top trees that are higher than the surrounding canopy, but they will also nest on platforms and power poles. Nest trees frequently occur in flooded riparian zones and wetlands created by beavers. We speculate that reductions in beaver populations have likely affected the availability of preferred osprey nest sites, as has been documented elsewhere (Ewins 1997).

9.1.10. Great Blue Heron

Currently, Great Blue Herons are not known to breed in the Newaukum Creek basin (Table 7). Herons prey on fish, amphibians and small, field-dwelling mammals, and breed in colonies called rookeries; their nests are built in tall trees. The Breeding Bird Atlas reports this species is observed in the basin during breeding season. No actual breeding behavior has been observed.

9.1.11. Red-tailed hawk

Red-tailed hawks are known to breed in the Newaukum Creek basin. This species, which is somewhat ubiquitous in King County, hunts over open fields, road shoulders, and utility right-of-ways (Table 7). Their primary prey is small mammals, which are abundant in the Newaukum Creek basin. Nests are usually large platforms made out of sticks placed in a tall hardwood tree (Seattle Audubon Society 2006), however they may nest in conifers as well (Richter, *pers. comm.*). The scattered small stands of forest throughout the Plateau in addition to the forest of the ravine and FPD likely provide ample nesting opportunities for this species.

9.1.12. Western toad

The western toad has apparently disappeared or declined significantly in many areas of Washington, but it is still widespread beyond the Puget Trough and locally abundant in some areas within King County (Table 7). For instance, the western toad has been confirmed in only 21 of 86 historical sites in the Puget Trough Ecoregion, since 1980 (Hallock and McAllister 2005). Several of these remaining populations are now extirpated, including the population at Beaver Lake in King County (Hallock and McAllister 2005). It is possible the western toad is present in the forest of the Upper Basin and breeds in the forested wetlands found in the Newaukum Creek basin.

The basic life history of the western toad is summarized by Leonard et al. (1993). The western toad breeds in permanent water wetlands and is found in uplands forests and field outside of breeding season. The breeding season lasts from spring to early summer, depending on elevation. Egg masses resemble long strings or shoelaces strewn across the bottom of floodplain pools or wetlands and may contain 12,000 eggs. Embryos develop into tadpoles in only three to 10 days, which graze on detritus, filamentous green algae or scavenge carcasses. Metamorphosis occurs at the end of their first summer. Western toads are particularly sensitive to the loss of wetland habitats.

9.1.13. Tailed frog

The current status and distribution of the tailed frog in Newaukum Creek has not been evaluated (Table 7). The tailed frog is generally limited to the mid to higher elevation mountain streams in mature forests (Dvornich et al. 1997; Leonard et al. 1993) but could potentially occur in clean, rapidly flowing streams in lower elevations of the upper basin as well (but not lakes or ponds).

Life history of the tailed frog is summarized by Leonard et al. (1993). Mating occurs in fall, and fertilized eggs are attached to the undersides of large rocks in the stream. Embryos hatch within six weeks and commence grazing on biofilms covering instream rocks. Most tadpole activity occurs at night, presumably to reduce risk of predation by fish or Pacific Giant salamanders. Tadpoles metamorphose in one to four years, depending on elevation, and mature within six more years, depending on the length of summers. Adult tailed frogs primarily forage on insects from riparian areas at night (Leonard et al. 1993).

9.1.14. Long-eared myotis

Long-eared myotis (bats) roost in caves, buildings, and trees and they forage over water and in open areas (Table 7). The lack of old-growth trees and snags as well as lack of caves in this basin severely limit the number of potential maternity roosts for the large maternity colonies that Myotis bats commonly form in spring (Christy and West 1993). There are no known bat maternity colonies or hibernating sites in the basin, nor are there any known day roosts. However, there is no comprehensive survey information available for bats in the basin, so it is possible that any of these three bat species could be present. The status of this species in the basin is unknown.

9.1.15. Long-legged myotis

Long-legged myotis are usually found along forest edges and among trees; summer day roosts include buildings, crevices in rock cliffs, and under tree bark; maternity colonies have been found in fissures in the ground, attics, and under tree bark (Table 7). Additional details are in the preceding section. The status of this species in the basin is unknown, but it is presumed to be absent.

9.1.16. Pacific Townsend’s big-eared bat

The Pacific Townsend’s big-eared bat establishes breeding and hibernation colonies in abandoned mines, caves, and buildings (Table 7). The status of this species in the basin is unknown, but it is presumed to be absent.

9.2. STREAM COMMUNITIES

We describe the species comprising the aquatic communities of the Newaukum basin according to where they typically occur – streams or wetlands. Within each of these categories, we group species according to their trophic level. Our rationale is that this approach will shed light on the ecological – not just taxonomic – structure of the community. Species are grouped with related taxa within trophic levels. In most cases, we explain their status, life history, and distribution within the Newaukum Creek basin. For brevity, we explain only a limited number of competitive interactions (e.g, mutualism, competition, predation, etc) between species. Our characterization of stream and wetland communities is clearly biased toward fish, which have particular political and social relevance.

The biological condition of Newaukum Creek is mostly fair, ranging to good/excellent, according to recent estimates of the Benthic Index of Biotic Integrity (B-IBI; Karr 1998) EVS method (Fig. 41, McElligott and Holt 2004, McElligott et al. 2005). The average total number of macroinvertebrate taxa was 33.8 (± 7.0 SD), with 19.2 (± 5.0 SD) in the Ephemeroptera-Plecoptera-Trichoptera orders. Generally, B-IBI scores are divided into qualitative intervals representing, 'very poor' (10-16), 'poor'(18-26), 'fair'(28-36), 'good' (38-44), and 'excellent' (46-50). Average B-IBI scores have gradually improved in the past few years, climbing from 30.4 (±8.3 SD) in 2002, to 33.3 (±9.2 SD) in 2003, and finally to 37.4 (±5.6 SD) in 2005[45]. In 2003, Newaukum Creek scored 3.7 (± 0.8 SD) on the Hilsenhoff Biotic Index scale (1-10), which discriminates between pollution intolerant communities (i.e., low scores) and those that tolerate pollution (i.e., high scores) (McElligott et al. 2005). Samples were also collected in 2004 where the North Fork intersects 292nd SE and where the mainstem crosses the Veazie-Cumberland Road[46] (R. Fritz, *unpublished data*). Scores and sampling locations are included in Fig. 41.

9.2.1 Aquatic Primary Producers and Herbivores

Aquatic primary production plays in important role in supporting the biological productivity of Newaukum Creek. Photosynthetic organisms provide energy and autochthonous (i.e., produced instream) organic matter for consumption at higher trophic levels. Levels of aquatic primary production are primarily regulated by the availability of light, nutrients, water temperature, streamflow (and its connection to bed mobility), and grazing by aquatic herbivores (e.g., macroinvertebrates) (Murphy 1998). Three common forms exist; benthic algae, macrophytes, and phytoplankton, though the first two forms dominate in Newaukum Creek. We list several of the common representatives in each form to illustrate the variety of aquatic primary producers in the system. Comprehensive surveys of existing taxa in Newaukum Creek are unavailable, so we emphasize that only partial lists are provided here.

Benthic algae attaches to the streambed and underwater debris, and consists of diatoms (which form microscopic coatings on rocks) and macroalgae (in filaments, sheets or mats)(Murphy 1998). Algae is integrated with a complex mix of bacteria, fungi, inorganic sediments, and organic matter, collectively referred to as 'periphyton' (Murphy 1998). Diatoms are common during winter and in the shaded, high-gradient tributaries of the Upper Basin. They provide much of the high-quality forage for grazing macroinvertebrates, due to their relatively high energy content and vulnerability to grazing (see Murphy 1998). Taxa include *Cybella* and *Synedra* (Goldstein 1982), but probably also *Navicula* and *Meridion*. Desmids such as *Closterium* (spindle-shaped) and *Cosmarium* (ellipse-shaped) are common (Goldstein 1982). The dominant macroalgae is the filamentous green algae *Ulothrix* spp., particularly during summer in low-gradient stream reaches with high nutrient concentrations (e.g., the Plateau; Goldstein 1982). This filamentous algae is important because it forms the basic structure of algal mats in which diatoms are embedded. These diatoms are the primary food resource for aquatic herbivores (e.g., macroinvertebrate scrapers [e.g., *Dicosmoecus*], grazing snails [e.g., *Juga silicula*], and larval tailed frogs *Ascaphus truei* [see Section 9.1]), though filamentous algae is also somewhat vulnerable to grazing invertebrates (Murphy 1998).

Benthic algae is often inconspicuous, but its ecological importance should not be underestimated; the casual observer only sees what has not been eaten. Algae is replaced

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[45] Samples are replicated within basins but generally not at individual sites. Results are suitable for cross-basin comparisons and for evaluating trends over time, but have limited value for comparing the condition of sites within the Newaukum Creek Basin.

[46] Surveys conducted for King County Roads by ABR, Inc., on September 16, 2004. Data available from R. Fritz.

much more quickly than detrital inputs from riparian forests. Though the existing amount (i.e., standing crop) of leaves and twigs may greatly outweigh algal biomass at any given time, algae is constantly being renewed and therefore may be much more important in supporting biological production than appearances would suggest (see Hershey and Lamberti 1998).

Aquatic macrophytes include vascular angiosperms (flowering plants) that send roots into the streambed, and aquatic bryophytes that lack a vascular system (e.g., mosses and liverworts) (Murphy 1998). Vascular plants either live submerged underwater or float on the surface, and either root in the streambed or dangle their roots in the water column. Floating plants can be either attached or unattached, whereas submerged plants are usually rooted in place. Mosses can function as excellent invertebrate habitat by trapping food particles and provide refuge from streamflows for a variety of genera (Suren and Winterbourn 1992).While living, these plants are generally not important food resources for aquatic herbivores, but may be important after they die and enter the detritivorous food chain or create cover from predators for juvenile fish. They may also play an important role in nutrient cycling within the basin.

Phytoplankton likely occurs in Newaukum Creek, though much of it probably originates from standing (i.e., lentic) water bodies such as wetlands and ponds that are connected to the river network. True phytoplankton is uncommon in small streams, where the residence time of the water is insufficient for the development of sizeable phytoplankton populations. Most suspended algae are instead benthic algae or diatoms that have been sheared off the streambed (Murphy 1998).

Primary production supports a variety of grazing and scraping aquatic invertebrates (i.e., those feeding primarily on epilithic biofilms and periphyton) (Table 9). Recent surveys estimate that scrapers and grazers compose roughly 39.4 % (± 4.8 SD) of the aquatic invertebrate community in Newaukum Creek (Mc Elligott et al. 2005)[47]. Herbivore-piercers (which feed on macrophytes) are absent. Aquatic invertebrates have been sampled in numerous locations (Fig. 41) , including where the North Fork intersects 292nd SE and where the mainstem crosses the Veazie-Cumberland Road[48] (R. Fritz, *unpublished data*). Relatively few scrapers occur at these sites, including *Cinygmula* mayflies (Order Ephemeroptera, Family Heptageniiedae), and *Glossosoma* caddisflies (Order Trichoptera, Family Glossosomatidae). Aquatic wheel-snails (Family Planorbidae) are also present in Newaukum Creek and graze on biofilms (McElligott et al. 2005).

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[47] This figure excludes taxa that are present, but not assigned functional feeding groups.

[48] Surveys conducted for King County Roads by ABR, Inc., on September 16, 2004. Data available from R. Fritz.

Table 8. Benthic macroinvertebrate families (arthropods only) known to exist in Newaukum Creek (from McElligott et al. 2005; see that report for final identifications). Relative abundance (Rel. Ab.) is given as percent of the total number of individuals collected, for orders and for families. Other invertebrates, including mollusks, nematodes, platyhelminthes, and sponges are also present.

Order	Rel. Ab. (%)	Family	Genera	Rel. Ab. (%)	Frequency	Sampling location NEW 1667	NEW 2076	NEW 2102	NEW 2128	NEW 2151
Coleoptera	10.8%	Dytiscidae	-	0.2%	1 of 5			5		
		Elmidae	4	10.6%	5 of 5	86	62	74	6	15
Diptera	36.0%	Blephariceridae	1	0.2%	3 of 5			1	2	1
		Chironomidae	-	27.4%	5 of 5	98	114	178	150	87
		Empididae	-	0.5%	4 of 5	1	6	2	3	
		Pelocorhynchidae	-	0.2%	2 of 5			2	2	
		Psychodidae	2	5.2%	5 of 5	2	20	28	46	23
		Simuliidae	1	0.9%	5 of 5	3	2	1	6	8
		Tipulidae	6	1.6%	3 of 5	20	1			16
Ephemeroptera	24.0%	Baetidae	2	10.8%	5 of 5	126	29	30	10	51
		Ephemerellidae	4	6.2%	5 of 5	1	5	91	14	30
		Heptageniidae	5	5.6%	5 of 5	3	64	11	23	27
		Leptophlebiidae	1	1.5%	5 of 5	2	4	5	10	13
Plecoptera	18.6%	Chloroperlidae	2	9.4%	5 of 5	2	89	24	52	47
		Leuctridae	1	0.3%	2 of 5				1	5
		Nemouridae	2	6.7%	5 of 5	4	12	36	81	20
		Perlidae	1	0.8%	4 of 5		3	3	1	11
		Perlodidae	2	1.5%	4 of 5		13	7	11	3
Trichoptera	10.5%	Brachycentridae	1	0.1%	2 of 5	2				
		Glossosomatidae	2	6.6%	5 of 5	45	13	43	27	24
		Hydropsychidae	1	0.0%	1 of 5		1			
		Lepidostomatidae	1	1.0%	1 of 5					23
		Limnephilidae	1	0.2%	1 of 5					4
		Philopotamidae	1	0.2%	1 of 5		4			
		Rhyacophilidae	1	2.3%	4 of 5	16	12	3		21
		Uenoidae	1	0.1%	1 of 5		3			

The long history of riparian forest clearing, agriculture, livestock grazing, and urban development within the Newaukum Creek basin has likely altered levels of aquatic primary productivity. No site-specific studies have been conducted, though substantial evidence exists from observations in other systems (see review by Murphy 1998). For example, forest clearing along relative small streams such as Newaukum Creek consistently results in temporary enhancement of primary production (Lowe et al. 1986, Murphy 1998). Increased production funnels more energy into the aquatic food web, supporting higher levels of production in both fish and aquatic invertebrates (Murphy and Meehan 1991, Bilby and Bisson 1992). Increasing the biomass of benthic algae leads to higher productivity in invertebrate communities directly – by improving food quality (Behmer and Hawkins 1986) - and indirectly, as the community is increasingly dominated by species with rapid life cycles (Gregory et al. 1987). Specifically, Newaukum Creek is likely dominated by grazing invertebrates in areas where riparian forests have been cleared, and gravel or cobble substrates persist.

The long-lived Western pearl shell mussell

One interesting and potentially important filter feeder that exists in Newaukum Creek (B. Brenner, *pers. comm*.) is the Western pearl shell mussel (*Margaritifera falcata*). This mussel is relatively unique among other detritivores in the system in that it is extremely long-lived. The average lifespan of a Western pearl shell mussel is 60-70 y, and some live >100 years. They are much more long-lived than fingernail clams (Family Pisidiidae), which typically live less than four years (Holopainen and Hanski 1986). Maturation is also delayed until they reach 9-12 years in age. Their ecology is intimately linked to stream fishes, which host their larvae and assist in their dispersal throughout the channel network, including: *O. clarki clarki, O. mykiss, O. tshawytscha, O. kisutch, O. nerka, Rhinicthys osculus*a (see later sections for details on these fishes). Fertilization occurs in early spring; males release sperm and females 'inhale' them from the water column. Females are gravid from May to July. They then release glochidia (larvae) which attach to fish gills, where they remain for days to months. After they leave the host fish, the larvae burrow into stream sediments, where they remain for a few years to indefinitely. Preferred habitats for these mussels are cold, clean streams and rivers supporting salmonids. In particular, they dwell in stable sand, gravel, cobble substrates near the leeward side of large boulders or along banks. Aggregations can reach very high densities (e.g., hundreds of mussels per m^2). Restoration activities that benefit salmonid fishes are generally expected to aid Western pearl shell mussels, as well, given the similarity in their habitat requirements and their commensalistic relationship (i.e., one animal benefits and the other is not harmed). Special consideration is warranted to their vulnerability to rapid deposition of fine sediments.

Higher prey availability – due to increased algal biomass - can lead to strong and predictable shifts in the density of some species of juvenile fish (e.g., *Oncorhynchus kistuch*; Murphy et al. 1981) which respond by adjusting (decreasing) the size of their feeding territories (Dill et al. 1981). Nutrient enrichment, like forest clearing, can produce similar increases in the growth and abundance of benthic algae and associated invertebrates and fish at higher levels in the food web (see Hershey et al. 1988, Johnston et al. 1990). However, in systems where fish populations are limited more by spawning or refuge habitat (food is not limiting), enhanced aquatic primary production may be of little consequence (e.g., Murphy et al. 1986).

Thus, it is vital for restoration efforts to recognize that aquatic primary production varies throughout a stream, across seasons and years, and is not necessarily positively correlated with the biological integrity of a stream ecosystem (Karr and Dudley 1981). Equal or greater attention must be focused on ensuring proper system function and the availability of diverse sources of energy for aquatic communities (Murphy 1998).

9.2.2. Aquatic Detritus and Detritivores

Aquatic detritus and the detritivores that consume it (e.g., aquatic macroinvertebrates [collector-gatherers, filter feeders and shredders], crayfish, mussels, and some fish) play an important role in supporting the productivity of the instream communities in Newaukum Creek. Detritivorous organisms capture and consume dead plant and animal matter (e.g., microbes, leaves, twigs, carcasses) that would otherwise be transported downstream. In contrast to primary producers, these materials often originate from riparian forests bordering the stream, which is thus termed 'allochthonous' organic matter. The material entering Newaukum Creek varies greatly in size, quality (e.g., energy and nutrient content); each of which likely varies along the length of the stream, depending on the composition of the riparian forest. These differences are likely reflected in the composition of the detritivorous animal community inhabiting the streambed.

Coarse particulate organic matter (CPOM; organic particles > 1 mm) and the microbes that colonize it (e.g., algae, bacteria, fungi, protozoans) represent a major food source for 'shredding' invertebrates. Recent surveys estimate that shredders compose roughly 16.3 % (± 4.5 SD) of the aquatic invertebrate community in Newaukum Creek (Mc Elligott et al. 2005) (Table 9). CPOM consists primarily of leaves entering streams during fall, but also includes agricultural detritus, dead aquatic macrophytes, and particles from decaying salmon carcasses. Shredding invertebrates process much of this material into smaller particles that can be more fully utilized by other members of the biotic community. Stream surveys indicate that and *Lepidostoma* caddisflies (Order Trichoptera, Family Lepidostomatidae) are important shredders in the North Fork and mainstem of Newaukum Creek (R. Fritz, *unpublished data*). These have been found in locations along the Plateau. Prior studies suggest that bits of flesh from decaying salmon carcasses may also represent an important food resource for some stream fish (see Bilby et al. 1999). Communities relying on CPOM likely dominate in the upper basin, and to a lesser extent, in the ravine.

Fine particulate organic matter (FPOM; between <1 mm and 0.45 μm) is both generated and consumed by filter-feeding invertebrates, freshwater clams and mussels, and larval Pacific lamprey (ammocoetes). FPOM originates from a variety of mechanisms, but primarily consists of feces, processed leaf particles, microbes and their byproducts, and clumps of DOM that have stuck together (flocculated) (Hershey and Lamberti 1998). This resource is rough 10 times as abundant as CPOM (Wallace and Grubaugh 1996), providing energy and nutrients to collector gatherers, including *Baetis* (Order Ephemeroptera, Family Baetidae) and *Attenella* mayflies (Family Ephemerellidae), and *Heterlimnius* beetle larvae (Order Coleoptera, Family Elmidae). Recent surveys estimate that the majority (48.6 %, ± 8.4 SD) of the aquatic invertebrates in Newaukum Creek are collector-gathers, (Mc Elligott et al. 2005) (Table 9). Filtering collectors also exist in Newaukum Creek, including net-spinning *Hydropsyche* caddisflies (Order Trichoptera, Family Hydropsychidae) and Chironomids (Order Diptera, Family Chironomidae) (R. Fritz, *unpublished data*). Collector-filterers compose 11.5% (± 8.4 SD) of the macroinvertebrate community. Oligochaetes (worms) and fingernail clams (Family Pisidiidae) also occur in Newaukum Creek, and these organisms play important roles as collector gatherers. Stream communities relying on FPOM likely dominate across the Plateau. Dissolved organic matter (DOM) is not a major food source for stream organisms, except for microbial communities and perhaps larval black flies (Hershey and Lamberti 1998).

Newaukum Creek – particularly Big Spring Creek, the North Fork of Newaukum Creek, and Stonequarry Creek (R. Fritz, *pers. comm.*) - is also home to detritivorous fish – specifically, lamprey (Family Petromyzontidae) larvae called 'ammocoetes'. Adult lampreys construct nests in gravel-bed streams by using their mouths to move stones into position. Eggs hatch into ammocoetes, which lack developed eyes and do not possess the sucking discs that typify adults. Ammocoetes remain buried in stream substrates, feeding on FPOM strained from the water column for roughly four to five years before metamorphosing (Eddy and Underhill 1978). Lamprey are commonly observed in the basin (T. Fields, MSFEG, *pers. comm*.). One lamprey (80 mm) was observed in the lower Ravine by snorkelers (TetraTech, 2005, *unpublished data*). Lampreys (i.e., roughly 10 per season) are regularly observed during spring in smolt traps in Big Spring Creek (Mid-Sound Fisheries Enhancement Group). The taxonomy of fish in these sightings was not confirmed, though most were likely the detritus-eating Western brook lamprey *Entosphenus tridentatus*. This species eats detritus, and remains in fresh water for the duration of its life (Wydoski and Whitney 1996). Pacific lamprey *Lampetra pacifica* may also be present, but was not be confirmed. In contrast to the brook lamprey, Pacific lamprey forage on the bodily fluids of other fishes while at sea (e.g., predaceous or parasitic relationship). The adult Pacific lamprey is anadromous, returning to freshwater streams to spawn.

9.2.3. Aquatic Predators

Macroinvertebrate predators compose roughly 33% of the aquatic invertebrate community in Newaukum Creek; 26.4 % (± 8.9) are predator-engulfers and 6.9 (± 4.1) are predator-piercers (McElligott et al. 2005). Specifically, the free-living caddisfly *Rhyacophila* (Order Trichoptera, Family Rhyacophilidae) is an important aquatic predator occurring in the North Fork and mainstem of Newaukum Creek (R. Fritz, *unpublished data*). The predatory stonefly *Sweltsa* (Order Plecoptera, Family Chloroperlidae) is also present at these locations.

The primary amphibian predator in Newaukum Creek and its tributaries is likely the larvae of the Pacific Giant salamander *Dicamptodon tenebrosus*. Larval Pacific Giant salamanders likely inhabit the steep, cold, shaded tributary streams of the upper Newaukum Creek basin, including the North Fork and mainstem. This species is adapted to stream life; larvae have short, bushy gills and a long, powerful dorsal tail fin that makes it a strong swimmer (see Leonard et al. 1993 for life history details that follow). Females appear to breed year round, laying < 100 large eggs at a time. Each egg is attached to a rock or log, and guarded throughout development. Larvae remain instream for at least two summers; during this time they act as formidable predators. After this period of development, larvae may metamorphose into large adults – capable of eating small reptiles and rodents. However, some larvae remain instream and achieve sexual maturation while retaining a larval body form (this is termed neoteny). Stream sampling by King County Roads verified the presence of Pacific Giant salamander larvae in the lower reaches of Big Spring Creek in September 2006 (R. Fritz, KC *unpublished data*). Northwestern salamanders *Ambystoma gracile* – a pond-adapted species – are also commonly observed in Big Spring Creek (Mid-Sound Fisheries Enhancement Group).

At least four bird species are fish-eating (piscivorous), and thereby qualify as important aquatic predators. Three of these – Osprey, Great Blue Heron, and Bald Eagles – are described in Section 9.1. The Belted Kingfisher *Ceryle alcyon* is a conspicuous fish predator along Newaukum Creek. Common mergansers *Mergus merganser* also commonly prey on stream fishes in the Green River, though may not occur in Newaukum Creek.

River otters *Lutra canadensis* may have once been important aquatic predators in Newaukum Creek, but this species is not known to occur there now. In contrast, muskrats *Ondrata zibethica* occur in isolated locations. Muskrat feed on fish, mussels, and amphibians. They construct houses in shallow water or dig burrows in streambanks (though these are rarely evident because entrances are underwater). These animals breed multiple times per year from late spring through summer.

The majority of fish species in the Newaukum basin prey upon aquatic invertebrates, riparian arthropods, or other fish. We organize following subsections around the basic life cycle of stream fish (Table 8), as envisioned by Schlosser (1991). Our rationale is that it is vital to match the description of fish habitat to the intermediate scales in which stream fish carry out critical life-history events and the scales at which natural resource managers can affect change (Fausch et al. 2002).

Table 9. Factors considered in characterizing stream fish species

Factor	Details
Stock origin	Wild or hatchery-origin and stock status based on assessments by Washington Department of Fish and Wildlife
Life history and genetic variation in the population	This includes life history traits (phenotypes) present or expressed. This is valuable information – where available – because genetic variation is the 'unseen basis' for the biological outcome of restoration (Falk et al. (2006).
Spawning habitat	Characteristics and distribution of spawning habitat, including redd site selection and construction, and egg incubation to emergence.
Feeding habitat	Distribution and characteristics of feeding (rearing) habitat; areas with seasonally favorable growth conditions, including plentiful food and energetically profitable stream hydraulics and water temperatures.
Refuge habitat	Refugia (i.e., for overwintering or oversummering) habitats. These areas may have seasonally unfavorable growth conditions, but provide refugia for fish during harsh winter floods, or intermittent flows during late summer.
Habitat connectivity	Connectivity among habitats is vital for spawning migrations, feeding migrations (from spawning habitats to feeding habitats, and overwintering habitats to feeding habitats) and overwintering migrations (from feeding habitats to refugia). Connectivity is also important to sustain metapopulation dynamics; at larger scales, isolated populations are not likely to survive indefinitely.

Chinook salmon - *Oncorhynchus tshawytscha*

See Section 9.1.

Coho salmon - *Oncorhynchus kisutch*

Coho are thought to have historically been the dominant Pacific salmonid in Newaukum Creek (Boehm 1999). Coho in Newaukum are part of the Green River/Soos Creek stock (# 3140), which is considered to be mixed with composite production. The stock was declared healthy in both 1992 and 2002 by the Washington Department of Fish and Wildlife. Hatchery coho salmon were introduced into Newaukum Creek from Soos Creek, Puyallup, and Issaquah facilities[49]. Genetic analysis indicates Soos Creek hatchery coho salmon exhibit strong genetic differentiation from all other Washington coho stocks (of those examined).

Coho salmon spawning habitat is distributed throughout much of the channel network comprising Newaukum Creek. Adult coho salmon generally return to spawn after one full year at sea. Numbers of spawning adults vary among locations and among years (Fig. 40). Prime spawning areas are located in Big Spring Creek, in the mainstem across the upper Plateau (RM 10-12; RK 16.1-19.3), and in the North Fork (see Goldstein 1982, p. 23).

Coho salmon rely on high quality freshwater feeding (rearing) habitat due to their long stream residence. Fry emerge from redds at approximately 30 mm long and migrate to sea in the spring after their first or second year of stream residence, spending little or no time in estuaries (Quinn 2005). The Newaukum Creek basin offers feeding (rearing) habitat throughout remaining natural

[49] Releases occurred (at least) in 1978, 1977, and 1980, ranging from 37,000 to 245,000 individuals (see Goldstein 1982).

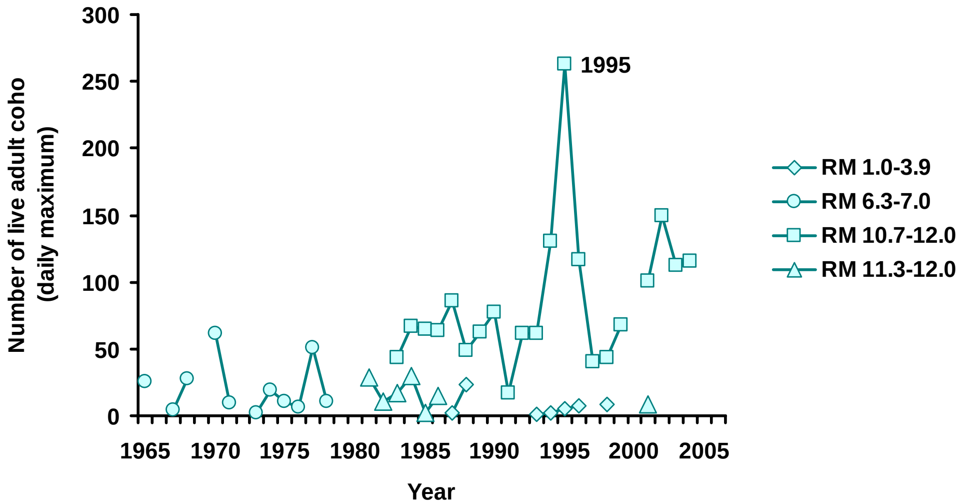
watercourses and some drainage ditches. The best rearing habitat likely exists in Big Spring Creek, the North and South Forks of the mainstem; though the road culvert along the North Fork at 292nd may - at times – potentially block juvenile fish passage (R. Fritz, *pers. comm.).* On average, roughly 1,400 coho smolts (ranging from 569 to 2006 fish between 2003 and 2006) outmigrate from Big Spring Creek, typically from mid-April to early May[50]. Outmigrating smolt typically range from 100 mm to 125 mm in size. Coho ranging from 55-100 mm in length were observed in Big Spring Creek during September 2006 (R. Fritz, KC *unpublished data*). Summer rearing habitat also exists in Watercress Creek, from the confluence with the mainstem to the 442nd Street intersection, in Stonequarry Creek along Veazie-Cumberland Road (though low flows and poor water quality in late summer can be problematic) and in an drainage ditch downstream connected to the mainstem at RM 6.8 (R. Fritz, *pers. comm.*). Coho juveniles also rear in the Ravine; recent surveys estimated juvenile coho abundance in the lower Ravine ranges from 0.034 to 0.072 fish m^{-2} among reaches, in mid-June (TetraTech, 2005, *unpublished data*). In 2006, coho represented 27-44% of the total fish abundance (among reaches), ranging from 10 to 130 mm in total length. Most (i.e., 50-74% among reaches) occurred in slow water habitats or in association with large wood (i.e., 13-41%).

Refuge habitats for overwintering and over-summering juvenile coho are relatively scarce due to the pervasive lack of complex habitat (e.g., instream wood, side channels with abundant cover) and pools. Exceptions can be found in portions of the mainstem in the ravine (e.g., upstream from the Whitney Bridge), side channel complexes in Mahler Park and Big Spring Creek, and numerous restoration projects involving wood supplementation (e.g. Malatesta site at RM 12, dam removal site on North Fork). Ditches may also offer some refuge from winter floods, similar to refugia provided by wall-base channels, though this has not been evaluated. Investigations of potential passage barriers to adult and juvenile migrants are ongoing.

Optimal temperatures for coho salmon vary among life stages (see review by Richter and Kolmes 2005). Spawning migrations tend to occur when temperatures are below 15.6˚C. Incubation temperatures of 2.5-6.5˚C are optimal for eggs, compared to 4-8˚C for alevins, though survival and health appears acceptable below 11-12˚C. Juveniles grow fastest in average water temperatures of 12-15˚C; the 7-DAM should not exceed 14-17˚C**.**

[50] Mid-Sound Fisheries Enhancement Group has studied coho salmon migration in Big Spring Creek since 2003 using a smolt trap: http://www.midsoundfisheries.org/SmoltTrap%20Data%20Overview.htm. Variation in smolt outmigration timing: http://www.midsoundfisheries.org/Spring%202006.pdf. Juvenile coho salmon constitute 65-92% of the fish caught in the smolt trap.

Figure 40. Historical counts of adult (spawning) coho salmon at four different index reaches of Newaukum Creek. Values depict the maximum number of live adults observed in that year (usually among six to ten dates of observation during spawning season). Note that observations were missing in many years. These observations are presented to illustrate trends across time at individual reaches, but should not be used for cross-reach comparisons.



Chum salmon - *Oncorhynchus keta*

Newaukum Creek contains Crisp Creek fall chum (stock # 2154); one of the two stocks of chum salmon in the Duwamish/Green River basin. This is a non-native stock with composite production supported by the Keta Creek Hatchery (operated by Muckleshoot Tribe). This stock is genetically indistinguishable from Quilcene hatchery chum (Phelps et al. 1995), which was the founding broodstock (also some from Hoodsport). Efforts are underway to replace this stock with one from another south Puget Sound system (Suquamish Tribal Hatchery; WDFW 2002). The historical abundance and distribution, nor present status is well known. Life history variation in fall chum salmon within Newaukum Creek has not been described.

Newaukum Creek offers spawning habitat for chum salmon, which generally return to spawn after 3-5 years at sea, where they attain large sizes (e.g., 3-5 kg; Quinn 2005). Spawning occurs from late November through December (WDFW 2002), primarily within the first mile of the North Fork of Newaukum, the first 0.6 mile of Big Spring Creek, and in the South Fork of the mainstem. Reaches located in RM 4.6-10 are also thought to comprise important spawning habitat (see Goldstein 1982, p. 23). Chum salmon eggs are relatively large, producing fry that measure 32-38 mm in length upon emergence.

Feeding (rearing) habitat within Newaukum Creek is relatively unimportant for juvenile chum salmon. Juveniles have small parr marks for camouflage, however most depart to downstream estuaries immediately after emerging from the gravel, or remain in their natal stream for only a few days or weeks. The lower 1.6 km of the South Fork Newaukum Creek is considered rearing habitat (WDFW SalmonScape). Due to their brief stream residence, the availability of overwintering and oversummering habitats in Newaukum Creek is likely unimportant for juvenile chum salmon production.

Passage barriers likely do not limit chum salmon adults from access to spawning habitat, nor does it limit juveniles migrating downstream.

Pink salmon - *Oncorhynchus gorbuscha*

The status of pink salmon in Newaukum Creek is unknown and potential life-history variation in juvenile pink salmon has not been examined. Spawners return in odd years (e.g., 2005, 2007) to spawn in lower reaches of rivers. Adult pink salmon spawn in Newaukum Creek up to RM 8 (RK 12.9), though most spawning occurs in the first mile (1.6 km) upstream from the confluence with the Green River. Pink salmon are characterized by high spawner densities, small eggs, and slim-bodied silver fry measure 29-33 mm long when they emerge from the gravel (Quinn 2005). Fry migrate directly to the ocean, meaning freshwater habitats for rearing and overwintering are unimportant for pink salmon production.

Coastal cutthroat trout - *O. clarki clarki* (resident and migratory forms)

Native coastal cutthroat trout are likely the most abundant, widely distributed salmonid in Newaukum Creek (Fig. 42)[51]. The stock (# 7830) status is unknown. Green River cutthroat trout are genetically distinct from other populations in south Puget Sound, based on allozyme (protein) markers (33 loci) and microsatellite analysis (6 loci) (WDFW). Coastal cutthroat trout exhibit substantial life history variation (see review by Trotter 1989). Both migratory and nonmigratory life history forms are thought to be present (WDFW 2002; Boehm 1999).

Newaukum Creek provides habitat for spring-spawning coastal cutthroat trout, though spawning and migration timing is unknown. River-migrating individuals may enter natal streams from July through October and spawn from January to May (WDFW 2002)[52]. Other life history forms likely spawn from January through mid-June (WDFW). Coastal cutthroat are iteroparous (repeat spawners), spawning up to two or three times in their lifetime (Trotter 1989). Spawning occurs in riffles with pea-gravel substrates under 15-45 cm of water (Trotter 1989); often in pool tail-outs.

Feeding (rearing) habitat exists throughout Newaukum Creek, including Big Spring Creek. Newly-emerged fry measure 25 mm and dwell in low-velocity habitats along channel margins, in backwaters, and in side channels (Trotter 1989). Amphidromous individuals typically outmigrate to river mouths and estuaries after 3-5 years in freshwater, ranging from 20-25 cm in length (Fuss 1982). Fluvial (or potomodromous) individuals use mainstem rivers (e.g., Green River) as feeding habitats. In contrast, nonmigratory individuals migrate little, mature early, and die young (e.g., within three or four years; Trotter 1989). Oversummering juveniles feed on drifting invertebrates from lateral habitats and move to pools with the onset of fall. Recent surveys (late July 2006) estimated cutthroat trout represented 1 to 3 % of the total fish abundance (among

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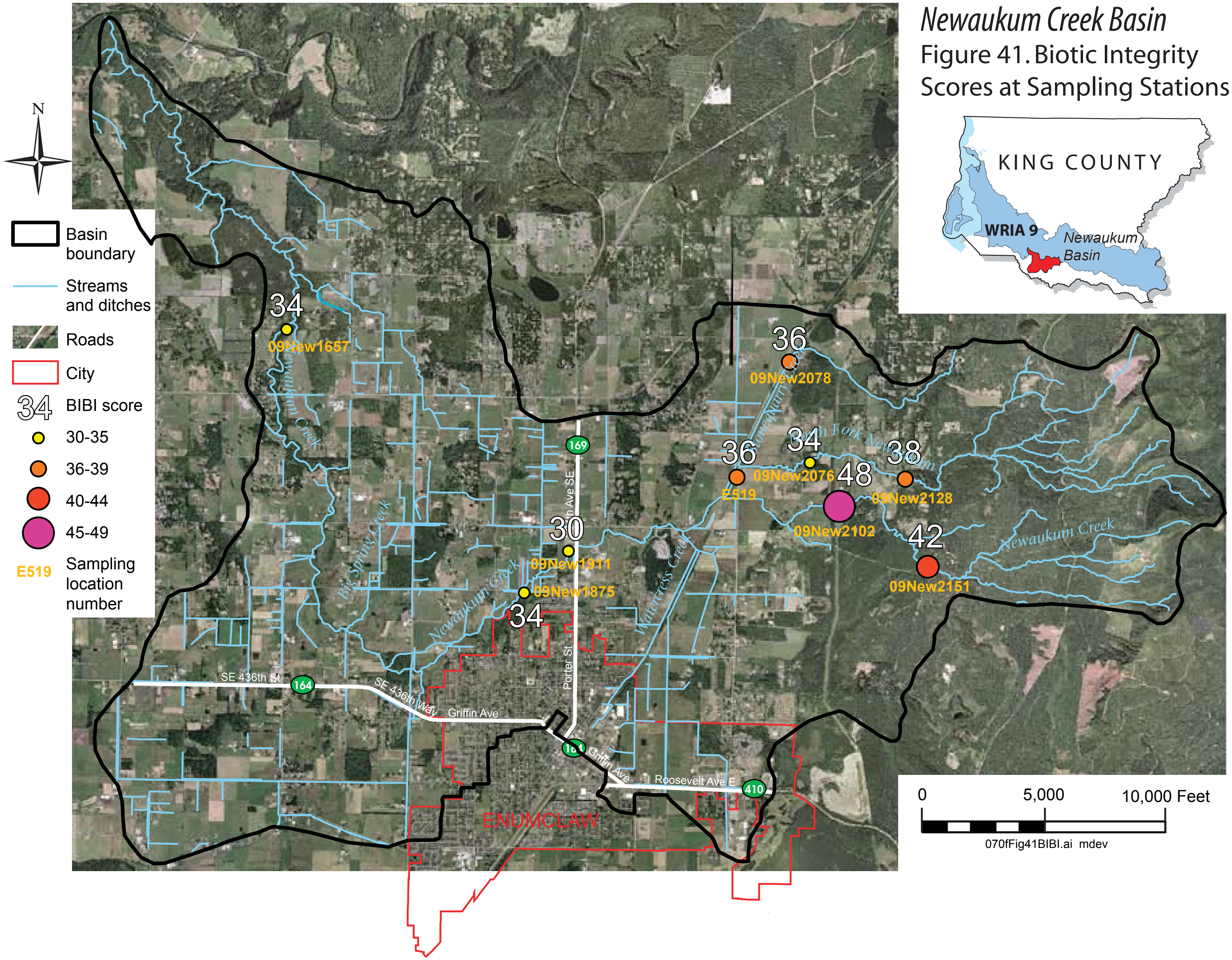
[51] We predicted the probability of trout presence in the upper basin (Fig. 42) from stream gradient using model A_G from Latterell et al. (2003). This model predicts the trout presence in 100 m stream reaches with 72% accuracy (where presence was assumed at probabilities ≥0.50), assuming no downstream passage barriers exist. Predictions are solely based on the stream gradient of the 100 m reach downstream from each point (Fig. 43). This model does not predict the upstream limit of trout distribution *per se*. Instead, it is intended to be an empirically-based, probabilistic decision-making tool for determining which roads cross stream reaches that are likely to contain fish, and for estimating the likelihood and extent of fish presence upstream from individual crossings. It is up to the user to decide whether the results sufficiently justify the repair of perched culverts on a site-by-site basis. Note that GIS-derived stream gradient typically underestimates true gradient because small channels are almost always more sinuous than depicted on stream maps (Latterell et al. 2003).

[52] This assumes similarities with coastal cutthroat trout in the Snohomish River.

reaches), ranging from 30 to 260 mm in total length (TetraTech, Inc. 2005, *unpublished data*). Cutthroat inhabited both fast and slow-water units within the stream.

Perched culverts at road crossings represent a potential threat to connectivity between stream habitats for coastal cutthroat trout in Newaukum Creek – particularly if and where they exist in low-gradient reaches in the Plateau. A comprehensive survey for potential fish migration barriers has not been conducted. However, we observed that 10 of 14 channels (mean wetted width 1.3, ± 0.8 SD) intersected by the old Weyerhaeuser mainline road had culverts that were 'perched' by > 30 cm and 7 of 14 were perched by over 0.5 m (up to roughly 2 m). However, our analysis (Fig. 42) suggests there is little chance that trout would be present either immediately downstream or anywhere upstream from the point where streams intersect the mainline road.



Newaukum Creek Basin
Figure 41. Biotic Integrity Scores at Sampling Stations
KING COUNTY
WRIA 9
Newaukum Basin
N
Basin boundary
Streams and ditches
Roads
City
34 BIBI score
30-35
36-39
40-44
45-49
E519 Sampling location number
34
09New1657
36
09New2078
36
E519
34
09New2076
48
09New2102
38
09New2128
42
09New2151
30
09New1911
09New1875
34
Newaukum Creek
Big Spring Creek
Watercress Creek
SE 436th St
SE 436th Way
Griffin Ave
Porter St
Roosevelt Ave E
169
164
410
ENUMCLAW
0
5,000
10,000 Feet
070fFig41BIBI.ai mdev

Newaukum Creek Basin

Figure 42. Probability of Fish Presence in Streams of the Upper Basin

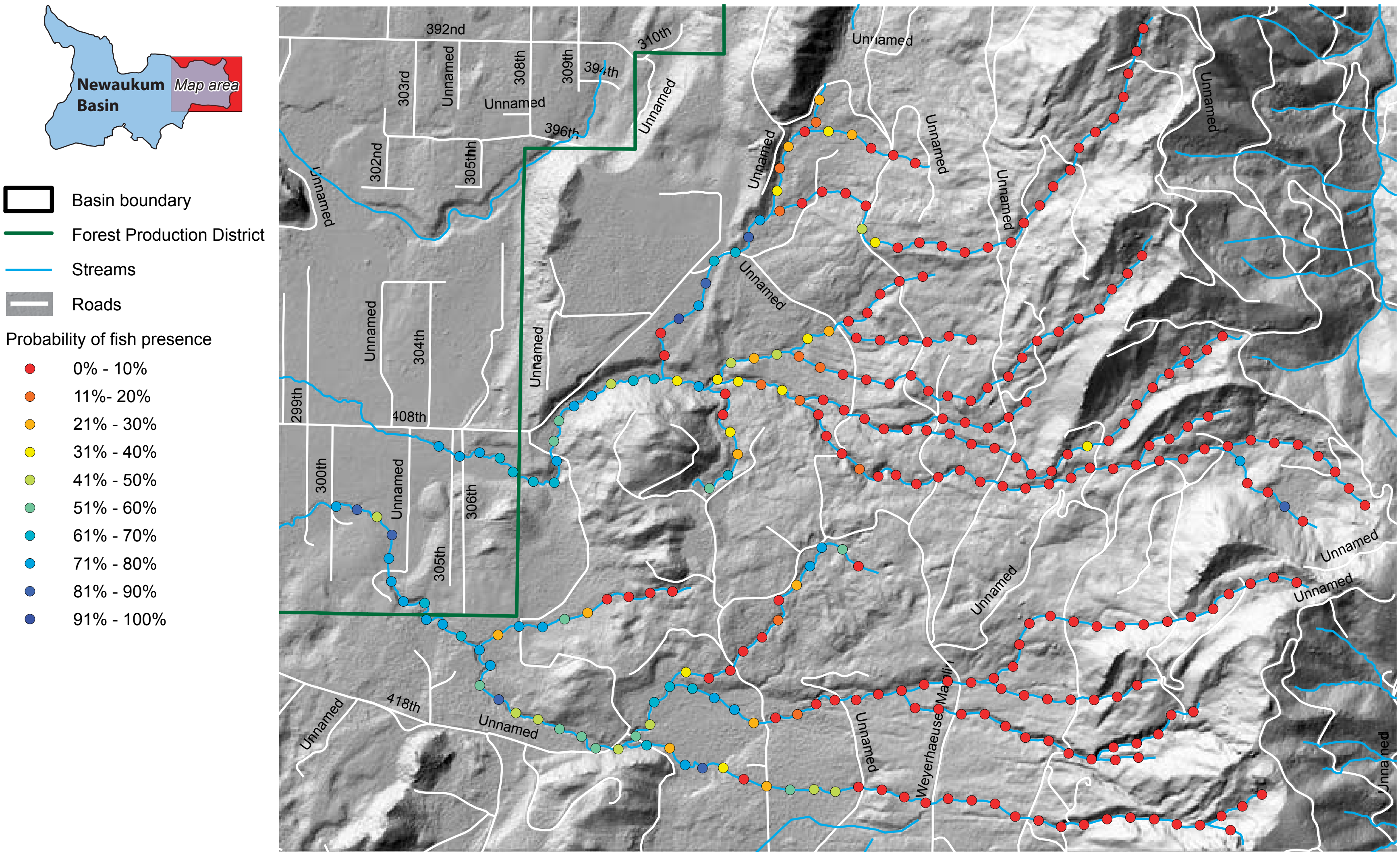


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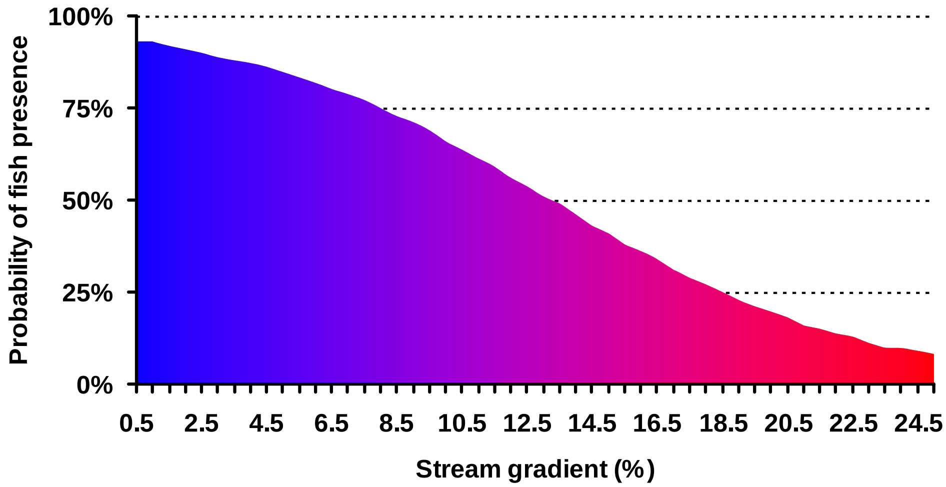
Figure 43. Modeled probability of fish (trout) presence in individual 100-m stream reaches where fish passage is not blocked downstream. Values represent results from model A_G in Latterell et al. (2003).



Threespine stickleback - *Gasterosteus aculeatus* Linnaeus

Newaukum Creek provides habitat for threespine sticklebacks, known to inhabit the lower reaches of Big Spring Creek, Stonequarry Creek, and the ditch joining the mainstem near RM 6.8 (R. Fritz, *pers. comm*, King County *unpublished data*, Mid-Sound Fisheries Enhancement Group[53]). This species lives in both freshwater and the marine environment, foraging on zooplankton, snails, and insects (Wydoski and Whitney 2003). In Washington, the freshwater residents spawn from May-July, and the marine form migrate up rivers in early June to spawn. Spawning habitats vary strongly from salmonids, in that stickleback do not construct redds. Instead, they build elaborate nests by building a nest from algae and detritus cemented together with gluey kidney secretions; these nests are spheres about 5 cm in diameter (Wydoski and Whitney 2003). Fertilized eggs (100-150 from freshwater form, compared to 250-300 from marine form; Wydoski and Whitney 2003) are protected in the nest and defended by the male until hatching a week later. Most adults die after spawning.

Sculpin - *Cottus spp.*

Newaukum Creek provides habitat to native sculpin, which have been observed in Big Spring Creek, Stonequarry Creek, the mainstem and North Fork (R. Fritz, *pers. comm*, King County *unpublished data*, Mid-Sound Fisheries Enhancement Group[53]). This genus likely occurs in most of the channel network, as they are often pervasive. No site-specific information exists regarding the life history of this genus within Newaukum Creek, however see Wydoski and Whitney (2003) for details on individual species and their general distribution. Recent surveys estimated that sculpin represented 2% of the total fish abundance in reaches in the lower

[53] http://www.midsoundfisheries.org/SmoltTrap%20Data%20Overview.htm

portion of the Ravine (TetraTech, Inc. 2006). Individuals ranged from 30 to 75 mm in total length. Most were found in fast water units.

Speckled dace - *Rhinicthys osculus*

Newaukum Creek provides habitat to speckled dace, which are known to inhabit the North Fork (R. Fritz, *pers. comm.*). In general, speckled dace inhabit small, swift streams and prefer water temperatures ranging from 9-11˚ C. No site-specific information exists regarding the life history of this species within Newaukum Creek. However, recent surveys estimated that dace represented 0 to 2% of the total fish abundance, ranging from 25 to 120 mm in total length. Most were found in fast water units.

9.3. WETLAND COMMUNITIES

This section briefly identifies and describes the remaining wetland areas with the highest values to wildlife. We also identify some of the species that use these areas, including nonnative invasive plants. In general, the Westside Riparian-Wetlands habitat type comprises wetland patches or linear forested riparian zones occurring in areas with wetland hydrology or soils, periodic riverine flooding, and perennial flowing freshwater (Chappell et al. 2001). This wildlife habitat type includes both wetlands and riparian zones, and therefore both are sometimes discussed together in this section.

The wetlands remaining in Newaukum Creek basin that likely provide the highest amount of value for wildlife are those with native vegetation. A total of approximately 407 acres of wetlands are present in Newaukum Creek basin that are categorized as forested, scrub-shrub, emergent, or open water wetland types. These wetlands are scattered across the basin in largely unconnected fashion (in other words, most of them are not forming wetland complexes; Figure 24). Regardless of hydrology, the emergent zone of wetlands is the most important for breeding amphibians, and it is also the most biologically productive area of the wetland. Wetland complexes are especially important because amphibians and other wildlife may still find water and breeding and foraging habitat when one or more of the other wetlands of a complex dries and is unavailable for use.

Two wetland areas stand out as providing the most actual and potential wildlife function. The first of these two wetlands lies north of the City of Enumclaw, south of 424th, along the left bank of Newaukum Creek. Black cottonwoods and red alder are the dominant canopy species, and willow and red-osier dogwood are present in the midstory. A small tributary flows out of this forested wetland into a roadside ditch along 424th. This wetland represents one of the most valuable wildlife habitat areas on the Plateau because of its relative size, the native vegetation present, and because of the presence of forest, wetland, and riparian habitat all in one location.

The second wetland of high value to wildlife is the forested wetland complex upstream of Big Springs Creek, including Mahler Park. Both of these wetlands are remnants of what were once much more extensive, connected wetlands. Each of these areas contain invasive species, including Himalayan blackberry, reed canarygrass, English ivy, and English holly, yet they retain diverse plant communities in terms of species composition, structure, and age. Animals breeding in these small wetlands are more vulnerable to predation, diseases, and human disturbance than species in much larger wetlands with naturally vegetated buffers. Nonetheless, these two wetland complexes offer the best available habitat on the Plateau in the basin.

The remainder of wetlands in the Newaukum Creek basin is highly altered and has limited value to wildlife in their present state. For example, “wet fields” occupy approximately 70% of wetlands in this basin (Table 3). Where wet fields are farmed for crops, seeds and grains that remain on the ground may provide valuable food for migrating and over-wintering birds such as American wigeon *Anas americana*. However, many of these wet fields contain a mixture of invasive reed canarygrass, bentgrass, and bulrushes *Juncus effusus*, or the fields are surface-dry all or part of the year, and they are not connected to other wetlands. Such wetlands provide little food for waterfowl and, lack (a) breeding habitat for amphibians; (b) foraging habitat for shorebirds; (c) forested vegetation appealing to beavers and muskrats; (d) and permanent water or access for salmonids.

9.4. RIPARIAN PLANT COMMUNITIES

Riparian areas[54] are among the most ecologically important elements of the Newaukum Creek basin, because they regulate sunlight, and thereby influence stream temperatures and primary productivity (also called 'autochthonous' production) (see map of forest types in Fig. 44). Another reason riparian areas are important is because they deliver vital organic materials to streams, including leaves and large wood. As summarized in King County (2004):

Riparian areas provide a variety of functions including shade, temperature control, water purification, woody debris recruitment, channel, bank and beach erosion, sediment delivery, and terrestrial-based food supply (Gregory et al. 1991; Naiman 1998; Spence et al.1996). These [functions] are potentially affected when riparian development occurs (Waters 1995; Stewart et al. 2001; Lee et al. 2001). Bolton and Shellberg (2001) provide an extensive discussion of the effects of riparian and floodplain development on aquatic habitats and species. Effects include: (1) reduction in amount and complexity of habitat; (2) increased scouring of channels due to channel and floodplain confinement; (3) reduction or loss of channel migration, vegetation, sediment supply; and (4) woody debris recruitment.

Riparian areas are also major food sources for aquatic organisms. Specifically, they support the productivity of aquatic animals that consume plant and animal matter (also known as heterotrophic consumers), through delivery of energy resources (called allochthonous organic matter, when it originates from outside the stream). These resources include organic matter (such as leaves, twigs) supporting animals (many aquatic invertebrates) that feed on dead vegetation and carcasses (also known as detritivores) in the stream, as well as invertebrates (namely, riparian arthropods) that drop into the stream where they can be eaten by aquatic consumers such as fish (for example, juvenile coho salmon and cutthroat trout) and amphibians.

Riparian areas (and wetlands) are used disproportionately to their relative area by wildlife (Thomas et al. 1979; Gregory et al. 1991; Oakley et al. 1985; McGarigal and McComb 1992; Nilsson et al. 1989; Knopf 1985; Knopf et al. 1988). In Oregon and Washington, 82 percent of inland bird species use freshwater, riparian, and wetland habitats; 77% of species breed in riparian and wetland environments (Kauffman et al. 2001). Many groups of mammals rely on riparian zones, including bats, small mammals such as shrews, mice, and voles, and mammalian predators such as mink, river otters, and raccoons. Seventeen herptile species (reptiles and amphibians) are closely associated with riparian zones in the Westside Riparian/Wetland habitat type. An additional 13 species are either associated with or present in this habitat type in Washington and Oregon (Kauffman et al. 2001). Riparian areas are particularly important travel corridors for herptiles, due to their limited mobility and dispersal capabilities.

Wildlife use riparian areas for a variety of reasons. For example, in Washington, these areas typically have higher structural diversity and spatial heterogeneity than adjacent areas. They

[54] Riparian zones are "transitional semiterrestrial areas regularly influenced by fresh water, normally extending from the edges of water bodies to the edges of upland communities" (p. 2, Naiman et al. 2005).

offer edge habitat (two or more habitats in close proximity), and reliable sources of water. Riparian areas produce substantial plant and insect biomass, which diminishes competition for food among consumers. Finally, riparian areas often provide more moderate microclimates than surrounding environments (Kauffman et al. 2001).

This section explains basic patterns in the native and current riparian forest community structure, composition and distribution including age, size, species composition, stand density and basal area, snag density. Between this and the next section, we contrast the typical pathways of vegetation succession in riparian and upland areas. Using generalized seral stages (steps in vegetation succession), we explain how the structure and composition of riparian forests change over time, including how they differ from one another. Specifically, we contrast the basic life history strategies of dominant plants and the primary mechanism used for reproduction, for each seral stage. We then explain the potential consequences of human alterations for forest regeneration, shade benefits to streams, delivery of wood, organic matter and insect prey to streams, and the development of productive riparian soils.

Boise Ridge in the Upper Basin is largely forested with conifer stands of various ages, reflecting a long (and continuing) history of timber harvest (Fig. 44). There is virtually no old growth forest remaining in this headwaters area and it appears that much of the area is in its third rotation of timber production. A network of logging roads, including many on steep sidehills, provides access for timber management and harvest activities.

Along the Plateau, the riparian vegetation has been more altered from its natural state than elsewhere in the basin (Fig. 44). Approximately 50 acres of riparian area (eight percent of total riparian area) is categorized as “agriculture or field” (Appendix D, Table D1), meaning that there is little to no discernable difference between the riparian vegetation and that of the surrounding field.

The riparian areas in the ravine are mostly forested and undeveloped (Table 10). Although the Ravine, like the rest of the basin, historically was logged of merchantable timber, the forest has been allowed to regenerate. The second-growth forest has been present long enough (80-100 years) to develop structural diversity in the canopy and understory. Generalized riparian conditions in the lower Ravine were recently (2006) evaluated by TetraTech, Inc. Surveys compared an ‘impact’ reach (i.e., site of future restoration project) and an upstream ‘control’ reach. The overstory density (above Newaukum Creek) was 76% (± 12 SD, among transects) in the control reach and 84% (± 12 SD, among transects) in the treatment reach. Deciduous vegetation dominated along roughly 91% of the control reach, and 77% of the treatment reach, whereas mixed conifer-deciduous overstory was relatively scarce.

Typically, wetland and riparian habitat would have either been shrubland (up to 30 feet in height) or forest (greater than 200 feet in height) or a mosaic of these (Chappell et al. 2001). Tree species were either conifer or hardwood or a mix. Some lowland forested wetlands may have been dominated by conifer trees. Large woody debris and snags would have been abundant in forested riparian areas and wetlands. The most dominant tree species was likely red alder, and other deciduous tree species would have included black cottonwood, bigleaf maple, and Oregon ash (Chapell et al. 2001). In the next sections, we identify the most obvious and important species in the riparian plant community, according to the successional stage in which it is most common.

9.4.1. Early-Seral Pioneers

Major riverine tree and shrub species can be generally classified into three groups according to their adaptation to disturbance –in this case, to floods (Naiman et al. 1998). 'Invaders' produce large quantities of seeds and branch fragments (known as propagules) that are dispersed by wind or water. These propagules colonize river sediments (also called alluvial substrates). In contrast, 'endurers' resprout from the stem or roots after being broken, partly buried by floods, or eaten by herbivores. 'Resisters' withstand flooding (or fires) during the growing season.

Table 10. Riparian landcover in Newaukum Creek basin.

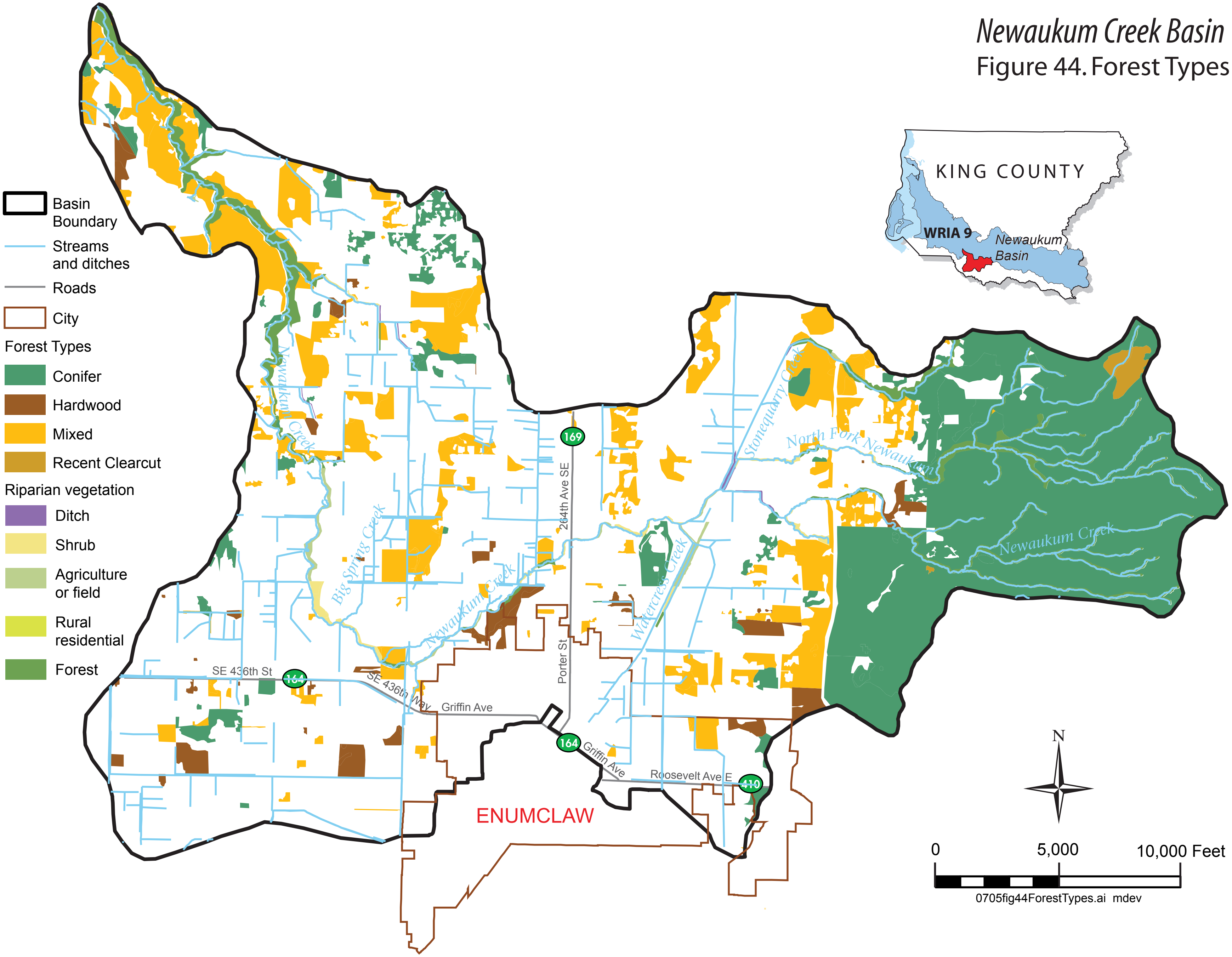
Landcover type	Primary landcover class	
	"Stream/Riparian"	"Wetland"
forest	463	21
agriculture or field	38	11
shrub	38	23
ditch	11	2
recent clearcut	2	0
rural residential	1	<1
total	554	58

Pioneering species in riparian areas largely colonize surfaces created by floods; which distinguishes them from upland forest species that regenerate in fire-dominated areas. Riparian pioneers play a vital role in creating hydraulic roughness – slowing down flood flows, causing sediment deposition and alluvial soil formation (Latterell et al. 2006). These species also produce high-quality (nitrogen-rich) seasonal inputs of litter. Litter input supports the productivity of macroinvertebrate communities, especially those that consume detritus.

Pioneering trees and shrubs in riparian areas of Newaukum Creek are mostly deciduous species. Most riparian pioneers have flexible stems that resist breakage, or can sprout roots from buried bark along their trunk or from fragments snapped off during floods (known as adventitious roots). Willows *Salix spp.* have attributes that qualify them as invaders, endurers, and resisters (see above). Red alder *Alnus rubra* and black cottonwood *Populus trichocarpa* are classifed as invaders and as resisters. Riparian pioneers frequently regenerate from transported live fragments. For example, cottonwood trees can shed healthy branch tips into the stream. When these tips are deposited on river sediments, they sprout to form produce genetically identical trees (this process is referred to as 'cladoptosis').

Newaukum Creek Basin

Figure 44. Forest Types



9.4.2. Late-seral Canopy Dominants and Foundational Species

Late-seral canopy dominants are those trees that occupy most of the upper canopy at a late stage of forest stand development. Some of these species function as foundational species, which create substantial amounts of habitat for other species. For example, large conifer trees may host many other plant species either directly on their trunks or in their canopies, or indirectly create favorable microclimates for other species rooted beneath their canopies.

These are important species to consider during restoration planning. For example, it is vital to consider whether sources of seeds and propagules are nearby to sustain regeneration. Also, these are the species primarily responsible for the production and delivery of wood**,** because they are large and relatively durable instream. They also generate substantial shade, which helps to regulate water temperature. Finally, their massive canopies can have important influences on the hydrology of the basin because they affect soil moisture levels as they draw water from the ground, through their foliage, and into the atmosphere (evapotranspiration).

Late seral canopy dominants in riparian areas of Newaukum Creek include conifer trees such as: western redcedar *Thuja plicata*, western hemlock *Tsuga heterophylla*, Sitka spruce *Picea sitchensis*, and to a lesser extent Douglas-fir *Pseudotsuga menzeisii* (Chappell et al. 2001). Indeed, GLO surveyors in the late 1800s confirm the presence of “alder, Spruce, hemlock,” as well as cottonwood and “fir” (Douglas-fir).

The existing canopy dominants in the Ravine include a mix of coniferous and deciduous species, including bigleaf maple *Acer macrophyllum*, black cottonwood *Populus trichocarpa* (early-seral), red alder (early-seral), Douglas-fir, western redcedar, and Sitka spruce. The conifer species and the cottonwood average 60 to 80 ft in height with diameters at breast height (DBHs) of about 18-20 inches; red alders average 40-50 ft in height with DBHs of 6-10 inches. These areas lack large snags: some may be present, but the area as a whole has not regenerated long enough to produce significant numbers of mature trees and snags.

9.4.3. Understory Trees and Shrubs

Understory trees and shrubs exist and regenerate under very different conditions than early-seral pioneer species. Dominant understory species in riparian areas under natural historic conditions included salmonberry *Rubus spectabilis*, salal, vine maple *Acer circinatum*, red-osier dogwood *Cornus stolonifera*, cascara, stink currant, devil’s club *Oploplanax horridus*, thimbleberry *Rubus parviflorus*, snowberry *Symphoricarpos albus*, beaked hazelnut *Corylus cornuta*, and Pacific ninebark *Physocarpus capitatus* (Chappell et al. 2001). Under natural historic conditions, Pacific willow *Salix laciandra* and other willow species, including Sitka willow *Salix sitchensis* and Hooker willow *Salix hookeriana* would have comprised some shrub wetlands and riparian areas. Other species in these shrublands would have included Douglas spirea *Spiraea douglasii*, western crabapple *Malus fusca*, and sweet gale *Myrica gale* (Chappell et al. 2001). Some patches of Oregon ash communities may have been present in the Newaukum Creek basin. Patches of vine maple and Sitka alder may have occurred along streams of the Upper Basin.

In riparian zones that are vegetated as shrub or forest, the ground story appears to be predominantly Himalayan blackberry. Reed canarygrass is pervasive and may be present along streams in any of the landcover types. Although trees line the riparian zone in narrow bands in various places throughout the basin, at only two locations in the plateau does the forest extend beyond the riparian zone into a more extensive stand. One of these locations is the City of Enumclaw’s Mahler Park, and the other is a forested wetland area just north of the city of Enumclaw on 424th. In both of these locations, Himalayan blackberry is one of the dominant groundstory shrubs. A variety of other shrubs are also present in the groundstory at Mahler Park, including salmonberry, snowberry, and another non-native species, English holly. Black cottonwood, Douglas-fir, red alder, and western redcedar comprise the canopy, and some of the cottonwoods are large enough that they may make sizeable snags in the not-too-distant future. English ivy is present on some of the canopy trees in this stand and could potentially cover all the large trees if not controlled. In the understory, some western redcedar saplings are growing.

9.4.4. Dominant Herbaceous Vegetation

Herbaceous vegetation is an important source of energy and nutrients for large herbivores, and contains substantial plant diversity. Dominant herbaceous species would have historically included slough sedge *Carex obnupta*, Sitka sedge *Carex aquilitis*, Dewey's sedge *Carex deweyana*, skunk cabbage *Lysichiton amercianum*, coltsfoot *Petasites palmatus*, Cooley's hedge-nettle *Stachys cooleyae*, stinging nettle *Urtica dioica*, and scouring rush *Equisetum telmetiea* (Chappell et al. 2001). Herbaceous plants of the Ravine include sword fern, reed canarygrass, and horsetail.

9.4.5. Non-native Vegetation

Invasive species are ubiquitous in the observed portions of riparian forests of Newaukum Creek. Reed canarygrass and Himalayan blackberry are most common and important, though English Ivy is also problematic in some locales.

Reed canarygrass is the most prevalent invasive species in the basin. It was introduced into the Pacific Northwest about 100 years ago. After an area was logged, reed canarygrass was planted because it helped break down stumps and log debris before crops were planted (USDA 2003). The species is problematic because it moves out of pasturelands and into stream bottoms and wetlands, and it may displace or prevent the establishment of native vegetation. It is also extremely difficult to eradicate once established. This monoculture reduces the amount of wildlife habitat for most native wildlife species by reducing: (1) habitat complexity, (2) a variety of forage plant species, and (3) the amount of other resources such as nesting materials. Conversely, it does provide shade and cover to aquatic areas and their invertebrates, fish, and amphibians. Reed canarygrass was present at nearly every Newaukum Creek road crossing that was viewed. Additionally, most of the "wet field" wetlands are covered in this aggressive species. Reed canarygrass may be also be found growing in the narrow floodplain of the creek near the confluence with the Green River (in the Ravine).

Himalayan blackberry is another prevalent non-native species in the Newaukum Creek basin. Himalayan blackberry was observed at every viewing location of the riparian zone within the Ravine to varying degrees. This shrub provides forage for birds such as Spotted Towhees and thrushes and omnivorous mammals, including coyotes, squirrels, and black bears. It also provides cover for birds and mammals. American Robins and Swainson's Thrushes may nest in these shrubs. However, Himalayan blackberry can form large impenetrable thickets, the density of which can reach 525 canes per square meter (Alaska Natural Heritage Program 2005). The thickets create dense shade, reduce native species diversity, and likely limit mammal movement (Alaska Natural Heritage Program 2005). In fact, Himalayan blackberry is allelopathic, which means that it releases a toxin into the soil that suppresses the growth of other plants such that understory competition is weakened and killed. Himalayan blackberry was noted in most small forest patches on the Plateau, in riparian areas of the Ravine, and at most of the road crossings of Newaukum Creek.

9.5. UPLAND FOREST PLANT COMMUNITIES

Upland forest was historically (and currently remains) the most extensive habitat type in the lowlands of Western Washington (Chappell et al. 2001). In the Newaukum Creek basin, it formed a matrix with other habitat types (Table 11). “The forests of western Washington…are the archetype of mesic temperate forests in the world….The environment is mild and extremely favorable for forest development” (Franklin and Dyrness 1973, pg 44).

Currently, the Newaukum Creek basin contains roughly 5,202 acres of upland forest (Table 11; Appendix D, Table D1)[55] (Fig. 44). Although the age and composition, not to mention the sizes, of these forest patches vary considerably, there are three general types of forest stands present in the basin: (1) deciduous; (2) conifer; and (3) mixed (Table 11). These stands range in size from very small patches under one acre to large connected forest in the Upper Basin (Forest Production District).

Table 11. Area of upland forest types inside and outside the Forest Production district in the Newaukum Creek basin based on 2005 aerial imagery and field reconnaissance.

Forest Type	Inside FPD (acres)	Outside FPD (acres)	Total (acres)
Conifer	2,756	478	3,234
Hardwood	31	244	275
Mixed	34	1,608	1,642
Recent Clearcut	51	0	51
Total	2,872	2,330	5,202

Conifer stands are almost exclusively composed of Douglas-fir in the Upper Basin, within the Forest Production District (FPD), because existing forest is being managed as high-yield Douglas-fir monocultures. Outside the FPD, some monotypic stands of western redcedar were also observed. The most common type of forest found outside the FPD is the mixed forest type (both deciduous and conifer species present). Currently, where stands of pure deciduous trees are present, they are dominated by either red alder or black cottonwood. Mixed stands were composed of varying combinations of Douglas-fir, western redcedar, bigleaf maple, red alder, black cottonwood, and occasionally Sitka spruce. A frequent hardwood species also encountered in mixed stands was bitter cherry.

9.5.1. Early-seral pioneers

The three main pioneering tree species occur in Newaukum Creek basin; Douglas-fir, red alder, and bigleaf maple. Douglas-fir is considered a fire ‘resister ‘, whereas red alder is an ‘invader’ after a fire (Naiman et al. 1998). It is important to consider that forest regeneration does not typically begin from a ‘clean slate’ after disturbances in upland forests. Remnants from the previous forest still remain (e.g., snags, logs, and remnant trees; Franklin et al. 2002). These remnants can have important influences on the rate and trajectory of forest regeneration (see Franklin et al. (2002) for details.

Douglas-fir is the most fire-resistant species and is also the most common dominant colonizing species after a fire (Chappell et al. 2001). However, depending on seed sources and other

[55] Forest patches were mapped in GIS as part of the landcover shapefile (Appendix D), and forest type was assigned to each polygon by using a combination of field work (ground truthing) and high-definition color aerial photographs from 2005 and infrared images from 2002. 2002 landcover data from University of Washington was also used to aid in assigning forest type; however, this data only used two forest types (conifer and mixed/deciduous).

conditions, any of the dominant tree species in the Westside Lowlands Conifer-Hardwood Forest habitat type can re-establish after fire or other disturbance. After a fire, the canopy would begin to open up to allow ground story species to return by about 60-100 years of age, and eventually a multi-layered canopy will be formed by age 200-400 (Chappell et al. 2001). If no fire or other disturbance were to intervene, Douglas-fir trees could reach ages of 800-1,000 years.

Red alder is commonly the first tree species to establish after logging activities, but such is not the case in fire-disturbed areas (Franklin 1988). As a result, red alder stands are far more common under current conditions than they would have been historically. Nonetheless, a red alder stand will decline in importance (dominance) by age 70 and will typically completely die off by age 100 (Chappell et al. 2001). If conifer seedlings are present when the alder dies off, they may replace the alder stand, or if salmonberry has grown in thickly, it often precludes the establishment of conifer species (Franklin and Dyrness 1973).

Another species that responds well to logging and is therefore now relatively widespread is bigleaf maple (Chappell et al. 2001). Mature bigleaf maples are often the largest diameter tree with the greatest potential for providing near-term future habitat as snags in managed forests. Bigleaf maples also frequently have cavities, deep cracks and fissures, huge branches, and other features that provide cover and shelter for numerous species of wildlife.

9.5.2. Late-seral Canopy Dominants and Foundational Species

The Newaukum Creek basin lies within the Western Hemlock zone in the Puget Sound Area as defined by Franklin and Dyrness (1973). The Western Hemlock zone dominates most of Washington west of the Cascade Crest. Historically, western redcedar and western hemlock would have been present as late seral canopy dominants and foundational species in upland forests. Douglas-fir also would have been part of the forest, especially at higher elevations in the foothills (Table 1). According to Franklin and Dyrness (1973, pg. 55), “At the time of the first settlers, conifer stands clothed almost the entire area of western Washington…from ocean shore to timberline except for…some prairies in the Puget Sound trough.”

Deciduous species, primarily red alder and bigleaf maple, would have been uncommon and subordinate in upland forests except for disturbed sites. In the lowlands (on the Plateau), species found in undisturbed conditions would have included Sitka spruce along with bigleaf maple, black cottonwood, and red alder, though neither of the latter two species would dominate the canopy.

Western hemlock typically would live 400 years or more and attain diameters at breast height of 30-40 inches (75-100 cm) and heights of 82-118 ft (25-36 m). The amount of old-growth forest present in the basin at any given time, prior to Euro-American settlement, is uncertain. Notes taken during Government Land Office (GLO) surveys during 1872 and 1881 describe everything from thickets of young conifer trees to coming across Douglas-fir with 12 foot diameters. During the mid- to late-Nineteenth Century it appears that the forests of the Newaukum Creek basin were a patchwork of ages, and the varying ages were mainly the result of fires.

Douglas-fir is now the most common tree species found in the overstory of forest stands in the Newaukum Creek basin. Much of the zone has been logged, burned, or both, during the last 150 years, and Douglas-fir is the species that has been available for regeneration and planting. Thus, it is usually a dominant (often a sole dominant) tree in the stands that have developed after human disturbances (Munger 1930, 1940, as cited in Franklin and Dyrness 1973). In addition to Douglas-fir and western hemlock, other conifer species now present include western redcedar, Sitka spruce, and grand fir. Hardwood canopy species, dominated by red alder, bigleaf maple, and black cottonwood, are common in recently disturbed sites.

9.5.3. Snags

Snags and coarse woody debris (CWD) would have been an important component of every seral stage, even with most natural disturbances, with the possible exception of very high-intensity fires (Franklin et al. 2002). Peak abundance of coarse woody debris is in the first 50 years after a fire, and it is least abundant during stand ages of 100-200 years (Chappell et al. 2001). Large-diameter snags would have been present at varying densities. These snags provided nesting and denning opportunities for birds and mammals[56]. CWD would have been relatively abundant on forest floors, where it provides forage and nesting/denning opportunities for numerous species[57].

The forest that remains in the Upper Basin of Newaukum Creek, specifically in the FPD, is in private ownership and is managed for timber harvest. Snags, called Wildlife Reserve Trees, by the Forest Practices Rules are now required in WAC 222-30-020 to be left during timber operations; only 3 snags per acre >12 inches dbh are required by this WAC. However, the adoption of rules that regulated retaining snags first took place in 1992, so only stands harvested in the past 15 years have been subject to Wildlife Reserve Trees requirements. Almost no snags were observed during field visits to forests in the FPD portion of Newaukum Creek basin.

Snag density and CWD density is obviously well below historical levels in the Plateau. According to the DecAID model (Mellen et al. 2006) an average of 18.6 snags per acre over 10 inches (46 snags per ha over 25 cm in diameter (dbh) are needed to maintain the snag component at the 50 percent tolerance level for wildlife habitat[58]. Of those, 8.1 snags/acre (20/ha) should be larger than 20 inches (50 cm) dbh. These guidelines are conservative; at the 80 percent tolerance level, these densities should be doubled. The model also recommends managing areas for the complete range of snag densities and diameters to provide habitats for a variety of species. For example, to manage for all species at the 50 percent tolerance level, some snags as large as 57 in (145 cm) dbh should be provided for Pileated Woodpecker roost trees, and for all other species, snags from 32-39 in (80 to 100 cm) dbh should be present on the landscape.

In addition to snag numbers far below amounts recommended by the DecAID model and others over one century of forest management in the upper Newaukum basin has likely resulted in additional ecological consequences. Forests managed for timber production have greatly reduced function as wildlife habitat. These forests, which are typically on 50-year harvest rotations (but possibly as short as 35-year rotations), lack plant species diversity as well as structural diversity, including snags, trees with broken tops, and CWD. All of these are critical components of wildlife habitat in forests of the Pacific Northwest. Buffers should be present along qualifying streams in the FPD in areas logged after 1987 (the past 19 years) (see legislative changes in Section 5.0). Despite the variability of riparian management zones, it is

[56] Species using snags include: spotted owls, barred owls, western screech owls, great-horned owls, pileated woodpeckers, various flycatcher species, kestrels, hawks, Vaux's swifts, martens, fishers, long-tailed weasels, raccoons, black bears, striped skunks, and various bat and myotis species.

[57] Shrews, voles, squirrels, foxes, bears, and skunks, winter wrens, song sparrows, and towhees.

[58] In DecAid, the tolerance level is the percent of observations of each wildlife species that correspond to particular sizes or amounts of snags and down wood. This can be interpreted as the level of "assurance" of providing for species' needs. We refer here to the managed forests in western Washington conifer-hardwood lowlands.

possible that with time the resulting corridors will re-establish the some of the structural diversity required for animal species diversity.

9.6. WILDLIFE COMMUNITIES

This section explains the general distribution and life history requirements of important wildlife (birds, mammals, reptiles and amphibians) in the Newaukum Creek basin. Summaries draw from the Washington Gap Analysis Program. Current wildlife communities reflect a long history of human activity, including land cover conversion and extensive road construction.

No formal surveys were conducted for any wildlife species. However, wildlife presence was assessed using the Washington Gap Analysis Program (WAGAP) data[59], which are supplemented by *Wildlife-Habitat Relationships in Washington and Oregon* (Johnson and O'Neil 2001)[60]. Table B2 in Appendix B summarizes the land cover identified in the Newaukum Creek Basin by WAGAP. This table represents a broad view of landcover groups present in the basin. These data are the foundation for the WAGAP species distributions discussed in this section. This habitat typing scheme was used in the analysis of wildlife species expected to be present in Newaukum basin. Discussions of both current and historic conditions will be based largely on 'wildlife habitat types' (Johnson and O'Neil 2001), which are based on the similarity of many wildlife species using a suite of vegetation types, and it is assumed that each type provides for all essential needs for a given species' maintenance and viability[61].

WAGAP data is generally representative of both breeding and non-breeding habitats of mammals, amphibians, and reptiles (hereafter, land animals), but not for migratory birds. Land animals may migrate or disperse to different habitat types or elevations, but generally speaking, these animals are more restricted to smaller ranges than birds. With a few exceptions- most of land animals do not migrate very far between breeding and non-breeding seasons. In contrast, some birds over-winter in the Newaukum Creek basin, then migrate north to breed. Therefore, overwintering species would be ignored if only WAGAP data were used to predict bird habitat. The following discussions are intended to capture habitat requirements for all the life histories of wildlife present in Newaukum Creek basin.

Current patterns of wildlife species abundance and distribution (including extirpation) in the Newaukum Creek Basin reflect the loss of large expanses of structurally diverse forests interrupted only by wetlands or streams and the increase of agricultural lands. The wide range of natural structural variability in the historical landscape provided cover, breeding habitat, food,

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[59] The WAGAP uses digital map overlays in a Geographic Information System (GIS) to "identify vegetation types, individual species, and species-rich areas that are unrepresented or underrepresented in existing biodiversity management areas" (WDFW 1999). The resulting land cover and vertebrate distribution maps are useful for our purposes. WAGAP landcover data are based on 1991 aerial imagery and therefore underrepresents the current extent of residential development near the City of Enumclaw. However, agricultural and forested areas are likely similar to 1991 levels.

[60] In the book *Wildlife-Habitat Relationships in Oregon and Washington* (Johnson and O'Neil 2001), 32 wildlife-habitat types are established and described. A wildlife-habitat type is a group of vegetation or land use/land cover types that are based on the similarity of wildlife use. Historically, these types would have been solely vegetation communities (as opposed to "land use" – for example, agricultural fields).

[61] Establishing the wildlife-habitat types included the selection of 541 native breeding species in Washington and Oregon and the subsequent identification of which of 119 classes of vegetative/land cover/marine types the species were found in. Statistical analyses were performed to establish species groupings with habitat associations (for methods, see O'Neil and Johnson 2001).

and water for many wildlife species. It is likely some of the same wildlife species are in Newaukum Creek Basin now as were present before the landscape was drastically altered by Euro-American settlement, but species' distributions and abundances would have been quite different from those of current conditions. Wildlife movement, migration, and dispersal routes are now affected by roads and vehicles, clearcutting, development, and by drained wetlands and channelized stream beds. Historically, the landscape would have been fragmented either by natural disturbance, such as fire, flooding, and insect and pathogen outbreaks, or by transitions in the native landscape from one habitat patch to another.

Road-building is widespread in Newaukum Creek basin, and this activity is potentially detrimental to wildlife populations. Strategies for mitigating transportation impacts should involve identifying important travel corridors for animal guilds (Jackson and Griffin 1998). For example, there are approximately 130 miles of road in Newaukum Creek Basin.

Roads are known to impact wildlife at the individual, local, and regional (population) scales (Forman et al. 2003; Sherwood et al. 2002). Animals are frequently struck and killed in vehicle collisions (e.g., amphibians, deer, reptiles) and roads have indirect impacts such as behavior modification, including altered home ranges or feeding behaviors (Trombulak and Frissell 2000). Roads can change the quality and quantity of adjacent habitat, and these changes can have both positive and negative effects on wildlife at the local scale. At the local scale, the density of animals and overall species richness tend to decrease with increasing proximity to a road as well and with road density. These relationships occur through a variety of factors, including direct mortality, avoidance, and disturbance (USDA 2000). Road maintenance can introduce a variety of herbicides, hydrocarbons, dust, and metals that negatively impact roadside aquatic habitats. The presence of roads and fragmented forests may facilitate the spread of bark beetles and fungi to areas that previously would have been relatively inaccessible (Trombulak and Frissell 2000; Perendes and Jones 2000). Alternatively, maintenance of roadside grass plant communities can provide dependable foraging habitat for raptors such as red-tailed hawks because of the small mammals that breed and live in them.

The impacts of roads on wildlife may be compounded at the landscape and population (or metapopulation) scale (see Jackson 2000). Population effects include the habitat isolation and fragmentation that separate individuals from each other and from access to critical habitats, hinder wildlife movement, and stop gene flow. Habitat connectivity can be reduced or eliminated for some wildlife species by roads. The extent of these impacts varies by species and animal guild: roads can present complete barriers to low-mobility species such as reptiles, amphibians, and invertebrates (Forman et al. 2003), whereas they may pose no barrier to raptors. Amphibians may be one of the most vulnerable groups of species that crosses roads. It is unknown whether there are annual amphibian migrations that are impacted by roads in the Newaukum Creek basin.

9.6.1. Birds

Approximately 114 bird species may breed in the Newaukum Creek basin based on Washington Gap Analysis (WAGAP) of 1991 landcover data. According to the Breeding Bird Atlas (BBA) for King County (Opperman et al. 2006), 106 species are possible, probable, or confirmed breeders in the 10 survey blocks that encompass (and extend beyond) the boundaries of Newaukum Creek Basin (see Appendix E, Table E1 for data set). These sources strongly overlap, though

WAGAP predicts 12 species that BBA does not report, and BBA reports 4 species that WAGAP does not. These potential breeding birds are all listed in Appendix E; Table E2).

Perhaps the most valuable habitat remaining in the basin for many species of birds is the naturally vegetated and open-water wetlands and the naturally vegetated riparian zones[62]. These areas provide foraging and nesting habitat for warblers, sparrows, shorebirds, vireos, wrens, flycatchers, blackbirds, ducks, and others. Additionally, wetlands provide forage and cover for many species that overwinter in Puget Sound, including song and fox sparrows, ruby-crowned and golden-crowned kinglets, black-capped and chestnut-backed chickadees, Bewick's and winter wrens, spotted towhees, juncos, Steller's jays, downy and hairy woodpeckers, and great-blue and green herons.

The extensive agricultural lands in Newaukum Creek basin likely provide increased amount of foraging habitat for species that use open areas and meadows, and as such their populations may be higher in Newaukum Creek basin than they were historically. These species include raptors such as the Northern Harrier, American Kestrel, and Red-tailed hawk. In fact, each of these species were observed during field work. For species such as the American Kestrel, which is a cavity nesting bird, their limiting factor in the basin may be adequate nesting cavities in snags. Red-tailed hawk is a year-round resident in King County (Section 9.1.).

Bird abundance and richness of forest interior bird species has likely decreased in communities within the forest interior, but richness has likely increased in communities that thrive in open or disturbed conditions. Current conditions may actually enabled a net gain in species richness, because few species have been extirpated, though populations are often reduced; the ecotones associated with the introduction of farmland and agricultural areas offer additional habitat types for new species to utilize.

Some guesswork is required to ascertain which birds were once abundant but are now scarce in the Newaukum Creek basin. We can use the example of wetlands to examine some of the potential changes that have occurred in bird species composition in the basin. It is unknown how much of the historic wetlands were lacustrine, palustrine, and riverine. Moreover, it is unknown what proportions of the historic wetlands were characterized by open water, how much were forested, and how much were scrub-shrub or emergent habitat types. Nonetheless, some broad generalizations are justifiable given certain assumptions. For example, if only 5 percent of the 6,445 acres (see Section 7.3) were open-water, that would be 322 acres of open water. This conservative estimate dwarfs the current area of 26 acres. Additionally, because beavers were present and building dams, the amount of open water would have been increased by their presence and thus provided habitat for many species of waterfowl and shorebirds, including great blue herons, American bitterns, and songbird species such as warblers and wrens. Wood ducks would have had a vast supply of snags in which to build their nests. It is speculated that great blue heron colonies would have likely been more abundant than at present, and osprey would have had ample trees and large snags for nesting, because the areas surrounding the wetlands would have been forested.

Approximately 5,202 acres of forest habitat are present within the basin, but very little of it has the mature forest structure and snags that woodpeckers require for foraging and breeding habitat. Given the appropriate conditions, up to five species of woodpeckers (northern flicker, pileated woodpecker, downy woodpecker, hairy woodpecker, and red-breasted sapsucker) may be present in the basin. Historically, snag would have been pervasive: in most forests,

[62] Old fields and woodlots may also be important, for different reasons.

regardless of age, as well as most types of wetlands (see details in Section 9.5.3). Snags provide habitat for primary excavators, including woodpecker, nuthatch, and chickadee species. Those primary cavity builders are responsible for creating habitat for a large array of secondary cavity users, including fisher, marten, flying squirrel, common merganser, wood duck, American kestrel, and various species of bats, swifts, swallows, and owls.

9.6.2. Mammals

Fifty-seven mammal species are predicted to breed in the Newaukum Creek basin (Appendix E, Table E3), according to Washington Gap Analysis (WAGAP), which relied on 1991 landcover data. Perhaps the single most important change from historical conditions is a decline in beaver populations.

We speculate that beavers (and muskrat) were once highly abundant, given the large, flat geography of the Plateau and evidence from surveyors notes (ca. 1800s). However, beaver and likely muskrat are now expected to have very limited distribution in Newaukum Creek basin. Beavers are considered ‘ecological engineers’, or ‘keystone species’ because they control hydrology, and thus their environment, (including sediment routing, nutrient cycling, and riparian forest composition) through construction of dam complexes. Resulting beaver ponds raise water depths and back up water. These waters inundate riparian habitats to form wetlands, and snags are often created from the forests that were flooded. Snags in wetland areas provide habitat for many cavity-nesting species, including swallow species and purple martins, as well as raptors that require large snags for their nests, such as osprey. Beavers are also considered an ‘umbrella species,’ because their protection favors the preservation of a whole series of other plants and animals with similar or related habitat requirements.

Forests of the Upper Basin (including the FPD) likely provide habitat for small mammals, including squirrels, shrews, voles, and mice. These small mammals provide an important prey base for predators such as bobcat and weasels, as well as raptors such as Cooper’s Hawks and owls. However, the forest in the FPD is nearly all second- or third-growth Douglas-fir in a monoculture that lacks structural diversity, snags, and CWD, all of which are important wildlife habitat components (see Section 9.5.2). The lack of structural diversity results in reduced native mammalian species diversity and shifts in abundance.

The loss of old-growth forest in the basin equates to a loss or reduction of marten, fisher, and Townsend’s big-eared bats, all of which require old-growth trees for breeding habitat. According to WAGAP, nine bat species are expected to breed in the basin, provided that their required habitat is available. Three of these species (Townsend’s big-eared bat, long-eared myotis, and long-legged myotis) are species of special status (see Table 7, Section 9.1.). Bats generally display similar reproduction, foraging, and hibernation behavior, with some variations (Ingles 1965, Christy and West 1993). Foraging habitat varies between species of bats, but all species use open water and riparian edges (Ingles 1965, Burt and Grossenheider 1980). Breeding females and juveniles often roost communally in large natural or man-made cavities and crevices with constant temperature and humidity.

Large herbivores, including Black-tailed deer *Odocoileus hemonius* and Rocky Mountain elk *Cervus canadiensis* use the basin to varying degrees. Their populations likely fluctuated historically depending on disturbances such as forest fires that affected forest age and structure. Generally speaking, deer are primarily browsers, fulfill their cover and food requirements from shrubs in forested areas, whereas elk are seasonal grazers, foraging on herbaceous vegetation in clearcuts and open areas to a greater extent. Both species use riparian areas and wetlands for their water needs (Witmer et al. 1985). Both of these ungulates also often calve in riparian areas, where the young feed on emergents and other herbaceous riparian and wetland species.

Forage areas for elk and deer are defined as "vegetated areas with less than 60 percent combined canopy closure of trees and shrubs taller than 7 feet" (Witmer et al. 1985). Clearcut areas provide a high amount of understory forage; however, as a new forest begins to regrow, the forage habitat declines steeply. Also as the new forest regenerates, the potential for hiding cover increases. Optimal hiding cover screens 90 percent of a standing adult deer or at 200 feet or less distance (adapted from Thomas et al. 1979). However, thermal cover (insulation from fluctuating temperatures) may not be present until the stand is exhibiting characteristics of a mature forest. Thermal cover is defined as a forest stand that is at least 40 feet in height with tree canopy of at least 70 percent (Witmer et al. 1985). Based on these definitions, a mix of habitats where forage is adjacent to dense tree and shrub cover is ideal for black-tailed deer and elk. Old-growth habitat is preferred over adjacent second-growth habitat in both winter and summer by deer and elk (Janz 1980; Pedersen et al. 1980; Witmer 1981; Hanley 1982; all as cited in Witmer et al. 1985). The Upper Basin in Newaukum Creek basin is used by deer and elk, but the habitat is considered suboptimal. Further, these ungulates would have occupied habitat throughout the entire basin historically, when forests and wetlands covered the Plateau. Deer still use the Plateau, but available cover habitat is limited.

Coyotes *Canis latrans* are present and common in most of Washington. Historically, coyotes likely would have been restricted primarily to the brushy mountain areas of Newaukum Creek basin because wolves *Canis lupus* occupied the forests. With the removal of gray wolves from the region, coyotes have been able to expand their range. They prefer open habitat and forest edges and readily use open forests and extensive burned or clear cut areas. They are found in agricultural lands and at the edges (and sometimes into) developed areas. Coyotes are adaptive enough that they appear to be maintaining their numbers and are possibly increasing in some areas.

Two large predators, grizzly bears and gray wolves, are now absent from the Newaukum Creek basin. Where they exist, these predators not only affected their prey populations, they also perform the key ecological function of providing carrion for other wildlife species such as fisher, mink, weasel, and skunks. The loss of grizzly bears and wolves equates to the removal of the largest predators in the area, and the reduction of predators has implications for other animal species. Historically, smaller predators, including marten, fisher, mink, and weasels would not have been uncommon. Additionally, because these species provided carrion, other predators that use carrion might be affected by their extirpation (Johnson and O'Neil 2001, pg. 178). However, coyote *Canis latrans*, bobcat *Lynx rufus*, black bear *Ursus americanus*, and cougar *Felis concolor* are still present in the basin. These predators may fill niches left vacant by the other large predators.

Cougars, also known as mountain lions, are almost exclusively carnivorous. Cougars generally prefer open or mixed forest and shrubby cover types with an abundance of prey. They feed primarily on ungulates (deer and elk), and they will also feed on a variety of smaller mammals, including porcupines, rabbits, beaver, ground squirrels (*Spermophilus* spp.), marmots (*Marmota* spp.), and other small rodents (Dixon 1982; Lindzey 1987; both as cited in Witmer 1998). Cougar occupy large home ranges from 12 to 400 square miles (Dixon 1982; Lindzey 1987; Seidensticker et al. 1973; all as cited in Witmer et al. 1998). Because it is likely that prey are not as abundant in the managed forests of the FPD, cougar home ranges in Newaukum Creek basin and surrounding areas are likely on the higher end of the range.

Bobcats are found where there is cover such as forests, thickets, wetlands, and agricultural areas. In summer, they may be found in high-elevation forests but are driven to lower altitudes by winter snow. They are expected to be present in varying densities throughout the Newaukum Creek basin.

The other large mammal that remains extant in the Newaukum Creek basin is the black bear. Black bears are omnivorous, and their food sources may include the cambium layer of trees, insects, carrion, livestock, deer fawns, and garbage. Plant matter makes up most of their diet, with grasses, sedges, forbs, and berries selected based on seasonal and spatial availability (Kolenosky and Strathearn 1987; Pelton 1982; both as cited in Witmer et al. 1998). Their preferred habitat is a mix of forest and open areas. Black bear also occupy large home ranges: from 4 to 40 square miles (Kolenosky and Strathearn 1987; Pelton 1982; both as cited in Witmer et al. 1998). The FPD in Newaukum Creek Basin lacks meadow areas as well as many types of vegetation black bears prefer. However, blackberry shrubs are common and likely augment their diet. The lack of denning sites often associated with old-growth forest may be a limiting factor for black bear populations in the Newaukum Creek basin.

Black bear and cougar "nuisance reports" are filed with WDFW when they occur. Frequently these reports are filed with a collision with a car or some other personal property damage has occurred, so these sightings do not indicate the range of these two species in the basin. Rather, they might be more indicative of where their ranges most frequently intersect with humans in the basin. Black bears are reported more frequently than cougars. Bears have been reported in the ravine near the mouth of the Green River. Both species have been reported at the eastern end of the Plateau; it is possible that these bears and cougars were exploring beyond the FPD, where they likely originated.

9.6.3. Amphibians and Reptiles

Washington Gap Analysis (WAGAP) used 1991 landcover data to predict approximately 17 amphibians and reptiles (herptiles, collectively) that may be present in Newaukum Creek basin (Appendix E, Table E4). Unlike bird species, herptile diversity would have been greater historically, because 1) the interdependent habitat components they require for survival would have been more common; and 2) no non-native species were present to compete with the native fauna. The distribution and abundance of native lentic, lotic and terrestrial breeding amphibian species was likely greater historically.

The western pond turtle would have possibly been found along the shorelines of ponds in the basin. This species has likely been extirpated from the basin, and throughout most of its historic range in the Puget Sound Ecoregion. According to the Washington Herp Atlas, "The major threats to this species are: (1) loss of hatchlings to bullfrogs, (2) alteration of important features of aquatic or terrestrial habitats, (3) loss of nests to human activities or predators, (4) disease and competition from introduced turtles, and (5) removal from the wild by humans." Painted turtles are presumed to have been introduced into the Puget Sound ecoregion, and it is now naturalized. The first records in King County are in the 1960s, so it is presumed that this species was either not present historically at all in Newaukum Creek Basin, or if it was present, it was not as widely dispersed as they are currently.

Several of our more upland garter snake species may have expanded their ranges and numbers in conjunction with increased clearing and human habitation; whereas the species associated with aquatic habitat types may have declined. Rubber boas may have been more widely distributed prior to extensive forest and agricultural practices; however, little is known about their population trends or even their current status because, according to the Washington Herp Atlas, "(1) it is difficult to find nocturnal, semi-fossorial snakes, (2) the records are primarily from opportunistic encounters and not systematic surveys, and (3) they occupy a variety of habitat types suggesting they are able to adapt to a variety of habitat conditions." Human disturbance has most likely decreased the distribution and abundance of Northern alligator lizards from historic conditions.

Amphibian species may have been more abundant and widely dispersed prior to habitat conversion, destruction and fragmentation. Terrestrial-breeding salamanders, especially those associated with mature and old-growth forests may have been more abundant and ranged more widely across the Puget Sound Trough than indicated by their present distribution. Stream-breeding species such as tailed frogs and Pacific giant salamanders have decreased in range and abundance with clear-cut and burn timber practices, land clearing and conversion to agricultural uses. These species are sensitive to stream temperature increases, sedimentation and other disturbances. Wetland-breeding species such as Oregon spotted frog, Northern red-legged frog, and western toad may have had greater distributions prior to extensive clearing of forests, conversion of land cover, disturbance to lakes and ponds, habitat fragmentation and the introduction of non-native fish, amphibians and other species.

Currently, the lack of permanent open water wetlands suggests that turtles, Northwestern Salamander, and American bullfrogs (non-native) are unlikely permanent residents in the basin, although permanently flowing ditches could be used by either of the amphibian. Seasonally flooded wetlands would provide breeding habitat for the remainder of the amphibians listed Table E4 (Appendix E), as well as foraging habitat for all garter snakes. Nearly all wetlands in the basin are found on the Plateau (99% of wetland area). Except in the case of some open-water ponds (most of which are agricultural ponds), most of the wetlands on agricultural fields are expected to dry out seasonally. Permanent and seasonal water sources are essential for the reproductive life stage of all aquatic-breeding amphibians (Nussbaum et al. 1983, Leonard et al. 1993). The forested wetlands on the plateau may be used for breeding, particularly for lentic[63]-breeding species such as northwestern salamander, roughskin newt, northern red-legged frog, and Pacific tree frog (Richter and Azous 2001). Newaukum Creek may provide habitat for lotic-breeding (stream-breeding) amphibians such as the giant salamander (Richter and Azous 2001).

Upland areas surrounding wetlands are also important habitats for amphibians and reptiles. Richter and Azous (2001) report that amphibian richness in 19 surveyed palustrine wetlands around Puget Sound was highest in wetlands that retained at least 60% of adjacent area in forest up to and exceeding 1,500 feet from the wetland. Approximately 9 wetlands in Newaukum Creek basin satisfy these criteria, and these wetlands are all in the Upper Basin. However, these wetlands appear to be either forested or open water ponds lacking emergent vegetation. Three of them may be emergent wetlands that potentially lack open-water, or if there is open water present, the amount of native amphibian habitat is extremely limited.

9.6.4. Arthropods

A detailed characterization of terrestrial and riparian arthropods exceeds the scope of this report, but we wish to acknowledge the importance of these organisms to ecosystem function, and as prey supporting the productivity of other consumers.

9.6.5. Non-native Wildlife

Non-native species introductions began with the arrival of Euro-Americans beginning around the mid-1800s. During the late 1800s, the diversity, abundance, and subsequent effects of non-

[63] Slow-moving or stationary water, such as ponds.

native species would have been in their infancy, and some non-natives would not have been present until well into the 1900s. Table E5 (Appendix E) summarizes the non-native species that have been introduced into the Newaukum Creek Basin in the past 150-200 years, as well as their effects on the native flora and fauna.

The list in Appendix E is not a comprehensive list of all non-native animals in the region, but identifies those with the greatest potential to do the most harm to native wildlife species. The European Starling is one example of an invasive non-native species. It has become one of the most numerous bird species in the United States, and their aggressive ability to out-compete native birds for nest cavities becomes problematic in areas where cavities are scarce (Witmer and Lewis 2001). In the Newaukum Creek basin, they would be likely have the greatest impact on woodpecker species and cavity-nesting ducks (Ingold 1994, 1996; Welsh and Howard 1983).

10. CONCLUSIONS

The findings in this report can be used to underpin a comprehensive set of management objectives that reflect unique aspects of the Newaukum Creek Basin and are consistent with the existing priorities set by the Salmon Habitat Plan for the Duwamish/Green River (WRIA 9 Planning Committee, 2005). Further study is needed to address several major data gaps listed below. Addressing these and other uncertainties will be a valuable next step to reduce uncertainty in the outcome of future restoration projects. In the meantime, we propose a simple set of recommendations for consideration in future planning efforts.

10.1. ECOLOGICAL ALTERATIONS IN NEWAUKUM CREEK BASIN

Current conditions in Newaukum Creek appear to be affected by a number of ecological alterations, listed below in no particular order. This is a partial list of the factors warranting consideration in plans to improve habitat conditions in the basin.

Low flow conditions are growing more extreme. The observed low flow rate (annual minimum 7-day mean flow) is declining at a rate of 0.12 cfs per year.

Streamflows are flashier, floods are more frequent than under historic conditions. Model simulations compared the historic ‘forested’ conditions with the ‘current’ developed condition of the basin, holding climate constant. Results suggest that flood events are now more frequent. For example, if Newaukum Creek Basin was completely forested, flows of 800 cfs would occur once every 10 years, whereas under ‘current’ conditions this flow occurs once every three years.

Peak annual flow magnitude is declining. Observed peak annual flow rates in Newaukum Creek declined at a rate of 5.4 cfs per year over the 60-year period of record, despite increases in impervious area and reductions in forest cover, meadows, and wetlands. Declines in peak flows may reflect both climatic change and impacts from human activities in the basin.

Surface and groundwater hydrology have likely been altered by growth of impervious surfaces. Impervious areas now cover 11% of the Newaukum Creek Basin, ranging from 2 to 59% among sub-basins. Model simulations suggest that forested areas show the least amount of hydrologic change from historic conditions. Areas with the highest amount of impervious surfaces show the greatest degree of change. Increases in the frequency of 10-year floods range from less than 10% to over 200% across the basin. Groundwater hydrology may be altered by landcover changes, as well as three large public water systems for domestic use (including two major springs) and 82 smaller public water systems that are almost entirely supported by wells. Personal wells for irrigation and livestock watering are common but poorly quantified.

Humans have created roughly 77 miles of artificial channels and reduced wetland area by at least 80%. These changes are largely attributable to extensive dredging, diking, draining, and ditching. Near the confluence with the Green River, Newaukum Creek has been locally straightened, armored and confined by berms, and large wood was historically removed. Additional factors contributing to wetland loss likely include declines in the number of beavers in the system and the introduction of reed canarygrass to improve land for cultivating agricultural crops.

Removal of riparian forests from most of the Plateau has likely exacerbated high stream temperatures, simplified stream channels, and encouraged the spread of non-native species. Loss of insulating shade from trees increases the heat load to the stream. Forest removal has also depleted the supply of trees that could otherwise fall into the channel and create pools and complex habitats. Impacts also extend to wildlife, which use riparian areas (and wetlands) extensively. Non-native species, such as reed canarygrass and Himalayan blackberry capitalize on harsh conditions resulting from forest removal. These species often exclude native plants and wildlife and may artificially stabilize streambanks and simplify the channel.

Water quality appears to have improved, but remains degraded. Water temperatures– specifically, the 7-day average daily maximum – in most portions of the mainstem and tributaries of Newaukum Creek consistently exceeded Washington state standards for spawning and incubation habitat as well as core summer salmonid habitat. The only locations that largely met standards for cool water were in Big Spring Creek and in the mainstem just below the forested headwaters. Stream temperature problems may be attributed to human activities that increase the heat load to the stream or reduce stream discharge. Factors can be ranked in order of increasing importance; (1) losses in riparian shade from forest clearing; (2) alterations to groundwater; (3) warming or reduced discharge in tributaries; (4) declines in mainstem discharge; and (5) reduced buffering from groundwater. Simulations suggest that nitrogen concentrations are elevated in the wet season, whereas phosphorous concentrations are elevated during the dry season, because of the relative contribution of groundwater to streamflows. Elevated phosphorus concentrations are likely from surface runoff from pastures during storms. Observed concentrations of bacteria are variable. Bacterial concentrations are higher in spring and fall when storms are large and infrequent, allowing fecal matter to accumulate on the landscape between storms. In summer, storms are small and infrequent; low, variable concentrations during this period are likely a result of animal activity with low potential runoff.

Conversion of native forests to plantations has reduced the structural habitat complexity of forest wildlife and the availability of snags and downed logs for nesting and feeding habitat. Most of the Upper Basin has been converted from natural forests to a high-yield (Douglas-fir) forestry plantation and fires are actively suppressed. Plantation forests have greatly reduced function as wildlife habitat, as snags, downed logs, and trees with broken tops or stands with multilayered canopies are relatively rare. Red alder stands and bigleaf maple are now far more common than they would have been historically.

Landcover changes and fragmentation may have benefited some birds, but have generally resulted in widespread loss of wildlife habitat. The extensive agricultural lands in Newaukum Creek Basin likely provide an increased amount of foraging habitat for species that use open areas and meadows. In contrast, the abundance and richness of bird species has likely decreased within the forest interior. The lack of structural diversity in forests of the Upper Basin likely reduces the diversity and abundance of native mammals. Amphibian species may have been more abundant and widely dispersed prior to habitat conversion, destruction and fragmentation. Road-building is widespread, and this activity is potentially detrimental to wildlife populations because of collisions, altered home ranges or feeding behaviors, and reduced gene flow.

10.2. MAJOR KNOWLEDGE GAPS

Agencies and landowners both possess considerable but incomplete knowledge of the streams, lands, and wildlife in the Newaukum Creek Basin. This report is not without substantial limitations, omissions, and speculations. Knowledge of the basin's ecological systems will evolve and improve by coupling scientifically robust studies with the local knowledge and long-term perspective of people that live and work in the basin. Further investigation is warranted on many topics, including the following:

- Mechanistic explanations for declines in peak flows and annual low flow levels.
- Cumulative effects of water withdrawals for irrigation, livestock watering, and domestic use on summer low-flow conditions.
- Spatially continuous evaluation of heat load and discharge in the mainstem to explain and correct exceedingly warm stream temperatures.
- Map of areas that lack fences to prevent livestock from damaging stream banks and better understanding of the potential instream consequences and effects on riparian vegetation.
- Life history, distribution, and productivity of Chinook salmon and steelhead trout using Newaukum Creek for spawning and rearing (for example, is a yearling life history form of Chinook salmon present?).
- Continuous surveys of fish distribution during spawning and rearing, as well as data on the variation in the distribution of spawning over time.
- Comprehensive assessment of road crossings to identify potential barriers to juvenile and adult fish migrations (currently underway).
- Better understanding of non-native plant and animal species distributions within Newaukum Creek Basin and their potential impacts on native plants and wildlife.
- Detailed studies of current water quality conditions, including fecal bacteria loadings, and the identification of ongoing sources of water quality degradation.

10.3. ANTICIPATING FUTURE CHANGE

Restoring and maintaining productive habitats for plants, fish, and wildlife in Newaukum Creek warrants consideration of the legacy of human impacts and present conditions, but also the anticipated future. Substantial uncertainty remains, but it is important to 'look before we leap'. This is accomplished by explicitly addressing potential consequences of future changes when planning management strategies.

More people in cities and rural areas: Human population growth and increasing development within the Urban Growth Area and in rural areas around the City of Enumclaw is expected to exacerbate existing ecological impairments and further constrain restoration opportunities in the basin. In particular, further development and related land use change may affect streamflow and water quality parameters and the extent and fragmentation of forested habitats.

Warmer stream temperatures from altered hydrology: Mean annual temperatures in the Newaukum Creek Basin are expected to rise in the future, and such a rise would exacerbate water quality problems in the basin. Results from model simulations suggest stream temperatures are likely to increase as a result of diminished groundwater base flows. Conversely, summer stream temperatures could be improved beyond existing conditions by increasing the riparian shade (e.g., in a forested stream system). Impacts of regional warming trends in air temperatures on stream temperature were not considered here, but may further exacerbate existing problems.

Slightly larger, more frequent floods and lower summer flows from regional warming trends: Streamflows in Newaukum Creek may be affected by regional warming trends. Six percent of the Newaukum Creek Basin receives seasonal snowfall (for example, where elevation exceeds 1,500 feet). Increases in air temperature cause more snow to fall as rain. Storms that drop rain on existing snowpacks (i.e., rain-on-snow events) will likely become more frequent in these areas. An increase in these events would amplify the annual number of storm run-off events, which also affect downstream areas along the stream. Moreover, higher elevations that would normally retain snow cover through May or June will lose their snowpack earlier in the year, causing higher spring flows and lower summer flows. Landcover change alone is not predicted to change flows drastically from current conditions, because agricultural land with naturally impervious soils will continue to be the dominant land cover type. Anticipated differences between current and future conditions are minimal, because the existing landscape is mostly ‘built out’ and increases in impervious area are expected to occur in zones that are already impacted by development.

Findings in this report can be used to support a comprehensive set of management objectives that reflect unique aspects of the basin and are consistent with the existing priorities set by the Salmon Habitat Plan for the Duwamish/Green River (WRIA 9 Planning Committee, 2005). Further study is needed to address the knowledge gaps listed above. Resolving these and other uncertainties require community partnerships. This will be a valuable next step to reduce uncertainty in the outcome of future restoration projects. In the meantime, management priorities and habitat improvements should be consistent with general themes outlined in Section 10.4.

Restoring and maintaining productive habitats for plants, fish, and wildlife in Newaukum Creek warrants consideration of the legacy of human impacts and present conditions, but also the anticipated future. Substantial uncertainty remains, but it is important to ‘look before we leap’. This is accomplished by explicitly addressing potential consequences of future changes when planning management strategies.

10.4. INTERIM CONSIDERATIONS

Identifying and prioritizing specific habitat improvement projects within Newaukum Creek Basin exceeds the scope of this report. Such an effort will require further study to characterize specific locations in detail. Input from key stakeholders in the basin will also be needed. Management priorities and habitat improvements should be consistent with the following themes:

Restoration actions in the alluvial fan reach near the base of Boise Ridge and in the Ravine should allow for lateral migration and channel switching. Channel change is particularly important in these areas, whereas the stream is relatively stable across the Plateau.

Restoration actions should support the productivity of existing juvenile Chinook and create opportunities in Newaukum Creek for the re-establishment of historic life-history diversity. For example, projects which promote greater abundances of the nearly extirpated ‘yearling’ (stream-type) juveniles. Stream type juveniles depend most heavily on the quality of freshwater rearing habitat, such as that provided by Newaukum Creek.

Restoration actions across the Plateau (and elsewhere) may benefit from allowing keystone species (beavers, for example) to create and maintain productive habitats. Likewise, enhancement of salmon populations may have far-reaching benefits. Spawning salmon are potentially important in supporting the productivity of stream and riparian plants and wildlife in the basin.

Fish abundance can be expected to vary within Newaukum Creek Basin – both among small tributaries, and along the mainstem between years. Fish production is naturally variable. Stable populations are often the exception, rather than the rule. These fluctuations may increase the resilience of the aquatic community and may prevent any one species from exploiting stream resources to the detriment of the others.

Restoration actions should consider terrestrial, riparian, and stream habitats – they are connected by flows of water, sediments, nutrients, and organic matter. In many ways, the riparian zone can be considered fish habitat; from this perspective, fishless streams are inseparable from fish-bearing rivers downstream (Naiman and Latterell 2005). Thus, the condition of the Ravine and Plateau is materially linked to the condition of streams and forests in the Upper Basin, whether or not fish are present in the headwaters.

Riparian restoration efforts will be important in reducing heat load to streams, but improving summer-low flow conditions should be coupled with reforestation efforts. Riparian plantings should capitalize on the natural patterns of vegetation succession (Franklin et al. 2002). To ensure additional benefits for wildlife, strategies should address not only the linear extent of riparian forests, but also forest structure: live trees, dead trees, large diameter trees, lower canopy tree community, ground community, downed logs, rootwads, vertical distribution of canopy, and gaps.

Habitat assessments (and corrective actions) should address the implications of climate change predictions for the Pacific Northwest. Strategies should also be linked across spatial scales because benefits from habitat improvements (like problems from stream degradation) can extend both upstream and downstream (Fausch et al. 2002).

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12. APPENDICES

APPENDIX A. HYDROLOGY

Table A1. Metrics for evaluating the accuracy of calibration model for hydrological analyses. Daily Flow Statistics at USGS Gage 12108500 (Oct 1999 – Sep 2002).

Statistic	Sim (cfs)	Obs (cfs)	Diff (cfs)	Diff (%)
Mean	54.77	55.12	-0.34	-0.6 %
Geometric Mean	38.08	39.20	-1.12	-2.9 %
Standard Deviation (SD)	56.48	56.08		
Correlation Coefficient	0.94			
Coefficient of Determination	0.88			
Mean Error	-0.35			
Mean Absolute Error	9.87			
Root Mean Square (RMS) Error	19.82			
Nash Sutcliffe	0.12			
Model Fit Efficiency	0.88			
Skill Score[†]	0.65			

[†] The skill score is computed as 1 – (RMS Error · SD^{-1} of the observed flow).

Table A2. Expert System Statistics at USGS Gage 12108500 (Oct 1998 – Sep 2002).

Variable	Sim	Obs	Diff	Diff (%)	Criteria (%)	Meets Criteria
Total (in)	28.69	28.87	-0.183	-0.6%	10%	Excellent
10% high (in)	9.86	9.66	0.196	2.0%	10%	Excellent
25% high (in)	16.95	6.53	0.422	2.6%	15%	Excellent
50% low (in)	5.26	5.66	-0.395	-7.0%	15%	Good
25% low (in)	1.99	1.99	0.002	0.1%	15%	Excellent
10% low (in)	0.69	0.67	0.024	3.6%	15%	Excellent
storm volume (in)	8.87	9.00	-0.127	-1.4%	20%	Excellent
average storm peak (cfs)	246.9	282.0	-35.07	-12.4%	15%	Fair
summer volume (in)	3.39	3.64	-0.249	-6.9%	15%	Good
winter volume (in)	11.82	11.70	0.114	1.0%	10%	Excellent
summer storms (in)	0.28	0.15	0.135	91.7%	10%	Poor
winter storms (in)	2.99	2.86	0.136	4.8%	15%	Excellent

Table A3. Impervious surfaces in each sub-basin of Newaukum Creek, in 200 by sub-basin. We estimate the total area of impervious area the entire ecosystem equals 2.96 square miles (1,897 acres). Other landcovers total 23.04 square miles (14,743 acres). Thus, 11% of the Newaukum Creek ecosystem is covered by impervious surface area.

Sub-basin	Total impervious area (acres)	Other (acres)	Total acres	Percentage of basin area in impervious surfaces
NEW011	60	1169	1229	5%
NEW021	2	81	83	3%
NEW031	44	323	367	12%
NEW041	33	860	893	4%
NEW051	21	331	352	6%
NEW061	14	368	381	4%
NEW071	13	274	287	5%
NEW081	78	1047	1126	7%
NEW091	40	375	415	10%
NEW101	264	564	828	32%
NEW111	169	1294	1464	12%
NEW121	39	361	400	10%
NEW131	115	721	836	14%

Sub-basin	Total impervious area (acres)	Other (acres)	Total acres	Percentage of basin area in impervious surfaces
NEW141	62	313	375	17%
NEW151	158	111	269	59%
NEW161	12	23	35	35%
NEW171	169	456	625	27%
NEW181	84	624	708	12%
NEW191	40	630	671	6%
NEW201	9	144	153	6%
NEW211	84	865	948	9%
NEW221	49	443	491	10%
NEW231	71	784	855	8%
NEW241	103	866	969	11%
NEW251	25	212	237	10%
NEW261	11	437	447	2%
NEW271	94	564	658	14%
NEW281	23	318	341	7%
NEW291	10	185	195	5%

Table A4. Flow rates (cubic feet per second) for specified return periods (e.g., 10-year flood) for each sub-basin in the Newaukum Creek Basin. Four scenarios are listed. The “Forest” scenario is intended to represent forested conditions. The “LC1995” scenario represents conditions from 1995, based on landcover maps from that year. The “LC2002” is intended to represent current conditions, based on landcover maps from 2002. The “Future” scenario is based on the current zoning of the Basin.

		Flow Rates for Specified Return Period (in years)							
Sub-basin	**Scenario**	**1**	**2**	**5**	**10**	**20**	**25**	**50**	**100**
11	Forest	10	87	157	218	277	295	356	424
	LC1995	12	95	166	227	284	301	361	425
	LC2002	11	89	159	220	279	296	357	426
	Future	11	89	159	220	279	296	357	426
21	Forest	1	7	13	18	23	24	29	34
	LC1995	1	8	13	18	23	24	29	33
	LC2002	1	8	13	18	23	24	29	33

		Flow Rates for Specified Return Period (in years)							
Sub-basin	**Scenario**	**1**	**2**	**5**	**10**	**20**	**25**	**50**	**100**
	Future	1	8	13	18	23	24	29	33
31	Forest	10	108	199	281	360	384	466	558
	LC1995	17	132	229	311	388	411	490	576
	LC2002	15	125	220	301	378	401	481	569
	Future	16	129	225	307	384	407	487	574
41	Forest	6	60	109	152	195	207	252	301
	LC1995	8	65	115	158	200	213	257	305
	LC2002	7	61	110	153	196	208	253	302
	Future	7	61	110	153	196	208	253	302
51	Forest	7	78	147	209	268	285	346	413
	LC1995	11	96	167	228	285	302	359	422
	LC2002	10	90	160	220	277	294	352	416
	Future	11	92	163	223	280	296	354	417
61	Forest	2	28	54	79	101	108	130	155
	LC1995	4	37	65	87	107	113	132	153
	LC2002	3	31	58	81	102	108	130	153
	Future	3	33	60	83	104	110	131	153
71	Forest	1	16	31	45	58	62	75	90
	LC1995	3	24	43	59	73	77	92	108
	LC2002	3	26	45	60	74	77	91	105
	Future	5	34	54	70	84	88	102	116
81	Forest	4	55	105	152	196	209	256	308
	LC1995	11	91	158	216	270	286	342	402
	LC2002	11	88	151	204	253	267	317	371
	Future	12	95	164	221	275	291	345	404
91	Forest	15	177	336	480	619	660	804	965
	LC1995	33	258	446	606	758	802	957	1127
	LC2002	32	245	424	576	719	761	908	1068

		Flow Rates for Specified Return Period (in years)							
Sub-basin	**Scenario**	**1**	**2**	**5**	**10**	**20**	**25**	**50**	**100**
	Future	35	264	454	615	766	811	965	1133
101	Forest	2	16	28	39	49	53	64	78
	LC1995	32	70	99	122	146	154	181	211
	LC2002	92	148	183	208	233	240	265	292
	Future	92	149	183	209	234	241	267	294
111	Forest	5	73	140	201	259	276	336	402
	LC1995	47	167	252	322	390	411	483	563
	LC2002	120	253	335	398	457	476	537	604
	Future	121	263	348	411	471	489	550	616
121	Forest	36	354	648	908	1160	1234	1496	1786
	LC1995	94	527	810	1025	1210	1261	1433	1609
	LC2002	146	584	858	1067	1253	1306	1486	1674
	Future	152	619	903	1117	1304	1356	1534	1718
131	Forest	27	328	622	887	1141	1215	1479	1771
	LC1995	98	520	807	1032	1231	1288	1481	1684
	LC2002	147	575	856	1074	1274	1333	1532	1744
	Future	154	610	901	1125	1327	1386	1584	1793
141	Forest	25	288	543	774	998	1064	1300	1563
	LC1995	86	471	745	963	1161	1218	1412	1620
	LC2002	138	528	796	1012	1215	1276	1485	1712
	Future	144	560	839	1061	1267	1328	1536	1761
151	Forest	0	2	4	6	8	8	10	12
	LC1995	16	25	29	33	36	37	40	43
	LC2002	30	40	46	50	53	54	57	61
	Future	30	40	46	50	53	54	57	61
161	Forest	0	2	5	6	8	9	11	14
	LC1995	16	26	32	35	39	40	43	47
	LC2002	33	45	52	56	60	61	65	69

		Flow Rates for Specified Return Period (in years)							
Sub-basin	**Scenario**	**1**	**2**	**5**	**10**	**20**	**25**	**50**	**100**
	Future	33	45	52	56	60	61	65	69
171	Forest	1	5	9	13	17	19	23	28
	LC1995	19	35	48	58	68	72	83	97
	LC2002	32	54	68	79	89	92	104	116
	Future	32	54	68	79	90	93	104	117
181	Forest	1	6	11	15	20	21	26	32
	LC1995	9	20	29	38	47	51	62	75
	LC2002	10	20	29	37	45	48	58	69
	Future	10	21	31	39	48	51	62	75
191	Forest	1	6	11	16	21	22	28	35
	LC1995	6	15	24	32	41	44	56	70
	LC2002	6	14	22	29	37	40	50	62
	Future	6	17	28	38	49	52	66	84
201	Forest	27	286	534	759	979	1044	1277	1537
	LC1995	109	507	790	1019	1232	1295	1511	1746
	LC2002	177	587	869	1095	1312	1378	1606	1856
	Future	184	620	913	1147	1369	1436	1666	1916
211	Forest	1	7	13	19	25	27	33	40
	LC1995	8	20	30	38	47	50	60	71
	LC2002	6	16	24	30	37	39	46	55
	Future	8	19	28	35	42	44	52	61
221	Forest	29	289	539	764	986	1052	1288	1552
	LC1995	117	525	815	1051	1272	1338	1564	1810
	LC2002	183	599	886	1117	1340	1408	1643	1902
	Future	191	635	937	1179	1409	1479	1719	1981
231	Forest	29	293	540	762	976	1040	1266	1517
	LC1995	119	531	823	1060	1281	1347	1574	1820
	LC2002	186	602	889	1120	1343	1411	1646	1905

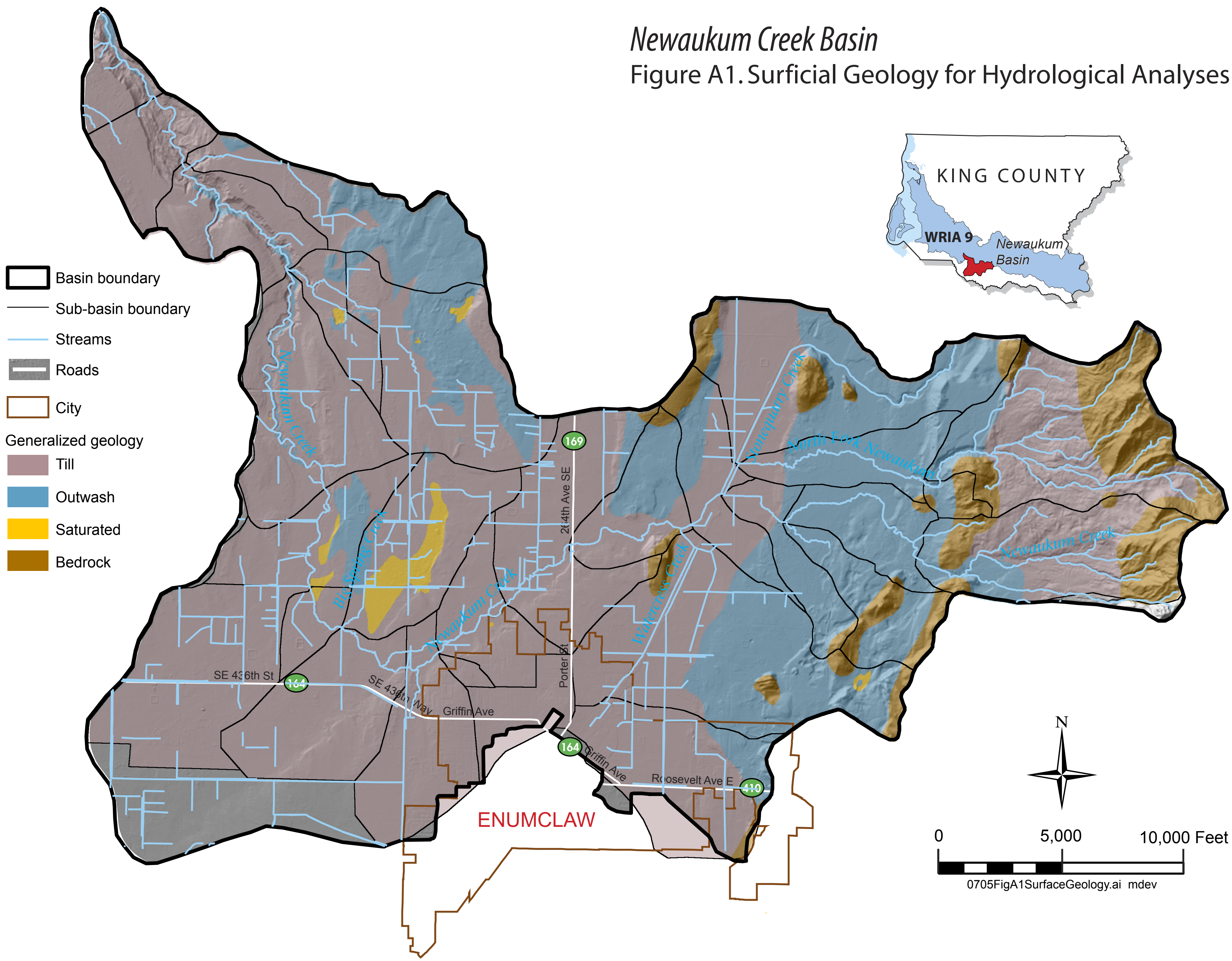
		Flow Rates for Specified Return Period (in years)							
Sub-basin	**Scenario**	**1**	**2**	**5**	**10**	**20**	**25**	**50**	**100**
	Future	194	640	942	1185	1416	1486	1726	1989
241	Forest	1	8	17	27	39	43	60	82
	LC1995	10	30	48	64	83	90	113	141
	LC2002	10	28	45	61	78	84	106	132
	Future	10	32	52	71	93	100	126	158
251	Forest	1	10	20	32	46	51	69	93
	LC1995	13	36	57	77	99	107	135	169
	LC2002	12	33	53	71	92	100	126	159
	Future	13	39	63	86	113	122	155	196
261	Forest	30	303	558	786	1006	1072	1303	1560
	LC1995	127	552	853	1097	1326	1394	1628	1882
	LC2002	192	621	915	1153	1382	1452	1692	1957
	Future	201	662	974	1225	1463	1536	1784	2056
271	Forest	1	5	11	20	31	35	52	77
	LC1995	6	19	32	45	59	64	83	107
	LC2002	6	19	32	45	60	65	83	107
	Future	7	21	36	50	66	71	92	118
281	Forest	31	310	569	800	1024	1090	1325	1586
	LC1995	132	565	872	1120	1354	1424	1664	1926
	LC2002	196	633	934	1176	1410	1481	1727	1998
	Future	206	676	995	1251	1495	1569	1823	2102
291	Forest	32	311	571	804	1029	1096	1333	1596
	LC1995	132	566	874	1123	1358	1428	1669	1932
	LC2002	196	635	937	1180	1415	1487	1734	2007
	Future	206	678	999	1256	1501	1576	1832	2112

Figure Captions for Appendix A:

Figure A1. Map of surficial geology for hydrological analyses in Newaukum Creek Basin. Geology was generalized into four types, according to the infiltration characteristics (in parentheses): (1) till (low); (2) outwash (high); (3) bedrock (low, but with possible fissures), (4) saturated soils (high water tables, generally associated with wetland vegetated areas).

Figure A2. Map of slope distributions in the Newaukum Creek basin. Slope is an important characteristic because it affects response time of runoff and potential moisture storage. Four categories are depicted, based on quintiles: flat (< %5), mild (5-10%), moderate (10-15%), and steep(> 15%).

Figure A3. Map of current (2002) and future landcover, basedon current land use zoning.

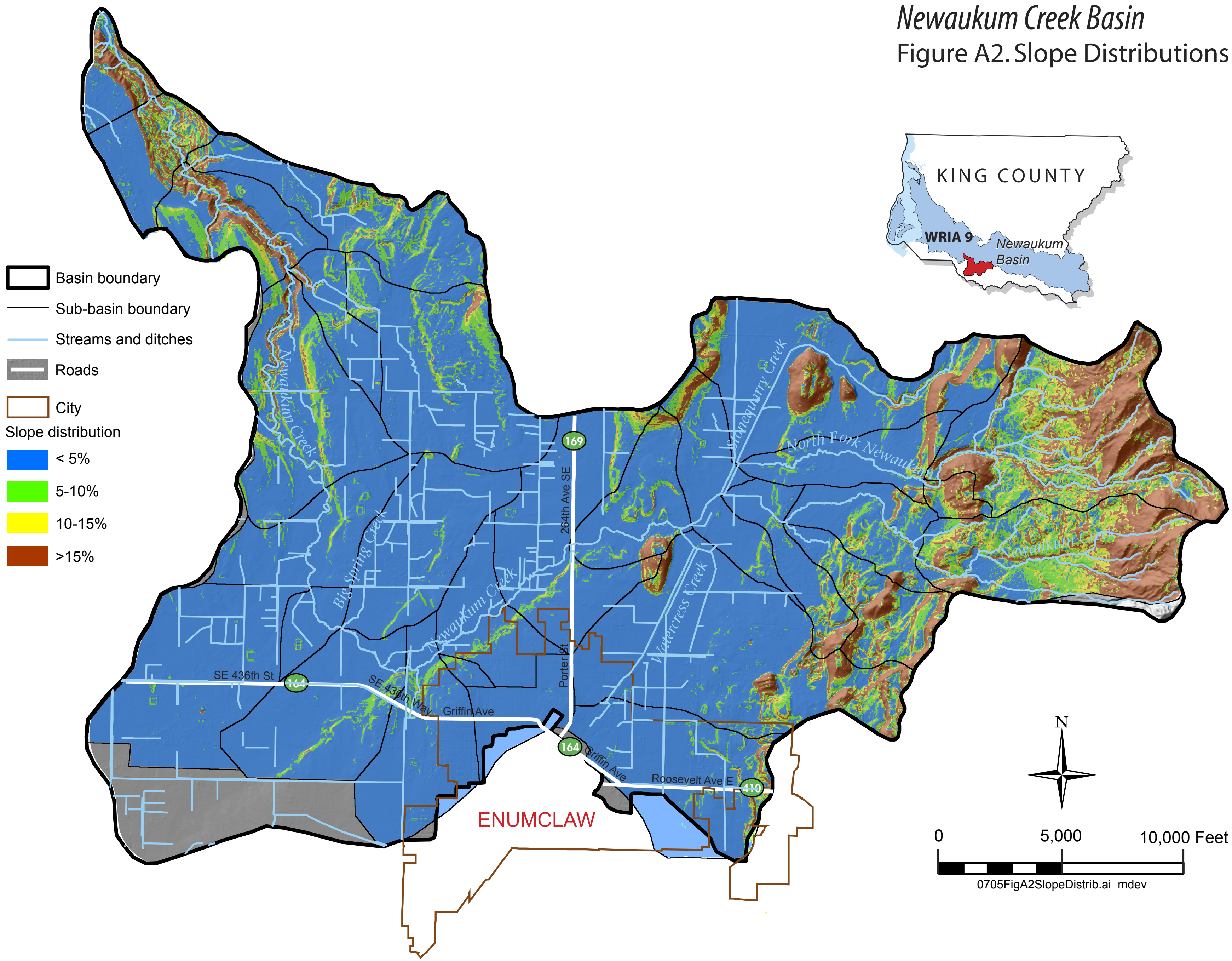


Newaukum Creek Basin

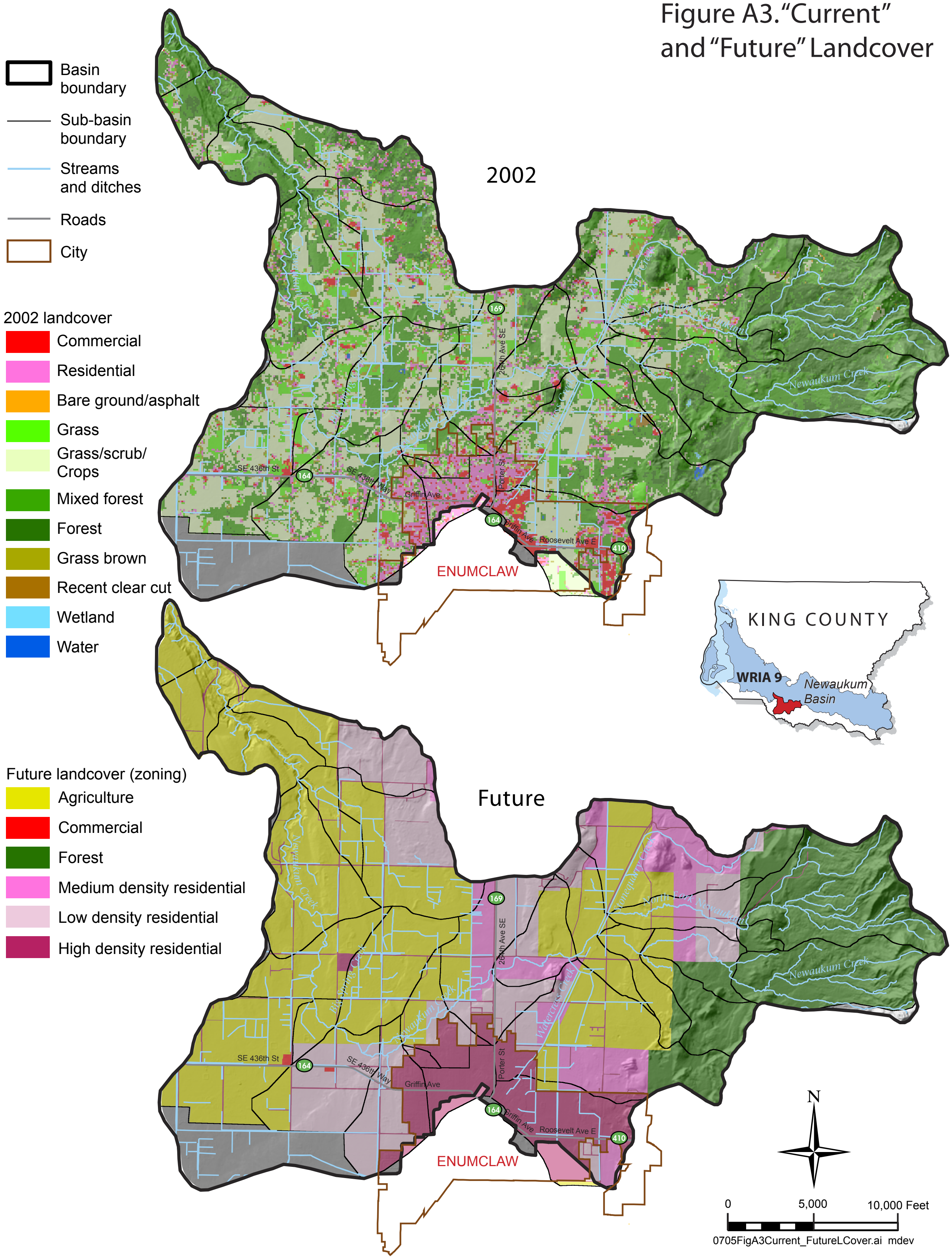
Figure A1. Surficial Geology for Hydrological Analyses

Newaukum Creek Basin

Figure A2. Slope Distributions



Newaukum Creek Basin
Figure A3. "Current" and "Future" Landcover



APPENDIX B. HISTORICAL PHOTO COMPARISONS

This section includes 10 matched pairs of sites that illustrate important changes in channel position and riparian conditions from 1936 to 2005 in Newaukum Creek. Most either depict stream reaches in the Ravine, where the channel exhibits the most lateral instability, or depict confluences between major tributaries and the Newaukum Creek mainstem. Channel positions in both 1936 and 2005 are shown in each image, as well as the current road network (for reference). The only difference between photos is the left image uses orthocorrected airphotos from 1936 as the backdrop whereas 2005 conditions are shown in the right panel.

Figure B1. Mouth of Newaukum Creek near 358th St. SE.

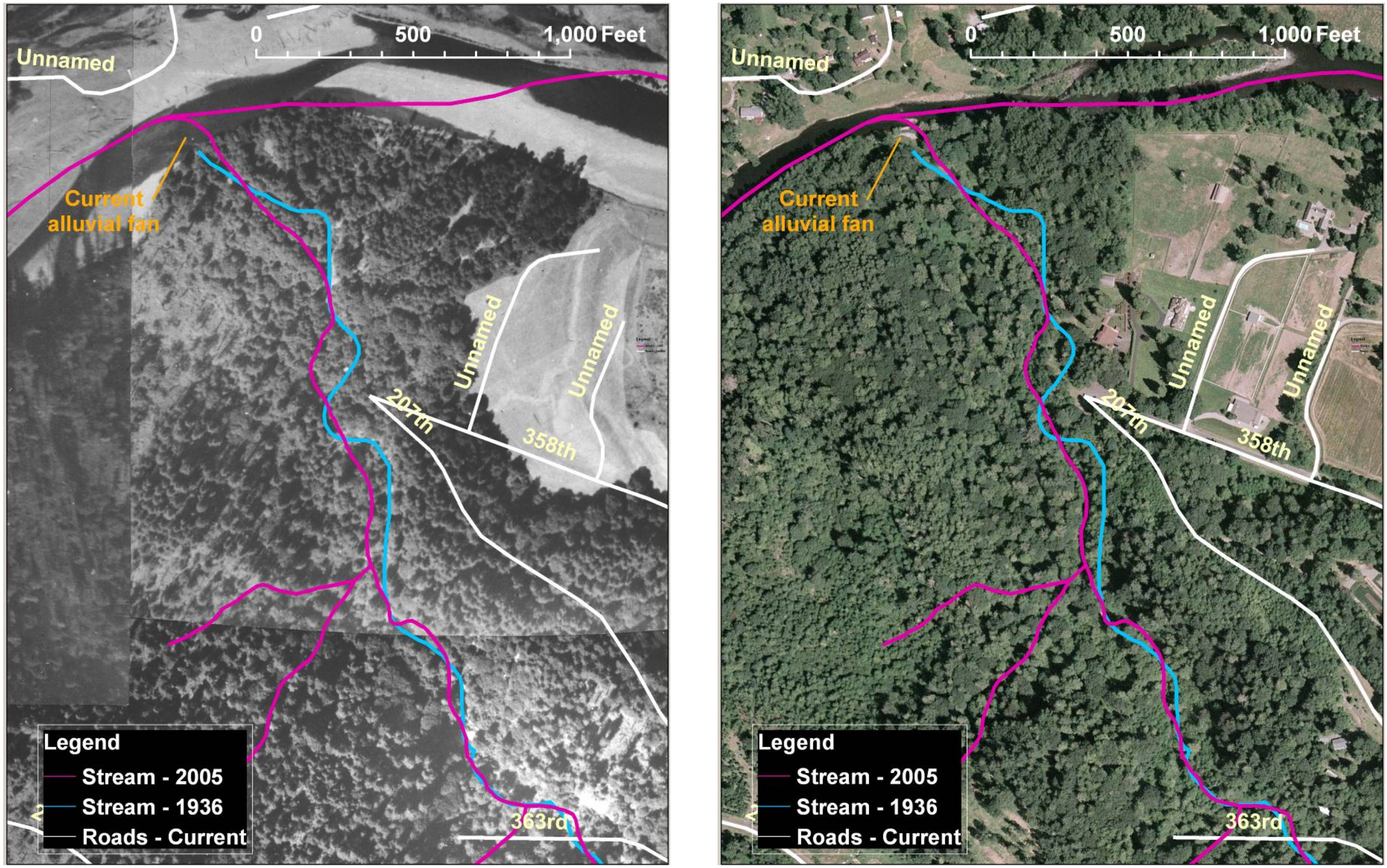


Figure B2. Newaukum Creek near the Whitney Bridge on 212th St. SE.

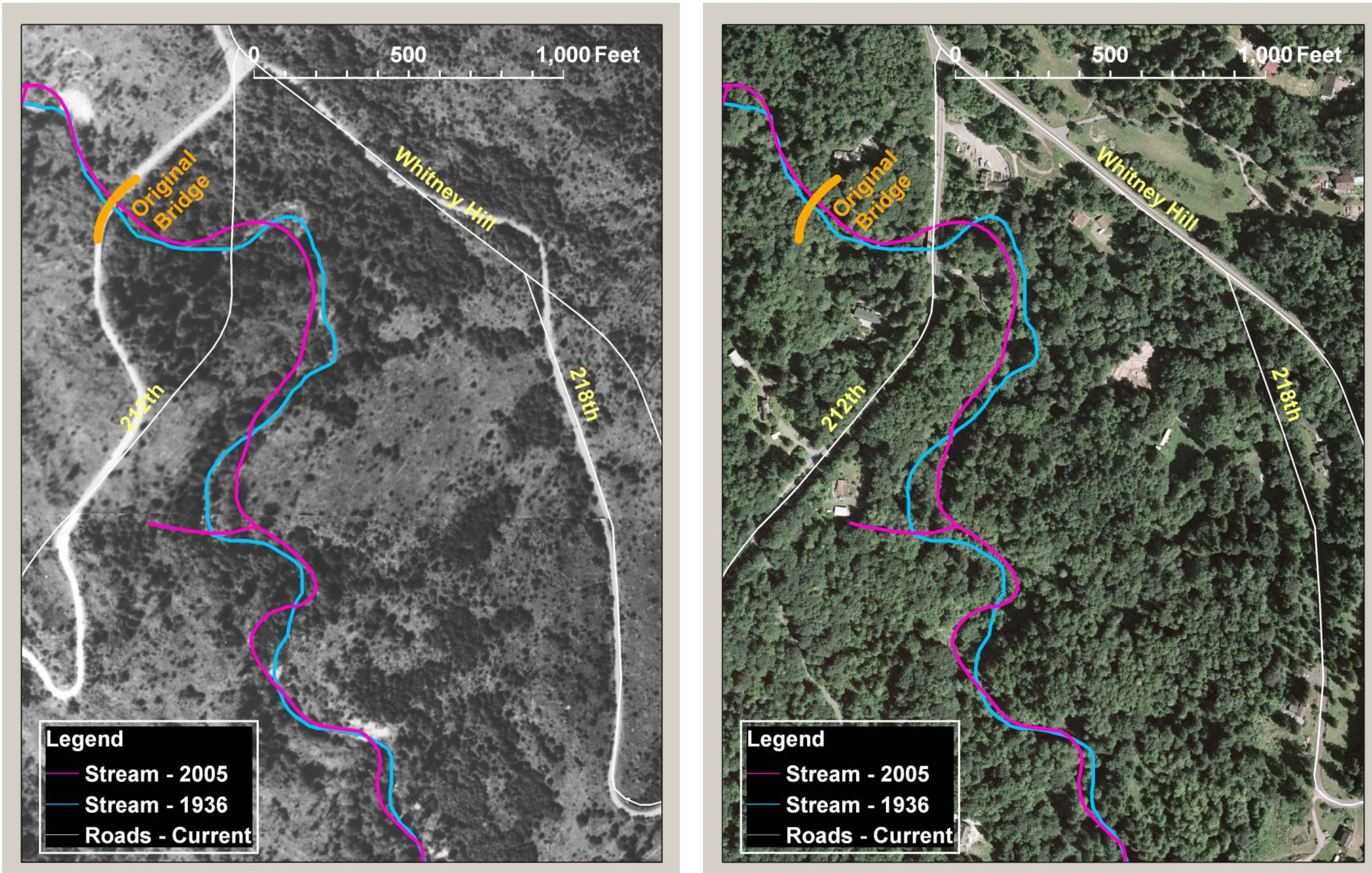


Figure B3. Comparison of Newaukum Creek in 1936 (left) and 2005 (right) near 380th St. SE.

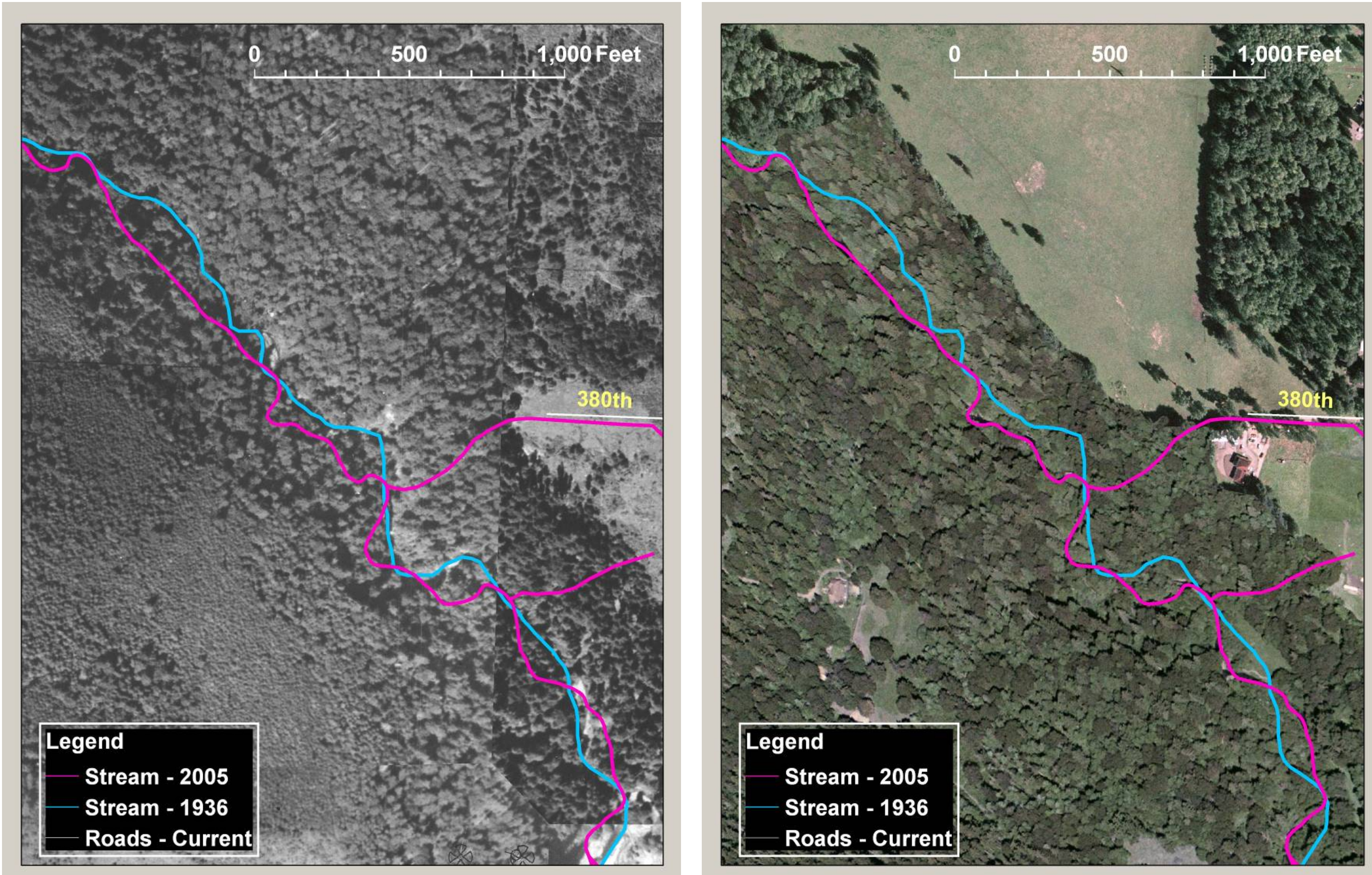


Figure B4. Newaukum Creek near 384th St. SE.

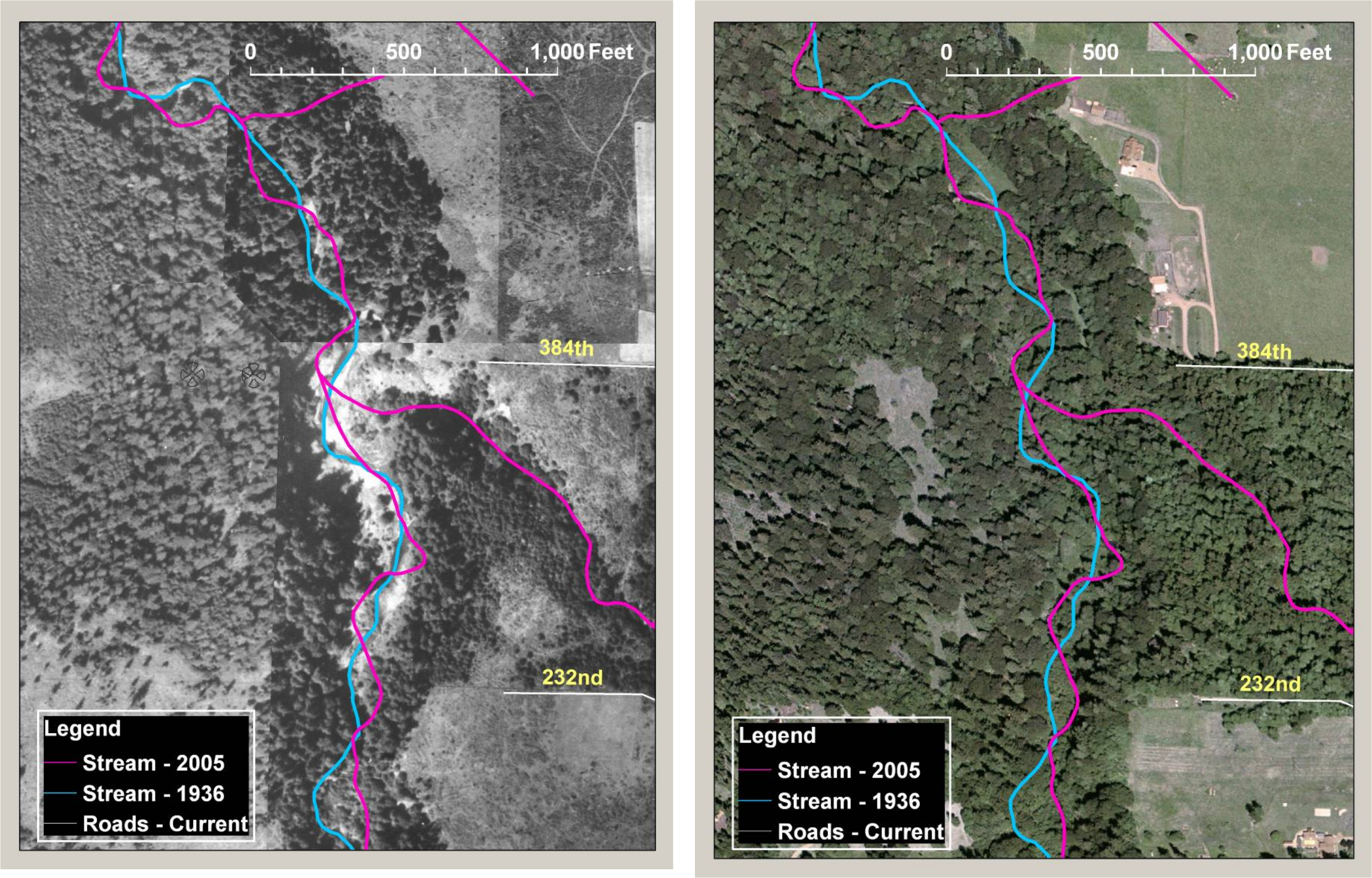


Figure B5. Newaukum Creek at the 400th St. SE crossing.

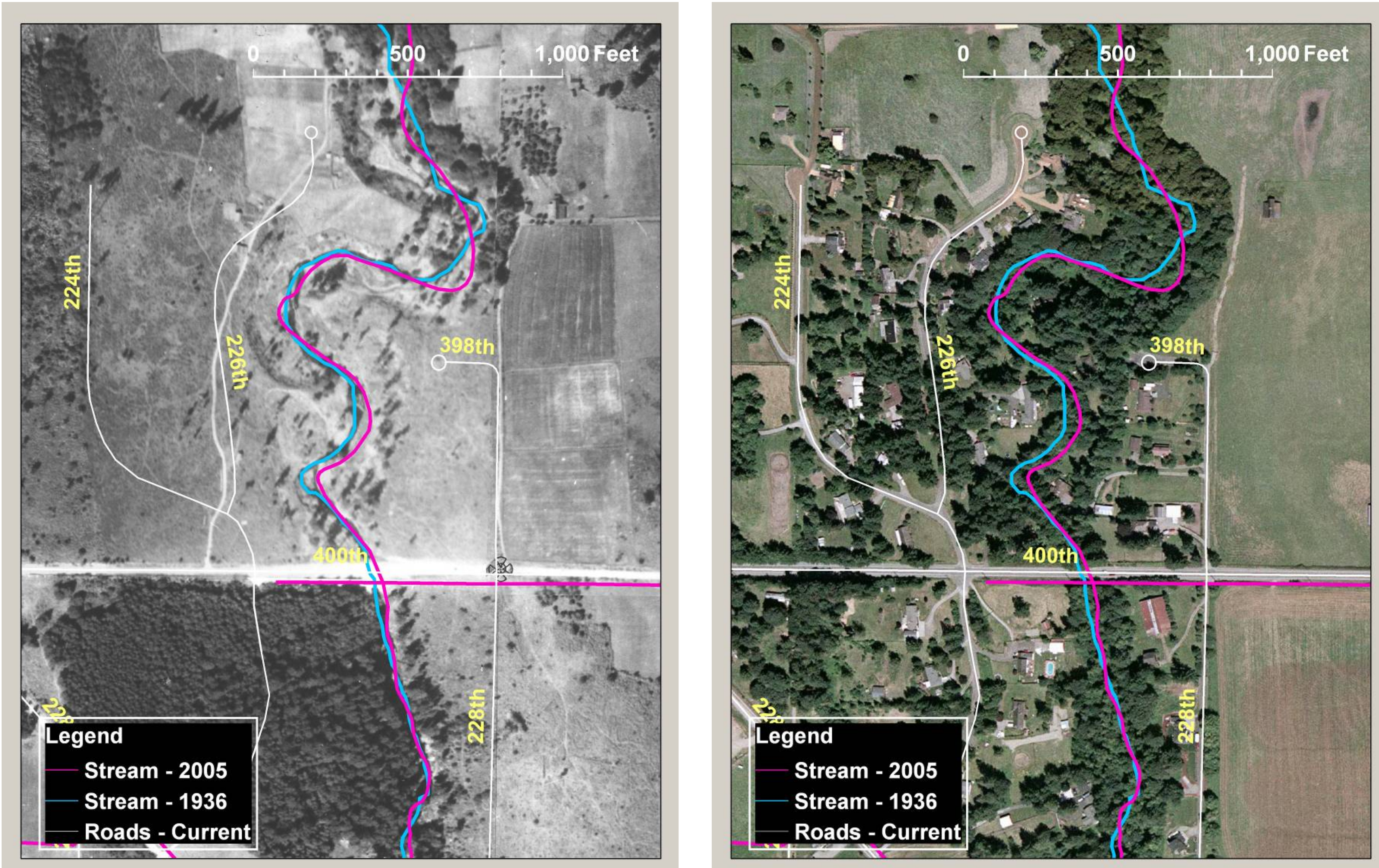
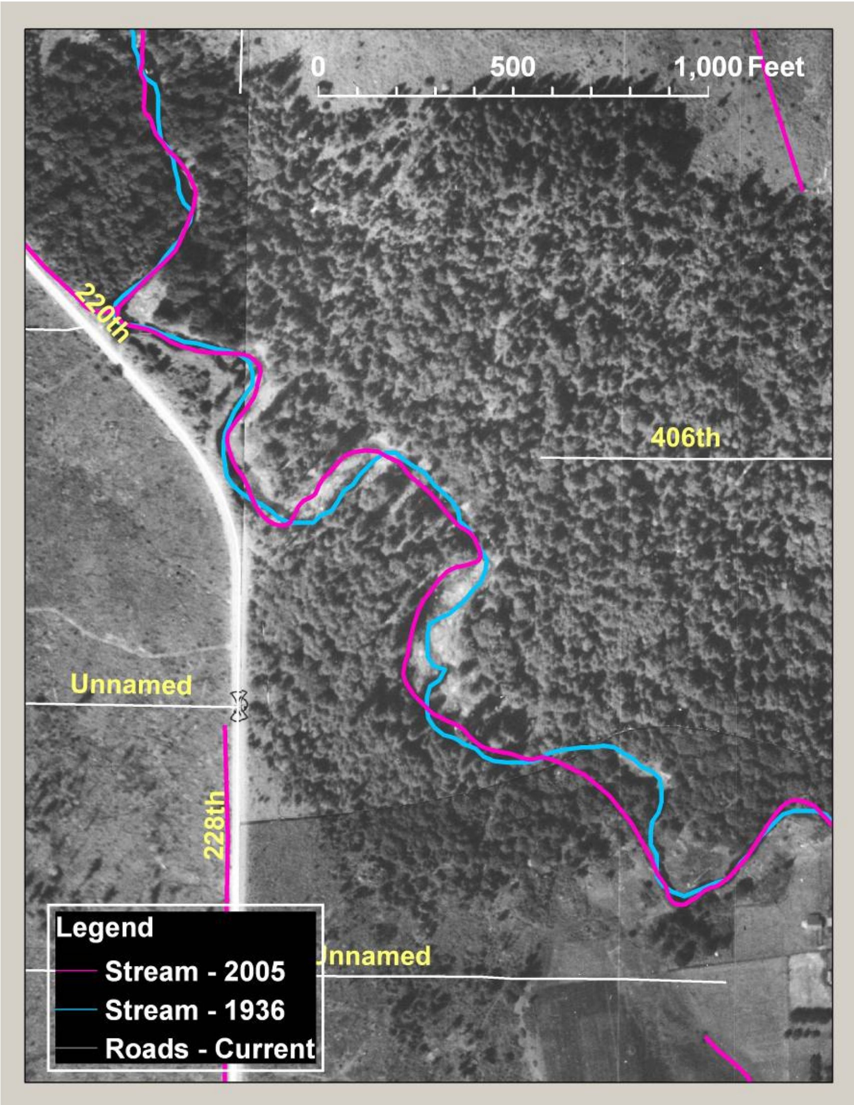


Figure B6. Newaukum Creek near 228th and 406th St. SE.



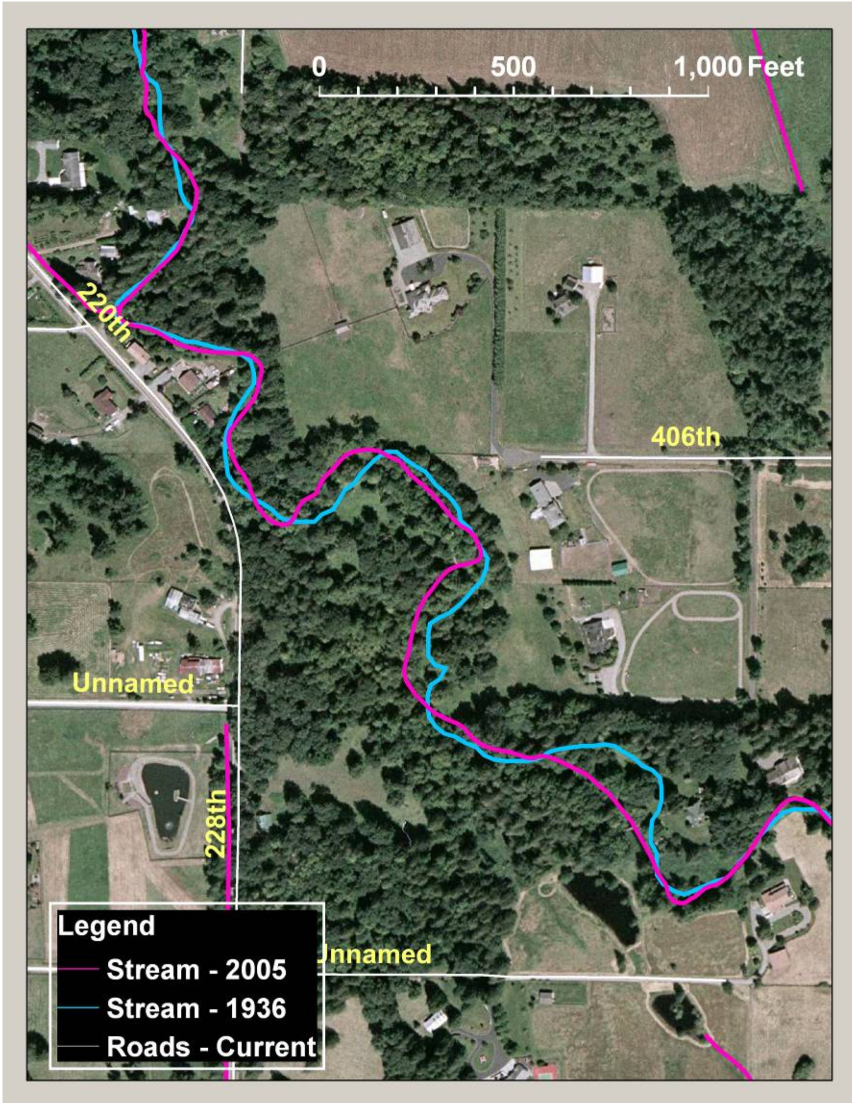


Figure B7. Newaukum Creek at the 424th St. SE crossing.

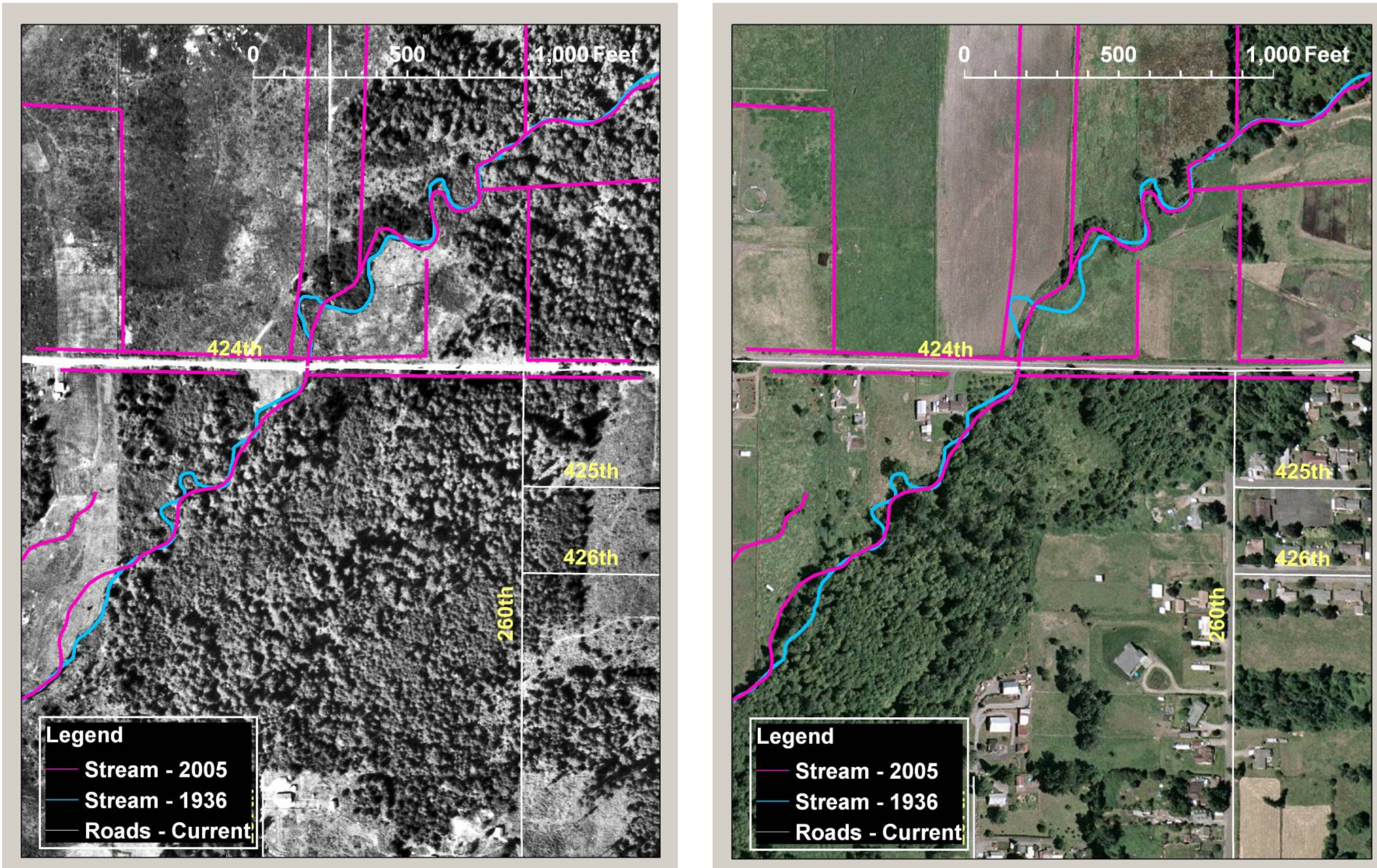


Figure B8. Confluence of Big Spring Creek and Newaukum Creek mainstem.

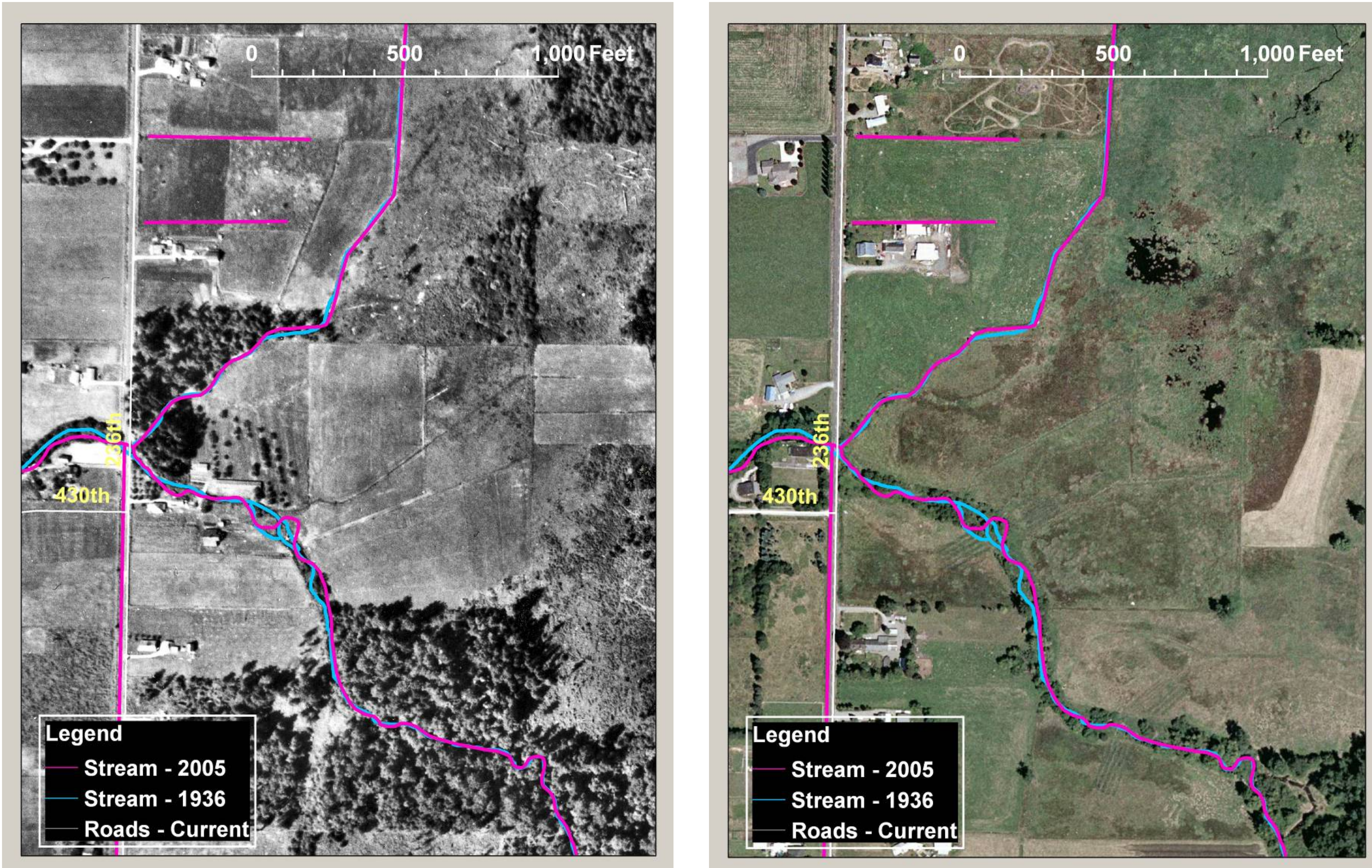


Figure B9. Confluence of Stonequarry Creek, North Fork Newaukum Creek mainstem, and the Newaukum Creek mainstem, near Veazie- Cumberland Road.

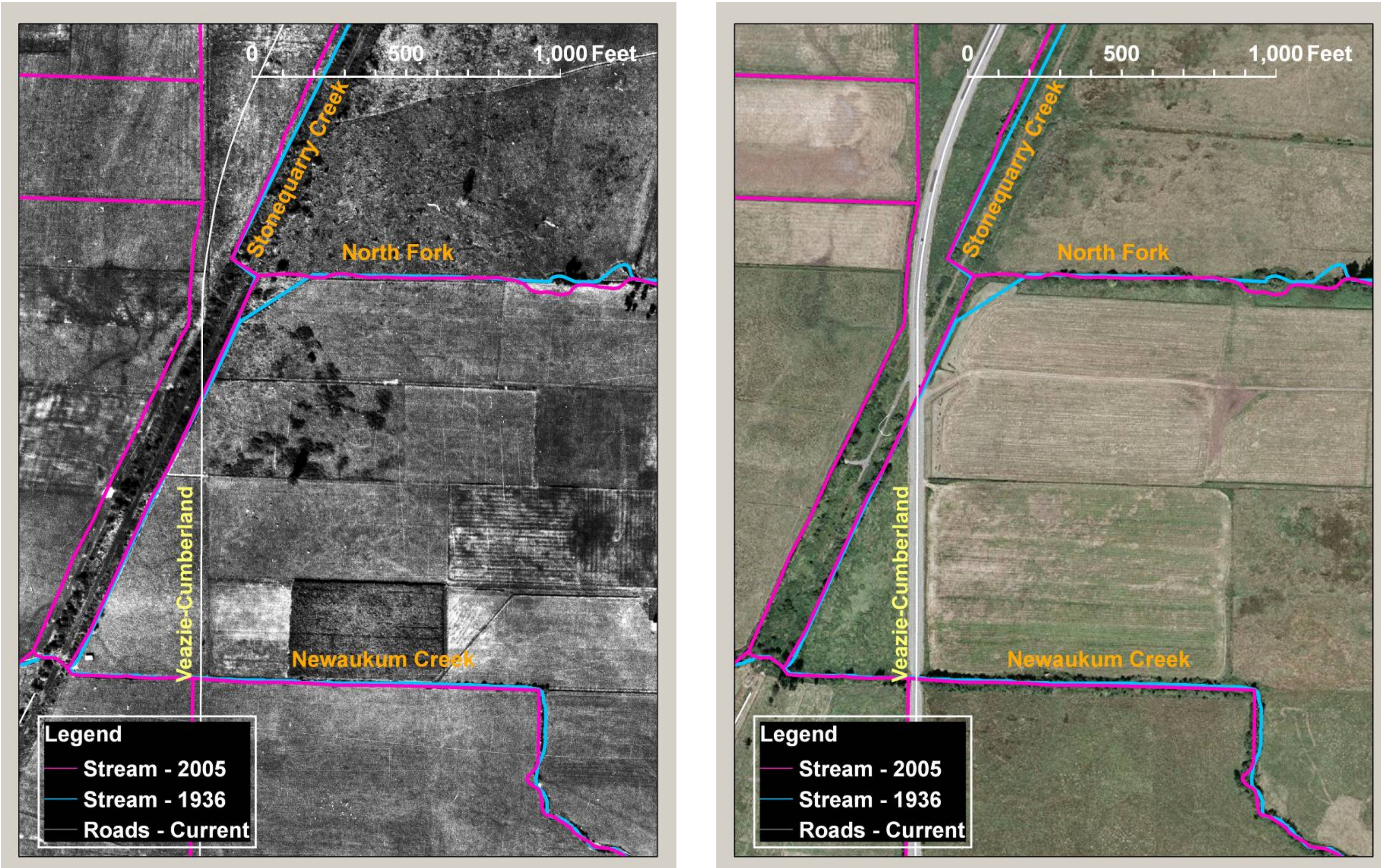
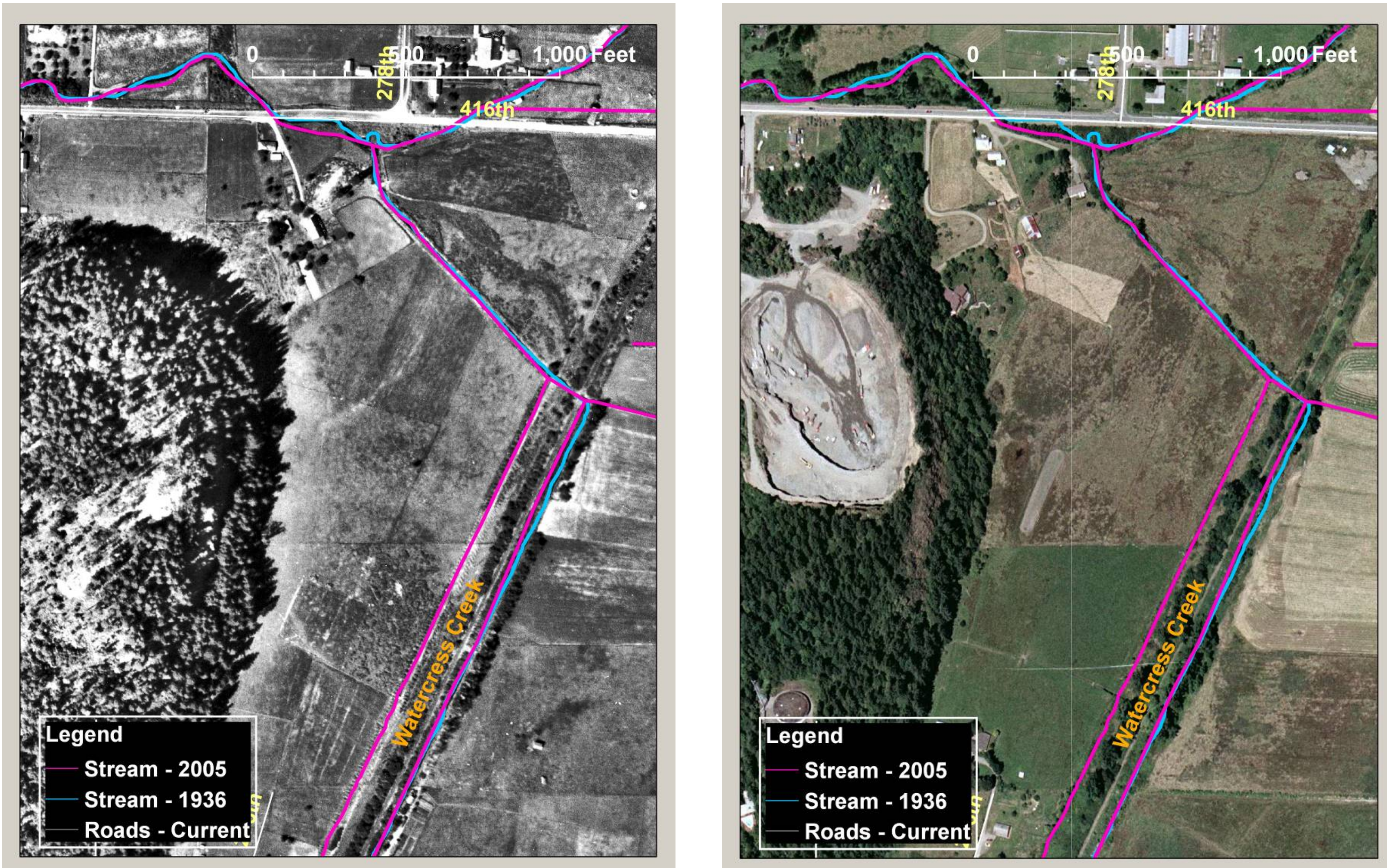


Figure B10. Confluence of Watercress Creek and Newaukum Creek mainstem.



APPENDIX C. WATER QUALITY MODELING

Table C1. Mean Simulated vs. Observed Concentrations on Sample Dates

Constituent	Newaukum Creek at Outlet - Station 0322			Newaukum Creek at Station F322			Newaukum Creek at Station AE322			Newaukum Creek at Station H322			Newaukum Creek at Station D322 (Agricultural)			Newaukum Creek at Station I322B (Residential)			Newaukum Creek at Station S322 (Forest)		
	Sim.	Obs.	Mean Daily Ratio *	Sim.	Obs.	Mean Daily Ratio *	Sim.	Obs.	Mean Daily Ratio *	Sim.	Obs.	Mean Daily Ratio *	Sim.	Obs.	Mean Daily Ratio *	Sim.	Obs.	Mean Daily Ratio *	Sim.	Obs.	Mean Daily Ratio *
Water Temperature (C)	9.26	9.43	1.04 (225)	9.22	9.18	1.05 (136)	8.81	8.78	0.98 (31)	9.14	9.12	0.99 (80)	9.72	9.77	1.12 (106)	9.73	9.30	1.03 (14)			
Suspended Sediment	11.6	12.0	1.22 (236)	4.5	4.7	0.82 (134)	6.4	4.7	1.04 (31)	6.7	6.6	1.10 (82)	9.0	8.8	1.53 (115)	13.7	13.8	2.14 (14)	16.2	16.6	1.05 (20)
Dissolved Oxygen	11.4	11.3	1.01 (215)	10.6	10.6	1.01 (135)	10.9	10.9	1.01 (29)	10.8	10.4	1.05 (80)	9.6	9.6	1.04 (105)	10.8	10.4	1.06 (14)			
Nitrate-Nitrite as N	2.04	2.03	1.02 (236)	2.00	1.83	1.11 (134)	1.69	1.63	1.04 (31)	1.64	1.46	1.14 (82)	2.43	4.08	0.70 (120)	2.20	2.17	1.15 (27)	0.84	0.88	1.75 (22)
Ammonia as N	0.053	0.053	1.59 (78)	0.031	0.073	1.05 (40)	0.035	0.046	1.22 (22)	0.029	0.044	1.16 (34)	0.054	0.046	1.22 (38)	0.023	0.027	1.06 (22)	0.017	0.017	1.08 (13)
Total Nitrogen	2.66	2.58	1.14 (182)	2.37	2.28	1.07 (81)	2.21	1.99	1.11 (31)	2.12	1.75	1.23 (31)	2.94	5.87	0.69 (67)	2.50	2.51	1.05 (27)	1.21	1.11	1.40 (22)
Orthophosphate as P	0.093	0.097	1.13 (101)	0.084	0.072	1.48 (53)	0.095	0.042	2.69 (31)	0.085	0.050	1.96 (36)	0.136	0.106	1.54 (39)	0.028	0.024	1.21 (27)	0.023	0.019	1.29 (22)
Total Phosphorus	0.135	0.157	1.03 (236)	0.111	0.127	1.24 (136)	0.144	0.073	2.33 (31)	0.118	0.096	1.82 (82)	0.132	0.197	0.94 (122)	0.056	0.055	1.13 (27)	0.058	0.037	1.52 (22)
Alkalinity as $CaCO_3$	46.7	47.3	0.99 (117)	48.8	47.8	1.01 (17)							50.0	53.9	0.98 (35)	35.0	28.0	1.69 (27)	37.0	39.5	0.96 (23)
pH	7.62	7.61	1.00(193)	7.24	7.31	0.99(40)	7.24	7.28	1.00(24)	7.37	7.34	1.01(23)	6.77	7.21	0.94 (17)	6.99	7.19	0.97(14)			
EColi (CFUs/100 ml)	1531	1540	8.03 (97)	722	1227	10.9 (45)	933	996	3.0 (29)	844	1139	6.3 (29)	1295	1333	1.8 (38)	754	977	1.7 (30)	103	100	2.1 (23)
Fec. Coli. (CFUs/100 ml)	1621	1688	6.1 (233)	974	1514	5.3 (130)	1110	1012	3.3 (30)	1288	1348	4.8 (78)	1084	1371	1.8 (120)	725	896	1.3 (30)	116	110	2.4 (19)
Copper (dissolved, ug/L)	2.77	2.11	1.41 (51)										1.13	2.62	0.47 (38)	2.41	2.40	1.00 (34)	0.84	0.70	1.12 (22)
Copper (total, ug/L)	4.02	3.98	1.10 (68)										2.46	3.34	0.61 (38)	3.57	3.55	1.05 (34)	1.35	1.36	0.86 (21)
Organic Carbon	7.86	8.54	0.97 (42)										11.3	10.3	1.10 (34)	6.13	6.07	1.07 (24)	7.43	6.47	0.99 (23)

APPENDIX D. LANDCOVER FOR WILDLIFE AND FOREST CHARACTERIZATION

Field reconnaissance was conducted to verify and update the mapped vegetative communities. Upland forest stands, wetlands, and stream riparian zones at road crossings were viewed; each of these habitat types will be discussed in this section. Field visits were conducted by an ecologist (J. Vanderhoof) and a basin steward (J. Kahan) in November and December, 2006, and January 2007. Because roads are present uniformly throughout most of the plateau, which is predominantly flat and in agriculture, driving the roads allows one to easily visually assess the aforementioned habitat types, albeit not at the micro-habitat scale. Access was also granted into the private forest land in the Forest Production District, and the forest environs were also primarily visually assessed from various points along the roads. Additionally, the FPD was viewed from the air during an helicopter flight. These methods of visual assessment were chosen as the most efficient manner to cover the greatest area in the ecosystem. High-resolution color aerial photos from 2005 were used to aid detection of habitat patches (i.e., forest stands; stream riparian zones; wetlands), and aerial imagery was also used to extrapolate vegetation community types in areas that were inaccessible.

A landcover spatial data file was built by hand in the County's Geographic Information System (GIS) using field information combined with color aerial photographs from 2005 and infrared images from 2002. Most water bodies and wetlands were ignored during the first polygon-building phase. A wetland shapefile was built separately, as described in greater depth below. The wetland layer was then "intersected" with the landcover layer to produce a new, separate wetland data shapefile that contained landcover information for each wetland polygon. Each wetland polygon was viewed individually using the color and infrared aerial images to assign wetland type. The new wetland shapefile with type information was then "unioned" back onto the original landcover data, and all polygons in the wetland shapefile superseded data in the original landcover file. The resulting shapefile represents one seamless landcover shapefile containing all landcover, including wetlands and other water bodies.

Field reconnaissance was used to create a new landcover map for the ecosystem (Figure D1) and determine the proportion of the ecosystem that each landcover comprises (Table D1).

Newaukum Creek Basin

Figure D1. Landcover for Wildlife and Forest Characterizations

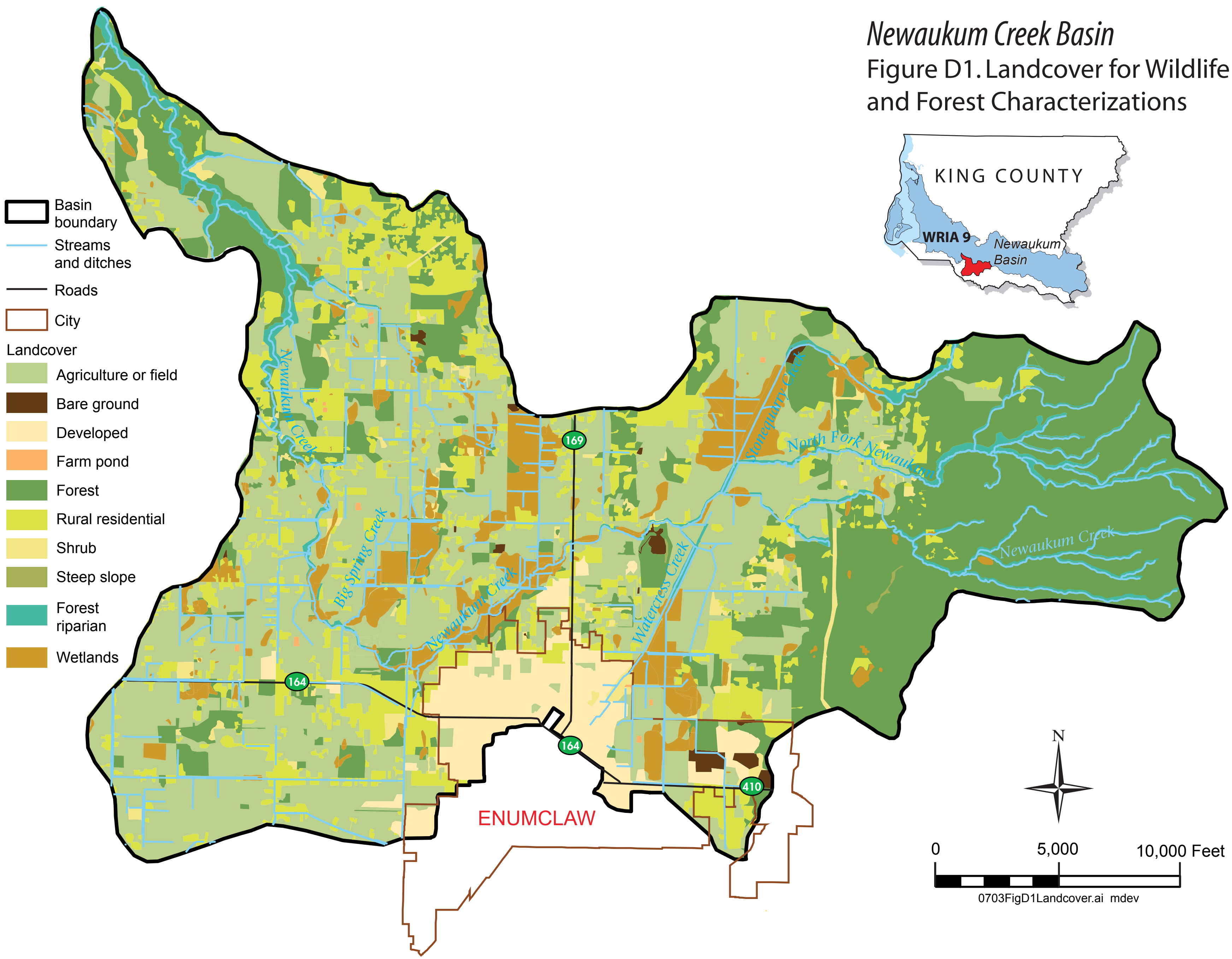


Table D1. Landcover in Newaukum Creek Basin.

Habitat Type	Description	Area in acres (% of basin)	Percent of basin area
Forest	Areas with forest cover of 50 percent or more. Vegetation structure characterized by any size forest, ranging from seedlings to mature trees. Includes recent clear-cuts in Forest Production District.	5,202	30%
Shrub	Areas with shrub coverage (as viewed aerially) of more than 50 percent, and typical vegetation height of 20 feet or less.	273	1.6%)
Agriculture or Field	Habitat dominated by grasses, herbs, and forbs with less than 20 percent shrub or tree cover. May include large, mowed lawns and ball fields. Some impervious structures (e.g., outbuildings) may be present.	6,527	37.7 %
Stream/Riparian	Streams and their adjacent areas of influence. These areas typically demonstrate obvious vegetation differences, such as density or structure. However, approximations were made in forested areas where the transition to upland habitat was not easily identifiable. Often does *not* include channels created to drain fields.	554	3.2%
Wetland	Areas of ground saturation, the frequency of which determines soil development and plant communities present. These areas do *not* represent delineated wetland boundaries. Includes open water ponds that did not appear to be constructed.	1,408	8.1%
Developed	Constructed farm ponds.	13.4	0.1%
Rural Residential	Areas dominated by moderate-density residential (i.e., neighborhoods) and industrial/commercial (i.e., warehouses, business districts, industrial farm operations) land uses. Less than 10 percent natural vegetation is present. Large areas of impervious surface are present.	878	5.1%
Total	Areas dominated by single-family homes, ranches, estates, and farms. Landscape is a mix of impervious and non-impervious surfaces. May include native and non-native vegetation, lawns, driveways.	2383	13.8%

Table D2. Landcover in the Newaukum Creek basin as mapped by Washington Gap Analysis.

Acres (Hectares)	Ecoregion* and Vegetation Zone**	Primary Cover***		Secondary Cover		Tertiary Cover	
602 (244)		50%-75%	Developed; mid-density; mostly residential	25%-50%	Developed; mid-density; mostly business		
430 (174)		75%-95%	Developed; low-density; mostly residential	5%-25%	Conifer forest; seral stage unknown or mixed; closure patchy or mixed; usually Douglas-fir	1%-5%	Lakes; including shoreline and possible marshy edges
10777 (4361)	Puget Sound region, Puget Sound Douglas-fir zone	75%-95%	Agriculture; non-irrigated, crop type unknown, often extensive in large, wide floodplains	5%-25%	Mixed forest; early seral; closed; usually Red Alder/Douglas-fir.		
384 (155)		50%-75%	Agriculture; non-irrigated, crop type unknown, often extensive in large, wide floodplains	25%-50%	Hardwood forest; seral stage unknown; closure patchy or mixed; usually either riparian forests or oak woodlands		
667 (270)		75%-95%	Mixed forest; seral stage unknown; closure patchy or mixed; usually Red Alder/Douglas-fir/shrubs	5%-25%	Hardwood forest; seral stage unknown; closure patchy or mixed; usually either riparian forests or oak woodlands		
4439 (1796)	Southwest Cascades region, Western Hemlock zone	50%-75%	Mixed forest; early seral; closed; usually Red Alder/Douglas-fir	5%-25%	Non-forested; logged	5%-25%	Conifer forest; early seral; closed; usually Douglas-fir

*Ecoregion (“region”) in this instance was defined by WAGAP as a contiguous geographic area of similar climate and geologic history (e.g., the Northwest Cascades region).

**A vegetation zone was defined as an area in which moisture, temperature, elevation, and other environmental parameters combine to create conditions that favor similar vegetation communities.

***Primary, secondary, and tertiary covers were each assigned one of six occupancy classes indicating the proportion of the polygon occupied by each.

APPENDIX E. WILDLIFE LISTS

Table E1. Possible (PO), probable (PR), and confirmed (CO) bird species, by quadrant, in the Newaukum Creek basin. Note that the Block Number is listed at the bottom of the table (Opperman et al. 2006). An atlas block is one quarter of a township/range and consists of a square three miles on a side, or nine square miles in area.

Township - Range - Quadrant	**21N 6E SW**	**20N 6E NW**	**20N 6E SW**	**26N 6E NE**	**21N 6E SE**	**20N 6E NE**	**20N 6E SE**	**20N 7E NW**	**20N 7E SW**	**20N 7E NE**
Breeding Bird Atlas Block Name	Metzler-O'Grady Park	Wabash	Southeast 456th Way	Duvall	Flaming Geyser	Krain	Enumclaw	Veazie	Mill Pond	Enumclaw Mountain
Canada Goose		CO		PR		CO				
Wood Duck	CO				CO		CO			
Mallard	CO	CO	PR	PR	CO	CO	CO	PO	PR	
Blue-winged Teal						PR				
Cinnamon Teal				PO		PR				
Hooded Merganser	CO									
Common Merganser	CO				PO					
Ring-necked Pheasant	PO	PO			PO				PO	
Ruffed Grouse					CO					
California Quail	PO	PR	PR			PO	PO	PO	PO	
Pied-billed Grebe	CO									
American Bittern				CO		PR				
Great Blue Heron	CO	PO			PO			PO		
Green Heron	CO									
Turkey Vulture	PO		PO	PO			PO		PO	PO
Osprey	CO		PO	CO	CO					

Township - Range - Quadrant	21N 6E SW	20N 6E NW	20N 6E SW	26N 6E NE	21N 6E SE	20N 6E NE	20N 6E SE	20N 7E NW	20N 7E SW	20N 7E NE
Breeding Bird Atlas Block Name	Metzler-O'Grady Park	Wabash	Southeast 456th Way	Duvall	Flaming Geyser	Krain	Enumclaw	Veazie	Mill Pond	Enumclaw Mountain
Bald Eagle						CO				
Northern Harrier									PO	
Sharp-shinned Hawk	PO									
Cooper's Hawk	PO	PO					PO			
Red-tailed Hawk	CO	CO	CO	PR	CO	PR	PR	CO	PO	PR
American Kestrel	PO	PO					PO	PO		
Virginia Rail					PO					
Sora						PR				
Killdeer	PO	CO	CO	PO	PO	CO	PO	PO	PO	
Spotted Sandpiper	CO			PO	CO					
Wilson's Snipe		PR	PR	PO		PR				
Rock Pigeon	PO	CO	CO	PO		CO	PR	CO	PO	
Band-tailed Pigeon	PO			PO					PO	PR
Mourning Dove	PO		PO				PR	PR	PO	
Barn Owl	PR						PR	PO		
Western Screech-Owl	PO									
Great Horned Owl	PR				PO			PO		
Northern Saw-whet Owl	PR									
Common Nighthawk	PO				PO					

Township - Range - Quadrant	21N 6E SW	20N 6E NW	20N 6E SW	26N 6E NE	21N 6E SE	20N 6E NE	20N 6E SE	20N 7E NW	20N 7E SW	20N 7E NE
Breeding Bird Atlas Block Name	Metzler-O'Grady Park	Wabash	Southeast 456th Way	Duvall	Flaming Geyser	Krain	Enumclaw	Veazie	Mill Pond	Enumclaw Mountain
Vaux's Swift	PO				PO	PR	CO		PO	
Rufous Hummingbird	PO	PO	PR	PO	PO	PO	PO	CO	PO	PO
Belted Kingfisher	CO			CO	CO					
Red-breasted Sapsucker	CO	PO		PO	CO	PO	PO		PO	
Downy Woodpecker	CO	CO	PR	PO	PR	PO	CO	PO		
Hairy Woodpecker	PR			PR	PO					PO
Northern Flicker	CO	PO	PO		PO				PO	PO
Pileated Woodpecker	PR				PR	PO				
Olive-sided Flycatcher				PO	PR				PO	PO
Western Wood-Pewee	PR	PR	PR	PO	PR	PR	PO	PR	PO	
Willow Flycatcher	CO	CO	PR	PR	PR	PO	PR	PR	PR	PO
Hammond's Flycatcher	PO								PO	PO
Dusky Flycatcher									PO	
Pacific-slope Flycatcher	PR		PR	PR	PR	CO	PR	PR	PR	PR
Cassin's Vireo						PO	PO	PO	PO	
Hutton's Vireo									PO	PO
Warbling Vireo	PR			PO	PO		PO	PO	PO	PR
Red-eyed Vireo	CO			PO	PR		PO		PO	
Steller's Jay	CO		PR	PO	PO	PO	PO	PO	PO	PR

Township - Range - Quadrant	**21N 6E SW**	**20N 6E NW**	**20N 6E SW**	**26N 6E NE**	**21N 6E SE**	**20N 6E NE**	**20N 6E SE**	**20N 7E NW**	**20N 7E SW**	**20N 7E NE**
Breeding Bird Atlas Block Name	Metzler-O'Grady Park	Wabash	Southeast 456th Way	Duvall	Flaming Geyser	Krain	Enumclaw	Veazie	Mill Pond	Enumclaw Mountain
Western Scrub-Jay						PR	CO			
American Crow	CO	CO	CO	PO	CO	CO	CO	CO	PO	
Common Raven									PO	PO
Tree Swallow	CO	CO	CO	CO	PO	PR		CO	PO	
Violet-green Swallow	CO	CO	CO	PR	CO	CO	PR	CO	PO	
Northern Rough-winged Swallow	CO			PO	PO	PO			PO	
Cliff Swallow	CO	CO	CO	CO	CO	CO	CO	CO	PO	
Barn Swallow	CO	CO	CO	CO	CO	CO	CO	CO	PR	
Black-capped Chickadee	CO	PO	PO	PO	PO	CO	PO	CO	CO	PO
Chestnut-backed Chickadee	CO		PO	PR	CO	CO	CO	CO		PO
Bushtit	PR	CO	CO	PO	PO	CO	CO	CO		
Red-breasted Nuthatch	PO	PO	PO		PR	PO	PO	PO	PO	PO
Brown Creeper	PR				PO					
Bewick's Wren	PR	CO	PO	PO	PR	PR	PO	CO	PO	PO
Winter Wren	PR	PO		PO	PR	PR	PO	PR	PO	PR
Marsh Wren	CO	PR		PO	PR	PR				
Golden-crowned Kinglet	PO	PO	PO	PO		CO			PO	PO
Western Bluebrid			PO							
Swainson's Thrush	CO	PR		PR	PR	PR	PR	PR	CO	PR

Township - Range - Quadrant	21N 6E SW	20N 6E NW	20N 6E SW	26N 6E NE	21N 6E SE	20N 6E NE	20N 6E SE	20N 7E NW	20N 7E SW	20N 7E NE
Breeding Bird Atlas Block Name	Metzler-O'Grady Park	Wabash	Southeast 456th Way	Duvall	Flaming Geyser	Krain	Enumclaw	Veazie	Mill Pond	Enumclaw Mountain
Hermit Thrush										
American Robin	CO	CO	CO	CO	CO	CO	CO	CO	CO	PO
Varied Thrush										PR
European Starling	CO	CO	CO	CO	CO	CO	CO	CO	CO	
Cedar Waxwing	CO	CO	CO	PR	CO	CO	PO	CO	PR	PR
Orange-crowned Warbler	PR	PO	PO	PO	PR	PR		PR	PR	PO
Yellow Warbler	PO	PR		PO		PR		PR		
Yellow-rumped Warbler										PO
Black-throated Gray Warbler	PO		CO		CO	CO	PO		PO	PR
Townsend's Warbler										PR
MacGillivray's Warbler		PO				PR		PR	PO	PO
Common Yellowthroat	PR	CO	PR	PR	CO	CO	PR	CO	PR	PO
Wilson's Warbler	CO	PO	PR	PR	PR	PR	PO	CO	PO	PR
Western Tanager	PR		PR	PO	CO	PO	PO		PO	PO
Spotted Towhee	CO	PR	CO	PR	PO	CO	PR	CO	PR	PO
Savannah Sparrow	CO	CO	CO	PR	CO	CO	PR	CO	PO	
Song Sparrow	CO	CO	CO	PR	CO	CO	PR	CO	PR	PR
White-crowned Sparrow	CO	CO	CO		CO	PR	PO	CO	CO	CO
Dark-eyed Junco	CO	CO	PR	PO	PR			CO	PO	PO

Township - Range - Quadrant	**21N 6E SW**	**20N 6E NW**	**20N 6E SW**	**26N 6E NE**	**21N 6E SE**	**20N 6E NE**	**20N 6E SE**	**20N 7E NW**	**20N 7E SW**	**20N 7E NE**
Breeding Bird Atlas Block Name	Metzler-O'Grady Park	Wabash	Southeast 456th Way	Duvall	Flaming Geyser	Krain	Enumclaw	Veazie	Mill Pond	Enumclaw Mountain
Black-headed Grosbeak	PR	CO		PR	CO	CO	PO	CO	PO	PO
Lazuli Bunting	PR	PR				PR	PR	PR		
Red-winged Blackbird	PR	CO	CO	PR	CO	CO	PO	PR	PR	
Western Meadowlark			PO							
Brewer's Blackbird	CO	CO	PR	CO	PO	CO	CO	CO	CO	
Brown-headed Cowbird	CO	PR	PR	PO	CO		PO	PR	PO	
Bullock's Oriole	CO	PR	PO	PO						
Purple Finch	CO	CO			CO		PO	PO	PO	PO
House Finch	CO	CO	CO	CO	CO	CO	PO	PR	PR	
Red Crossbill		PR		PO	PO	PO		PO		PR
Pine Siskin	PR	CO	PR		PR	PO		CO		
American Goldfinch	CO	CO	CO	PO	PR	CO	PR	PR	PO	PO
Evening Grosbeak					PO	PO		PO		
House Sparrow	CO	CO	CO	PO	CO	CO	PR	CO	CO	
Breeding Bird Atlas Block #	*KG82*	*KG83*	*KG84*	*KG85*	*KG96*	*KG97*	*KG98*	*KG111*	*KG112*	*KG126*

Table E2. Birds potentially inhabiting Newaukum Creek basin.

Common Name	**Scientific Name**
American Bittern	*Botaurus lentiginosus*
American Coot*	*Fulica americana*
American Dipper*	*Cinclus mexicanus*
American Goldfinch	*Carduelis tristis*
American Kestrel	*Falco sparverius*
American Robin	*Turdus migratorius*
American/Northwestern Crow	*Corvus brachyrhynchos/cau*
Bald Eagle	*Haliaeetus leucocephalus*
Band-tailed Pigeon	*Columba fasciata*
Barn Owl	*Tyto alba*
Barn Swallow	*Hirundo rustica*
Barred Owl*	*Strix varia*
Belted Kingfisher	*Ceryle alcyon*
Bewick`s Wren	*Thryomanes bewickii*
Black Swift*	*Cypseloides niger*
Black-capped Chickadee	*Parus atricapillus*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Black-throated Gray Warbler	*Dendroica nigrescens*
Blue Grouse*	*Dendragapus obscurus****
Blue-winged Teal**	*Anas discors*
Brewer`s Blackbird	*Euphagus cyanocephalus*
Brown Creeper	*Certhia americana*
Brown-headed Cowbird	*Molothrus ater*
Bullock`s Oriole	*Icterus bullockii*
Bushtit	*Psaltriparus minimus*
California Quail	*Callipepla californica*
Canada Goose	*Branta canadensis*
Cedar Waxwing	*Bombycilla cedrorum*
Chestnut-backed Chickadee**	*Poecile rufescens*
Cinnamon Teal	*Anas cyanoptera*
Cliff Swallow	*Hirundo pyrrhonota*
Common Merganser	*Mergus merganser*
Common Nighthawk	*Chordeiles minor*
Common Raven	*Corvus corax*
Common Snipe	*Gallinago gallinago*
Common Yellowthroat	*Geothlypis trichas*
Cooper`s Hawk	*Accipiter cooperii*
Dark-eyed Junco	*Junco hyemalis*
Downy Woodpecker	*Picoides pubescens*
Dusky Flycatcher**	*Empidonax oberholseri*
European Starling	*Sturnus vulgaris*
Evening Grosbeak	*Coccothraustes vespertinu*
Fox Sparrow*	*Passerella iliaca*
Gadwall*	*Anas strepera*
Golden-crowned Kinglet	*Regulus satrapa*
Great Blue Heron	*Ardea herodias*
Great Horned Owl	*Bubo virginianus*
Green Heron	*Butorides virescens*
Hairy Woodpecker	*Picoides villosus*
Hammond`s Flycatcher	*Empidonax hammondii*
Harlequin Duck*	*Histrionicus histrionicus*
Hermit Thrush	*Catharus guttatus*

Common Name	Scientific Name
Hooded Merganser	*Lophodytes cucullatus*
House Finch	*Carpodacus mexicanus*
House Sparrow	*Passer domesticus*
House Wren*	*Troglodytes aedon*
Hutton`s Vireo	*Vireo huttoni*
Killdeer	*Charadrius vociferus*
Lazuli Bunting	*Passerina amoena*
MacGillivray`s Warbler	*Oporornis tolmiei*
Mallard	*Anas platyrhynchos*
Marsh Wren	*Cistothorus palustris*
Mourning Dove	*Zenaida macroura*
Northern Flicker	*Colaptes auratus*
Northern Harrier	*Circus cyaneus*
Northern Pygmy-Owl*	*Glaucidium gnoma*
Northern Rough-winged Swallow	*Stelgidopteryx serripenni*
Northern Saw-whet Owl	*Aegolius acadicus*
Northern Shoveler*	*Anas clypeata*
Olive-sided Flycatcher	*Contopus borealis*
Orange-crowned Warbler	*Vermivora celata*
Osprey	*Pandion haliaetus*
Pacific-slope/Cordilleran Flycatcher	*Empidonax difficilis/occi*
Pied-billed Grebe	*Podilymbus podiceps*
Pileated Woodpecker	*Dryocopus pileatus*
Pine Siskin**	*Carduelis pinus*
Purple Finch	*Carpodacus purpureus*

Common Name	Scientific Name
Red Crossbill	*Loxia curvirostra*
Red-breasted Nuthatch	*Sitta canadensis*
Red-breasted Sapsucker	*Sphyrapicus ruber*
Red-eyed Vireo	*Vireo olivaceus*
Red-tailed Hawk	*Buteo jamaicensis*
Red-winged Blackbird	*Agelaius phoeniceus*
Ring-necked Duck*	*Aythya collaris*
Ring-necked Pheasant	*Phasianus colchicus*
Rock Dove	*Columba livia*
Ruffed Grouse	*Bonasa umbellus*
Rufous Hummingbird	*Selasphorus rufus*
Savannah Sparrow	*Passerculus sandwichensis*
Sharp-shinned Hawk	*Accipiter striatus*
Solitary Vireo	*Vireo solitarius*
Song Sparrow	*Melospiza melodia*
Sora	*Porzana carolina*
Spotted Sandpiper	*Actitis macularia*
Spotted Towhee	*Pipilo maculatus*
Steller`s Jay	*Cyanocitta stelleri*
Swainson`s Thrush	*Catharus ustulatus*
Townsend`s Warbler	*Dendroica townsendi*
Tree Swallow	*Tachycineta bicolor*
Turkey Vulture	*Cathartes aura*
Varied Thrush	*Ixoreus naevius*
Vaux`s Swift	*Chaetura vauxi*
Violet-green Swallow	*Tachycineta thalassina*

Common Name	Scientific Name
Virginia Rail	*Rallus limicola*
Warbling Vireo	*Vireo gilvus*
Western Bluebird	*Sialia mexicana*
Western Meadowlark	*Sturnella neglecta*
Western Screech-Owl	*Otus kennicottii*
Western Scrub-Jay	*Aphelocoma californica*
Western Tanager	*Piranga ludoviciana*
Western Wood-Pewee	*Contopus sordidulus*
White-crowned Sparrow	*Zonotrichia leucophrys*
Willow Flycatcher	*Empidonax traillii*
Wilson`s Warbler	*Wilsonia pusilla*
Winter Wren	*Troglodytes troglodytes*
Wood Duck	*Aix sponsa*
Yellow Warbler	*Dendroica petechia*
Yellow-rumped Warbler	*Dendroica coronata*

* = GAP list only

** = BBA list only

*** = note, blue grouse was split into two species in 2006: the Dusky Grouse (*Dendragapus obscurus*) and the Sooty Grouse (*D. fuliginosus*).

Table E3. The 57 species of mammals expected to breed within Newaukum Creek Ecosystem, according to 1991 landcover data used by Washington Gap Analysis (WAGAP).

Common Name	Scientific Name
Mountain Beaver	*Aplodontia rufa*
Coyote	*Canis latrans*
Beaver	*Castor canadensis*
Elk	*Cervus elaphus*
Gapper`s Red-backed Vole	*Clethrionomys gapperi*
Virginia Opossum	*Didelphis virginiana*
Big Brown Bat	*Eptesicus fuscus*
Porcupine	*Erethizon dorsatum*
Mountain Lion (Cougar)	*Felis concolor*
Northern Flying Squirrel	*Glaucomys sabrinus*
Silver-haired Bat	*Lasionycteris noctivagans*
Hoary Bat	*Lasiurus cinereus*
River Otter	*Lutra canadensis*
Bobcat	*Lynx rufus*
Marten	*Martes americana*
Fisher	*Martes pennanti*
Striped Skunk	*Mephitis mephitis*
Long-tailed Vole	*Microtus longicaudus*
Creeping Vole	*Microtus oregoni*
Richardson`s Vole	*Microtus richardsoni*
Townsend`s Vole	*Microtus townsendii*
House Mouse	*Mus musculus*
Ermine	*Mustela erminea*
Long-tailed Weasel	*Mustela frenata*
Mink	*Mustela vison*
Nutria	*Myocastor coypus*
California Myotis	*Myotis californicus*
Long-eared Myotis	*Myotis evotis*
Little Brown Myotis	*Myotis lucifugus*
Long-legged Myotis	*Myotis volans*
Yuma Myotis	*Myotis yumanensis*
Bushy-tailed Woodrat	*Neotoma cinerea*
Shrew-mole	*Neurotrichus gibbsii*
Pika	*Ochotona princeps*
Mule Deer	*Odocoileus hemionus*
Muskrat	*Ondatra zibethicus*
Forest Deer Mouse	*Peromyscus keeni*
Deer Mouse	*Peromyscus maniculatus*
Heather Vole	*Phenacomys intermedius*
Townsend`s Big-eared Bat	*Plecotus townsendii*
Raccoon	*Procyon lotor*
Norway Rat	*Rattus norvegicus*
Black Rat	*Rattus rattus*
Coast Mole	*Scapanus orarius*
Townsend`s Mole	*Scapanus townsendii*
Bendire`s Shrew	*Sorex bendirii*
Masked Shrew	*Sorex cinereus*
Montane Shrew	*Sorex monticolus*
Water Shrew	*Sorex palustris*
Trowbridge`s Shrew	*Sorex trowbridgii*
Vagrant Shrew	*Sorex vagrans*
Spotted Skunk	*Spilogale gracilis*
Townsend`s Chipmunk	*Tamias townsendii*
Douglas` Squirrel	*Tamiasciurus douglasii*
Black Bear	*Ursus americanus*
Red Fox	*Vulpes vulpes*

Common Name	Scientific Name
Pacific Jumping Mouse	*Zapus trinotatus*

Table E4. Washington Gap Analysis (WAGAP) used 1991 landcover data to predict approximately 17 amphibians and reptiles that may be present in Newaukum Creek Basin.

Common Name	Scientific Name
American Bullfrog	*Rana catesbeiana*
Common Garter Snake	*Thamnophis sirtalis*
Ensatina	*Ensatina eschscholtzii*
Long-toed Salamander	*Ambystoma macrodactylum*
Northern Alligator Lizard	*Elgaria coerulea*
Northwestern Garter Snake	*Thamnophis ordinoides*
Northwestern Salamander	*Ambystoma gracile*
Pacific Giant Salamander	*Dicamptodon tenebrosus*
Pacific Treefrog	*Hyla regilla*
Painted Turtle	*Chrysemys picta*
Red-legged Frog	*Rana aurora*
Roughskin Newt	*Taricha granulosa*
Rubber Boa	*Charina bottae*
Slider	*Trachemys scripta*
Western Redback Salamander	*Plethodon vehiculum*
Western Terrestrial Garter Snake	*Thamnophis elegans*
Western Toad	*Bufo boreas*

Table E5. Non-native species introductions in Western Washington, including Newaukum Creek Ecosystem (adapted from Witmer and Lewis 2001).

Species	Date	Ecological Consequences
Rock Dove	ca 1940	Forage competition, Nest competition, disease/parasites
European Starling	1940s	Forage competition, Nest competition, disease/parasites
House Sparrow	1897 (King County)	Prey competition, Forage competition, Nest competition, disease/parasites
Virginia opossum	ca 1941	Predation, disease/parasites
Red Fox	1909	Predation, Prey competition, Species endangerment, Hybridization, disease/parasites
House cat	ca 1800	Predation, Prey competition, Species endangerment, disease/parasites
Domestic dog	ca 1800	Predation, Prey competition, Species endangerment, Hybridization, disease/parasites
Eastern gray squirrel	1925 (King County)	Plant damage, Plant regeneration, Forage competition, Nest competition, Aggressive behavior, disease/parasites
Fox squirrel	ca 1940	Plant damage, Plant regeneration, Forage competition, Nest competition, Aggressive behavior, disease/parasites
Nutria	1930s (King County)	Soil erosion, Water quality/quantity, plant damage, plant regeneration, possible forage competition, disease/parasites
Black Rat	1800s - 1850s	Nest predation, forage competition, possible plant damage, disease/parasites
Norway Rat		
American Bullfrog	1895 (PNW)	Prey competition, Predation, Species endangerment, harbor diseases of harm to native amphibians
Sunfish (Largemouth, Smallmouth & Rock Bass (1893)	1869 (PNW)	Prey competition, Predation, Species endangerment
Other Sunfish (Bluegill, Crappie, Pumpkinseed	1890 (Lower Columbia River)	Prey competition, Predation, Species endangerment
Yellow Perch	1890 (WA)	
Brook, Brown Cutthroat, Rainbow & other trout	Late 1800s	
Red-eared Slider Turtle	Unknown	Prey competition, Predation, Species endangerment through transfer of diseases
Common snapping turtle	1950s	

APPENDIX F

Final Preliminary Assessment Screening for Newaukum Creek Habitat Restoration

Prepared by

Veronica Henzi
EC-TB-ET

Seattle District
Army Corps of Engineers

May 5, 2006

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TABLES

APPENDICES

1 Introduction

Purpose: The purpose of this Preliminary Assessment Screening (PAS) is to determine whether past, present, or future activities indicate the presence or likely presence of hazardous, toxic, or radioactive waste (HTRW) at the Newaukum Creek habitat restoration project site. Per Engineer Regulation (ER) 1165-2-132, *Water Resource Policies and Authorities, Hazardous, Toxic, and Radioactive Waste (HTRW) Guidance for Civil Works Projects* (1992), HTRW is defined as a "hazardous substance" under the Comprehensive Environmental Response, Compensation and Liability Act, which in turn includes hazardous substances under the Resource Conservation and Recovery Act, the Clean Water Act, the Clean Air Act, and the Toxic Substance Control Act. The U.S. Army Corps of Engineers (USACE) must ensure that any HTRW issues are addressed before project construction begins. Findings and recommendations based on the results of this PAS are included in Section 8.

Scope of the PAS: The scope of this PAS included a literature search and review of environmental information on file with government, state, and county. The literature search included a review of historical aerial photographs, history books, and historical property ownership and use information. A project area inspection was not conducted at this time (with the Project Manager's approval) because the restoration project has not been formally announced and because no access to the project area is currently available (the project area is primarily residential).

2 Project Information

Project Name: Newaukum Creek Habitat Restoration

Project Goals: The primary purpose of this project is to restore process-based ecological functions of wetlands on the Enumclaw plateau. A secondary goal is to promote formation of in-stream habitat complexity in Newaukum Creek for salmonids. The existing channel has been heavily altered and degraded by development, logging, and farming, and consequently provides little to no functional value as fish habitat. The project is being conducted as part of the Duwamish/Green River Ecosystem Restoration Project authorized under Section 101 of the Water Resources Development Act of 2000.

Proposed Actions: The USACE and King County are proposing to restore wetland and stream habitat through the following actions:

- by planting native plants in the wetlands to increase functions/values of the wetlands and stream connections;
- by providing additional large woody debris (LWD) pieces to the mid-lower sections of the Newaukum Creek channel to encourage new logjams that will create additional pools, side channels, and juvenile salmonid refuge; and
- by reconnecting a historic side channel (Plemmons Meanders) to Newaukum Creek approximately 1300 feet upstream from the mouth of Newaukum Creek.

Project Location: Newaukum Creek (Water Resources Inventory Area (WRIA) 09.0014) is one of two major tributaries flowing into the middle reach of the Green River and is located in southeast King County, northwest of Enumclaw, Washington. Newaukum Creek passes through Township 21 North, Range 06 East, and Township 20 North, Range 06 East. The mainstem of Newaukum Creek is 14.3 river miles long, and can be divided into three distinct sections: the upper headwater 5-mile section; the middle 6-mile section that meanders through plateau farmland near Enumclaw, Washington; and the lower 3-mile section that descends through a steep-walled ravine from the plateau to the Green River at river mile 40. The project area will encompass the majority of the length of the creek, with a 100-foot buffer on either side of the creek. The adjacent project area has been defined as the immediate parcel area outside of the 100-foot buffer.

3 History of Land Ownership and Use

The history of land ownership and use of the project area and adjacent areas is discussed below to provide insight into past, present, or future contamination that may have the potential to affect the project area. Due to the size of the project area, nine maps showing property parcel numbers are included in Appendix A (the maps are numbered by Roman numeral I through IX).

Ownership and use information was obtained from the King County Assessor's database [KC, 2005], the King County property tax database [KCE, 2006], and aerial photographs (to help establish when development may have occurred) [Terraserver©, 2006]. Several attempts were made to contact someone at the Enumclaw Plateau Historical Society (1-360-825-4028) for historical use information, but calls were never returned (latest attempt 3/27/06). No relevant books describing historical industrial uses for the project area were identified by the USACE Librarian.

3.1 Project Area

The entire parcel list for the project area (i.e. properties through which Newaukum Creek flows) is included in Appendix B. The list provides the zoning of parcel (i.e., residential, agricultural, or commercial), the corresponding property map, and the tax payer. A review of the taxpayer list for the parcels indicates that the creek runs entirely through residential or agricultural properties. "Public" areas owned by the City of Enumclaw or King County are also zoned residential or agricultural. No commercial properties were identified, even though some limited liability companies exist. These companies appear to have been formed to manage certain parcels as open space. The residential, agricultural, and public properties are not expected to contain HTRW at levels that could contribute to project area contamination; however, environmental databases will still be reviewed (see Section 5.0) for project area properties to determine if any HTRW contamination has been identified in the project area.

3.2 Adjacent Areas

The areas adjacent to the project area are also predominantly residential, agricultural, or public. These adjacent areas are not expected to contain HTRW at levels that could contribute to project area contamination, and are not discussed further.

4 Photograph and Map Review

Photographs: A number of historical photos were available from internal USACE documents (obtained through Engineering and Map Records, point of contact: Joyce Rolstad, 206-764-6704) and Terraserver© [Terraserver©, 2005] for review. The photos that were reproducible are attached in Appendix C (some were too unclear to scan). All photos reviewed are discussed briefly below from earliest to most recent. The photos were reviewed for evidence or sources of contamination. No contamination or presence of heavy industry or manufacturing is readily apparent in any of the photos.

<u>1949 aerial photos (USACE internal records)</u>
A series of photographs (approximately 240 images) taken between March 5, 1949 and March 31, 1949 show that the land surrounding Newaukum Creek was primarily farmland, forest, or logged. Only a few dwellings and buildings are noticeable on any of images. They appear to be homes, barns, sheds, and possible small-scale logging mills. The logged areas are extensive and reflect the practice of clear-cutting. Skidding trails are evident in the photos.

<u>1998 aerial photo [Terraserver©, 2006]</u>
The 1998 photo is included in Appendix C. The location of Newaukum Creek has been drawn on the image by hand (in blue) and is not exact. A portion of the Green River (in green) has also been drawn on the image. Compared to the 1949 photos, the 1998 photo shows additional residential development along the creek; however, after using the zoom function to review the photo in greater detail, the residential development still appears to consist of very large parcels (one or more acres per home). Only limited patches of forest can be seen, with the exception of the area where Newaukum Creek meets the Green River.

Maps: 1980 and 1993 7.5-minute USGS topographical maps of the Newaukum Creek area are included in Appendix C [Terraserver ©, 2006; Topozone, 2006]. The maps show minimal elevation changes in the area, and do not show great detail since the area around Newaukum Creek is sparsely populated. There is very little change in green space or roadways from the 1980 to the 1993 map, suggesting that little development has occurred.

5 Environmental Data Review

A review of regulatory agency (U.S. Environmental Protection Agency (USEPA), Washington Department of Ecology (Ecology), and Enumclaw) databases was conducted for the project area and adjacent areas to identify known or potential sources of contamination that could adversely affect the project area. Table 1 below summarizes the results of the database search. No local Enumclaw environmental databases were identified.

The *Standard Practice for Environmental Site Assessments* discusses the "approximate minimum search distances" from the target property that are used depending on the database searched, and all are one mile or less [ASTM, 2000]. Because the Newaukum Creek project area is very long and oddly-shaped, no single address for the "target property" could be used to serve as the basis for the search. Thus, the nearest cities to the project area were used in the database search, and the information was evaluated based on its potential to affect Newaukum Creek. Any former, current, or potentially hazardous sites within one mile of Newaukum Creek are discussed briefly in the far right-hand column of the table and more extensively below the table. Specific distances from the potentially hazardous sites to the Creek were estimated visually from King County's iMAP web application [KC, 2006a].

Table 1. Summary of Environmental Databases Searched and Sites Identified

Agency	Database/ Acronym	Description of database	Citation	Cities used for database search [1]	Approximate Distance of Site to Newaukum Creek (miles)	Implication
USEPA	NPL / CERCLIS	National Priorities List (NPL) for sites needing cleanup / Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS)	USEPA, 2006	Enumclaw	0	
				Newaukum	0	
				Wabash	0	
USEPA	CERCLIS-NFRAP	Identifies CERCLA sites for which no further remedial action is planned (NFRAP) - also known as sites that have been archived.	USEPA, 2006a	Enumclaw	0.95	Site was known as Ballestrasse Logging and is not expected to affect the project area since the USEPA has designated the site as NFRAP.
				Newaukum	0	
				Wabash	0	
USEPA	RCRA-TSD	Resource Conservation and Recovery Act (RCRA)– Treatment, Storage and Disposal (TSD) facilities	USEPA, 2006b	Enumclaw	0	
				Newaukum	0	
				Wabash	0	
USEPA	CORRACTS	Identifies hazardous waste handlers with RCRA corrective action activity	USEPA, 2006b	Enumclaw	0	
				Newaukum	0	
				Wabash	0	
USEPA	RCRA – LQG	Large quantity generators of hazardous waste (HW) (>1000 kg of HW or >1 kg of acutely HW)	USEPA, 2006b	Enumclaw	0	
				Newaukum	0	
				Wabash	0	
USEPA	RCRA – SQG	Small quantity generators of HW (100 kg < generated <1000 kg)	USEPA, 2006b	Enumclaw	0	
				Newaukum	0	
				Wabash	0	
Coast Guard	NRC	The National Response Center (NRC), staffed by the Coast Guard, is the sole federal contact point for oil and chemical spills and provides information on such spills.	NRC, 2006	Enumclaw	0.9	Spill reported on 4/28/01 at 42827 282 Ave. S.E. Incident report stated that the property owner has been dumping tractor motor oil on his soil for three years (incident reported by neighbor).
				Newaukum	0	
				Wabash	0	

Agency	Database/ Acronym	Description of database	Citation	Cities used for database search [1]	Approximate Distance of Site to Newaukum Creek (miles)	Implication
Ecology	CSCSL / HSL	Confirmed or Suspected Contaminated Sites List (CSCSL) and Hazardous Sites List (HSL) for Washington State	Ecology, 2006	Enumclaw	0.15	Soil contaminated with petroleum products and non-halogenated solvents has been confirmed at 41604 264th S.E. (parcel 1320069057), which is an Exxon convenience store and gas station.
				Newaukum	0	
				Wabash	0	
Ecology	CSCSL-NFA	CSCSL properties which require "No Further Action (NFA)"	Ecology, 2006a	Enumclaw	0.95	Ballestrasse Logging (identified above in this table) confirmed as NFA.
				Newaukum	0	
				Wabash	0	
Ecology	LUST	Leaking Underground Storage Tanks	Ecology 2006b	Enumclaw	0.72	Circle K, 2415 Griffin Ave, (parcel 8661000006) – The LUST site has been undergoing soil and groundwater monitoring apparently since 1996.
					0.80	Puget Sound Energy (44720 244th Ave S.E) (parcel 8661000006) underwent soil and groundwater cleanup around 1998.
					0.15	The Exxon convenience store and gas station (mentioned above under CSCSL) began soil and surface water cleanup in 1995.
				Newaukum	0	
				Wabash	0	
Ecology	UST	Underground Storage Tanks	Ecology 2006b	Enumclaw	Various	85 sites in Enumclaw have underground storage tanks, none of which are listed as leaking.
				Newaukum	0	
				Wabash	0	

1 – Since most databases could be searched by city, the nearest cities to Newaukum Creek were used.

For the sites identified in Table 1, the key information is detailed below:

CERCLIS-NFRAP Sites
Ballestrasse Logging was located at 28015 S.E. 432nd, in Enumclaw, Washington (parcel 1920079068), approximately 0.95 miles from Newaukum Creek. The USEPA declared that no remedial action was required at the site after conducting a site inspection in 1988. In addition, the site appears on Ecology's "No Further Action List." Consequently, this site is not expected to affect the project area. However, it is recommended that the site be visually inspected for HTRW before construction is initiated.

NRC Sites
The neighbor of the property owner at 42827 282 Ave. S.E. (parcel 2482100080) contacted the NRC on 4/28/01 to report that the property owner had been dumping tractor motor oil on his soil for three years. This report does not show up again in the NRC database, which may mean that the property owner was contacted by the EPA (the NRC contacts appropriate agencies about spills) and that the issue has been resolved. However, it is also possible that the person notifying the NRC moved. A large volume of soil between the dumping area and Newaukum Creek decreases the likelihood of the oil migrating to the creek [ATSDR, 1999]. However, because of limited information available on this site and the proximity of the site to Newaukum Creek (within 0.90 miles), it is recommended that this site be visually inspected and the property owner interviewed before construction is initiated.

CSCSL/HSL Sites
An Exxon convenience store and gas station is located at 41604 264th S.E. (parcel 1320069057), which is within 0.15 miles of Newaukum Creek. Soil contaminated with petroleum products and non-halogenated solvents has been confirmed at this location. As noted in the "LUST" section of Table 1, cleanup of soil and surface water at this site began over ten years ago, in 1995. However, the cleanup has not been confirmed as completed in the LUST data table [Ecology, 2006b]. It is recommended that the site be visually inspected for HTRW and the convenience store owners interviewed as to the present HTRW status prior to the start of construction.

LUST Sites
- A Circle K convenience store and gas station is located at 2415 Griffin Ave. (parcel 8661000006), which is approximately 0.72 miles from Newaukum Creek. The LUST site has been undergoing soil and groundwater monitoring since 1996.
- A Puget Sound Energy facility is located at 44720 244th Ave S.E. (parcel 8661000006), which is approximately 0.80 miles from Newaukum Creek. This site underwent soil and groundwater cleanup around 1998.
- The Exxon convenience store is discussed under CSCSL/HSL above.

Because of the proximity of the LUST sites to Newaukum Creek and the unknown status of the site cleanups, it is recommended that the sites be visually inspected and interviews with the site owners be conducted before construction is started.

UST Sites

Although 85 tanks are registered in the Enumclaw area, these tanks are not expected to affect the project area because none are indicated in the databases as leaking. Consequently, no attempt has been made at this time to identify the subset that is within one mile of Newaukum Creek.

6 Other Documentation Reviewed

Internal District Records:

No	Yes	Item
X		Permits
X		Contracts
X		Leases
X		Easements
X		Deeds
X		Licenses

7 Site Inspection and Interview

As discussed above, a site inspection and interview were not conducted at this time. Once access is granted to all of the residential properties, it is recommended to perform an overall visual survey of the properties to ensure that no illegal dumping has occurred in Newaukum Creek or on the properties adjoining Newaukum Creek. In particular, it is recommended that the sites in Section 5 where visual inspections and interviews were recommended be included in the overall visual survey. Tables 2-4 below indicate what types of information should be collected during a site inspection.

Table 2. Environmental Conditions Observed

No	Yes	Condition
		Suspicious/Unusual Odors:
		Discolored Soil or Waste:
		Discolored Water:
		Distressed/Dead/Unusual/Lack of – Vegetation:
		Abnormal Mounding
		Area(s) of Ground Depression
		Other:

Table 3. Other Features Observed

No	Yes	Features
		Suspected Asbestos
		Above Ground or Underground Storage Tanks
		Landfills
		Surface Impoundments
		Underground Injection Wells
		Drums/Containers/Hazardous Waste
		Lagoons (Waste Water or Hazardous Waste):
		Incinerator
		Waste Piles/Disposal Sites/Pools of Liquid
		Oil-filled Electrical Equipment/Transformers
		Standpipes, Vent Pipes, etc., coming out of the ground
		Ordnance
		Industrial/Commercial Facilities:
		Waste Water Treatment Facilities
		Discharges to Surface Waters or Drainage Ditches
		Monitoring Wells
		Unknown:
		Potential Environmental/Agricultural Problems on Adjacent Land
		Industrial area
		Power or Pipe Lines:
		Sick/Dead Wildlife or Domestic Animals
		Other:

Table 4. Previous Contamination Found (based on visual survey)

No	Yes	Contaminants
		Petroleum Products
		Degreasers/Solvents
		Pesticides/Herbicides
		Radioactivity
		Heavy Metals
		Organic Chemicals
		Ammunition
		Underground Storage Tanks
		Other

8 Summary of Findings and Conclusions/Recommendations

As identified in Table 1 above, a limited number of sites with past contamination were identified within one mile of Newaukum Creek, in the reaches near to Enumclaw, Wabash, and Newaukum. Because of the limited amount of information available and the inability to perform a visual survey at this time, it is recommended that an overall visual survey be performed before construction is initiated, with particular emphasis on the sites identified in Section 5 as having a history of past contamination.

9 Limitations

The information provided here is a good faith estimate of environmental conditions at the site. Because of the inability to perform a visual survey and conduct site interviews at this time, there may be environmental conditions that may affect the project area. In addition, findings and conclusions presented herein are based in part on data provided by non-USACE sources, and inaccuracies may be introduced from the use of these data. It is recommended that this assessment be supplemented by a site inspection and interviews when access to the properties is available.

Prepared by: Veronica Henzi (CENWS-EC-TB-ET)

Independent technical review was provided by Carol Lee Dona (CENWS-EC-TB-ET)

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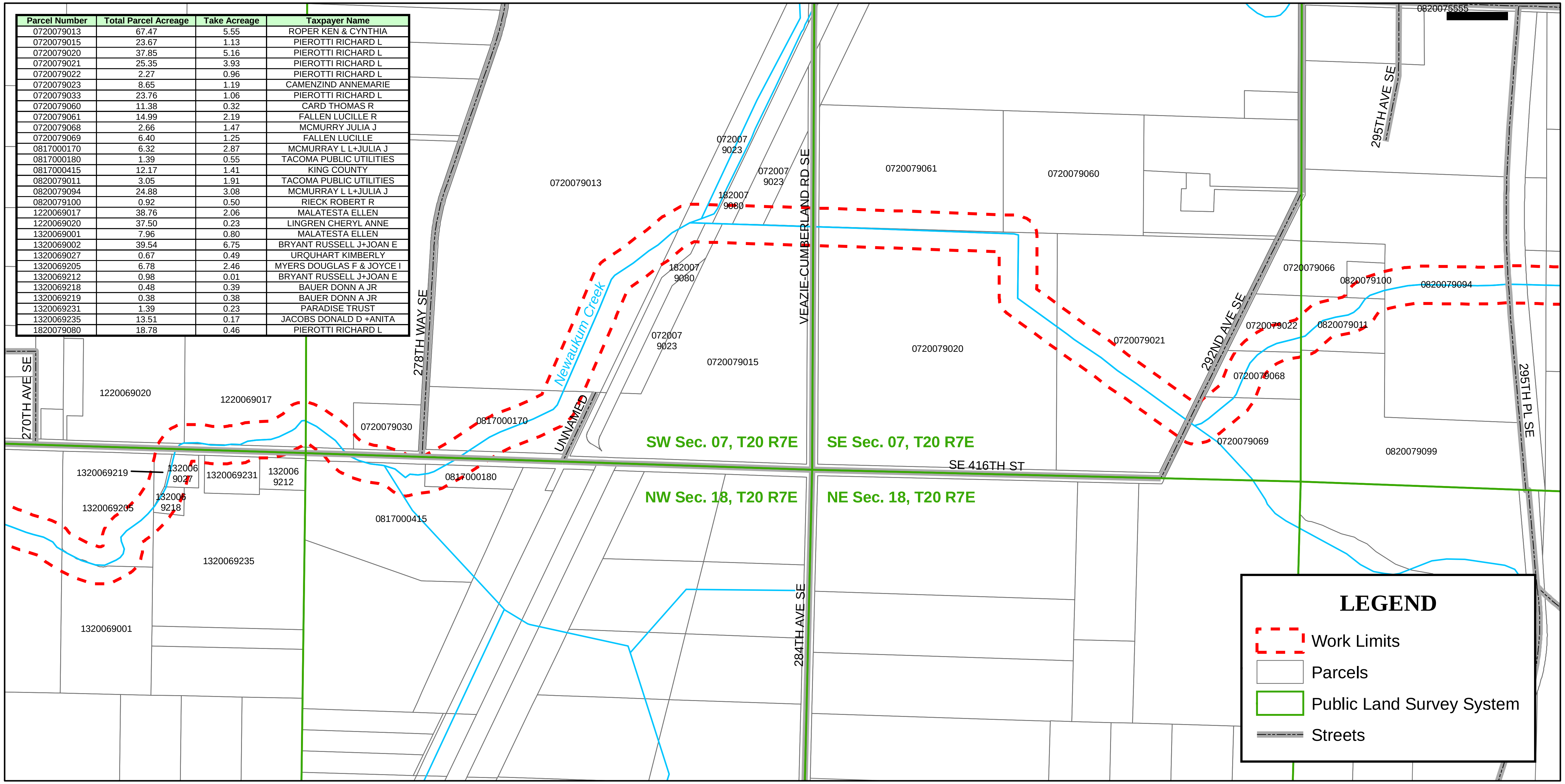
Appendix A – Project Area Maps

Parcel Number	Total Parcel Acreage	Take Acreage	Taxpayer Name
0720079013	67.47	5.55	ROPER KEN & CYNTHIA
0720079015	23.67	1.13	PIEROTTI RICHARD L
0720079020	37.85	5.16	PIEROTTI RICHARD L
0720079021	25.35	3.93	PIEROTTI RICHARD L
0720079022	2.27	0.96	PIEROTTI RICHARD L
0720079023	8.65	1.19	CAMENZIND ANNEMARIE
0720079033	23.76	1.06	PIEROTTI RICHARD L
0720079060	11.38	0.32	CARD THOMAS R
0720079061	14.99	2.19	FALLEN LUCILLE R
0720079068	2.66	1.47	MCMURRY JULIA J
0720079069	6.40	1.25	FALLEN LUCILLE
0817000170	6.32	2.87	MCMURRAY L L+JULIA J
0817000180	1.39	0.55	TACOMA PUBLIC UTILITIES
0817000415	12.17	1.41	KING COUNTY
0820079011	3.05	1.91	TACOMA PUBLIC UTILITIES
0820079094	24.88	3.08	MCMURRAY L L+JULIA J
0820079100	0.92	0.50	RIECK ROBERT R
1220069017	38.76	2.06	MALATESTA ELLEN
1220069020	37.50	0.23	LINGREN CHERYL ANNE
1320069001	7.96	0.80	MALATESTA ELLEN
1320069002	39.54	6.75	BRYANT RUSSELL J+JOAN E
1320069027	0.67	0.49	URQUHART KIMBERLY
1320069205	6.78	2.46	MYERS DOUGLAS F & JOYCE I
1320069212	0.98	0.01	BRYANT RUSSELL J+JOAN E
1320069218	0.48	0.39	BAUER DONN A JR
1320069219	0.38	0.38	BAUER DONN A JR
1320069231	1.39	0.23	PARADISE TRUST
1320069235	13.51	0.17	JACOBS DONALD D +ANITA
1820079080	18.78	0.46	PIEROTTI RICHARD L



0 600 1,200 2,400

1 Inch = 600 Feet

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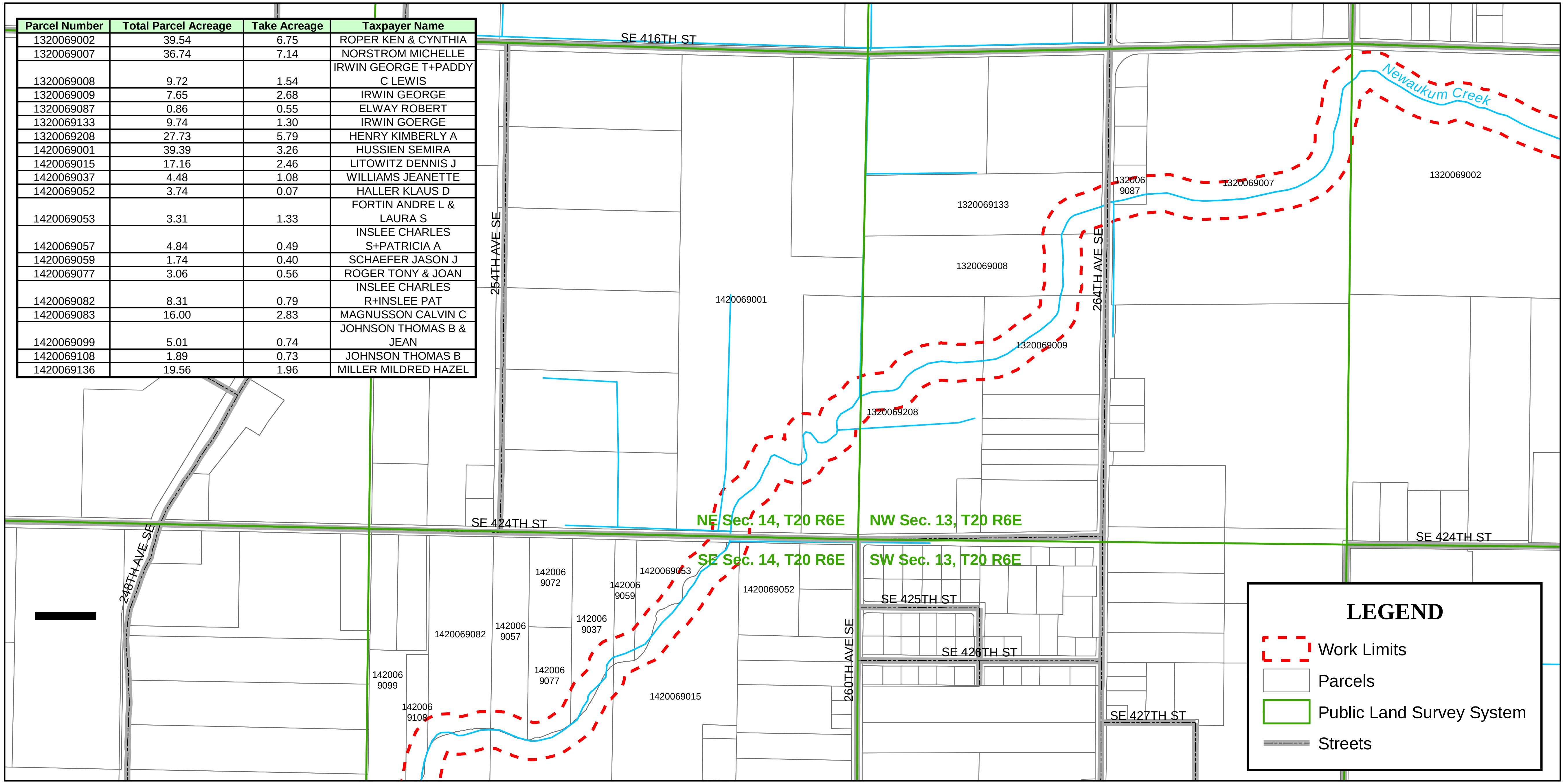
Newaukum Creek South Central King County		**PHASE I PARCEL & VICINITY MAP**	
DATE: 12/15/2005	**AUTHOR:** S. Jesse	**DEPT:** IMO	**DIVISION:** Planning

Parcel Number	Total Parcel Acreage	Take Acreage	Taxpayer Name
1320069002	39.54	6.75	ROPER KEN & CYNTHIA
1320069007	36.74	7.14	NORSTROM MICHELLE
1320069008	9.72	1.54	IRWIN GEORGE T+PADDY C LEWIS
1320069009	7.65	2.68	IRWIN GEORGE
1320069087	0.86	0.55	ELWAY ROBERT
1320069133	9.74	1.30	IRWIN GOERGE
1320069208	27.73	5.79	HENRY KIMBERLY A
1420069001	39.39	3.26	HUSSIEN SEMIRA
1420069015	17.16	2.46	LITOWITZ DENNIS J
1420069037	4.48	1.08	WILLIAMS JEANETTE
1420069052	3.74	0.07	HALLER KLAUS D
1420069053	3.31	1.33	FORTIN ANDRE L & LAURA S
1420069057	4.84	0.49	INSLEE CHARLES S+PATRICIA A
1420069059	1.74	0.40	SCHAEFER JASON J
1420069077	3.06	0.56	ROGER TONY & JOAN
1420069082	8.31	0.79	INSLEE CHARLES R+INSLEE PAT
1420069083	16.00	2.83	MAGNUSSON CALVIN C
1420069099	5.01	0.74	JOHNSON THOMAS B & JEAN
1420069108	1.89	0.73	JOHNSON THOMAS B
1420069136	19.56	1.96	MILLER MILDRED HAZEL



0 600 1,200 2,400

1 Inch = 600 Feet

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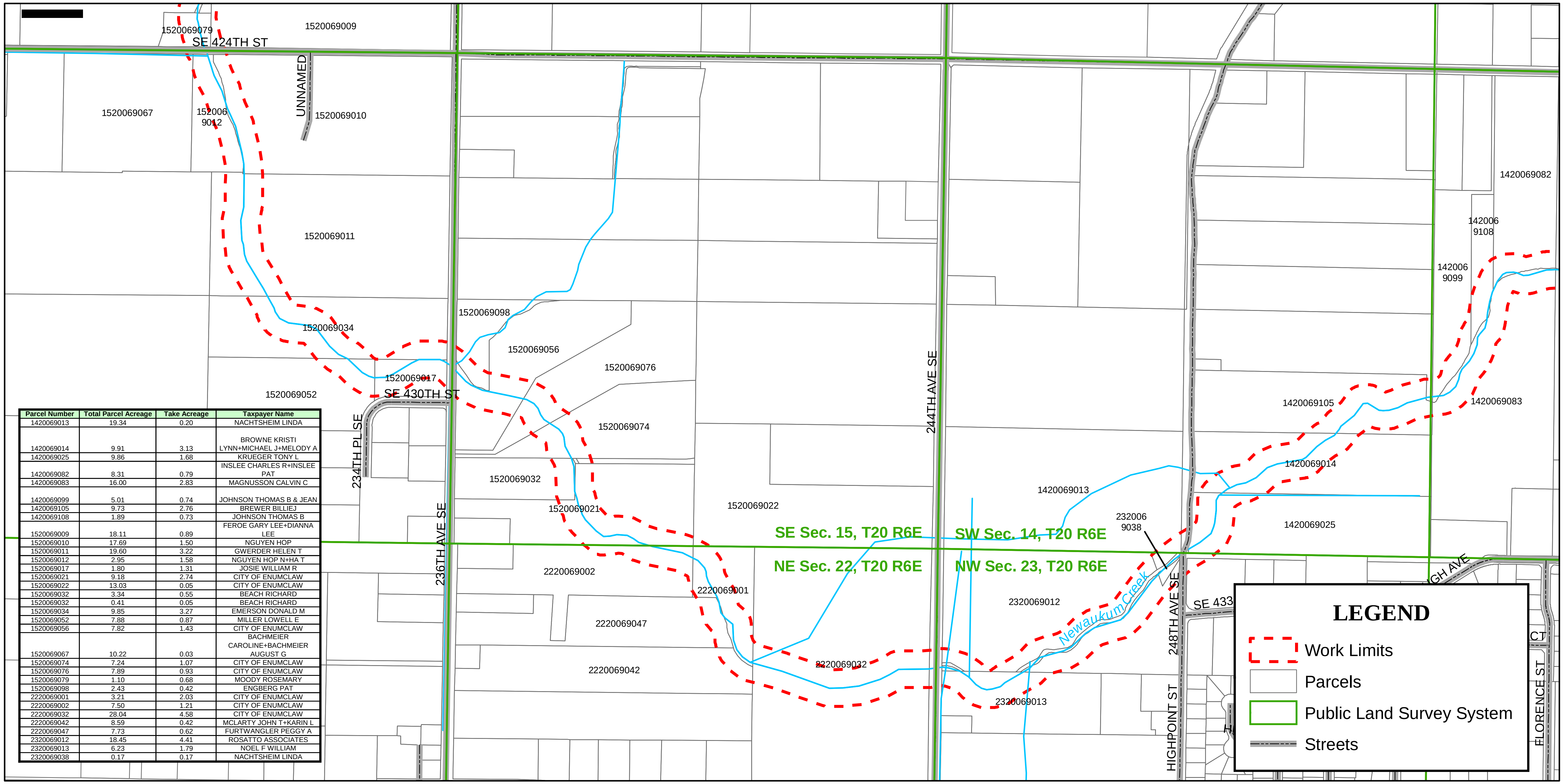
Newaukum Creek South Central King County		**PHASE II PARCEL & VICINITY MAP**	
DATE: 12/15/2005	**AUTHOR:** S. Jesse	**DEPT:** IMO	**DIVISION:** Planning



Parcel Number	Total Parcel Acreage	Take Acreage	Taxpayer Name
1420069013	19.34	0.20	NACHTSHEIM LINDA
1420069014	9.91	3.13	BROWNE KRISTI LYNN+MICHAEL J+MELODY A
1420069025	9.86	1.68	KRUEGER TONY L
1420069082	8.31	0.79	INSLEE CHARLES R+INSLEE PAT
1420069083	16.00	2.83	MAGNUSSON CALVIN C
1420069099	5.01	0.74	JOHNSON THOMAS B & JEAN
1420069105	9.73	2.76	BREWER BILLIEJ
1420069108	1.89	0.73	JOHNSON THOMAS B
1520069009	18.11	0.89	FEROE GARY LEE+DIANNA LEE
1520069010	17.69	1.50	NGUYEN HOP
1520069011	19.60	3.22	GWERDER HELEN T
1520069012	2.95	1.58	NGUYEN HOP N+HA T
1520069017	1.80	1.31	JOSIE WILLIAM R
1520069021	9.18	2.74	CITY OF ENUMCLAW
1520069022	13.03	0.05	CITY OF ENUMCLAW
1520069032	3.34	0.55	BEACH RICHARD
1520069032	0.41	0.05	BEACH RICHARD
1520069034	9.85	3.27	EMERSON DONALD M
1520069052	7.88	0.87	MILLER LOWELL E
1520069056	7.82	1.43	CITY OF ENUMCLAW
1520069067	10.22	0.03	BACHMEIER CAROLINE+BACHMEIER AUGUST G
1520069074	7.24	1.07	CITY OF ENUMCLAW
1520069076	7.89	0.93	CITY OF ENUMCLAW
1520069079	1.10	0.68	MOODY ROSEMARY
1520069098	2.43	0.42	ENGBERG PAT
2220069001	3.21	2.03	CITY OF ENUMCLAW
2220069002	7.50	1.21	CITY OF ENUMCLAW
2220069032	28.04	4.58	CITY OF ENUMCLAW
2220069042	8.59	0.42	MCLARTY JOHN T+KARIN L
2220069047	7.73	0.62	FURTWANGLER PEGGY A
2320069012	18.45	4.41	ROSATTO ASSOCIATES
2320069013	6.23	1.79	NOEL F WILLIAM
2320069038	0.17	0.17	NACHTSHEIM LINDA

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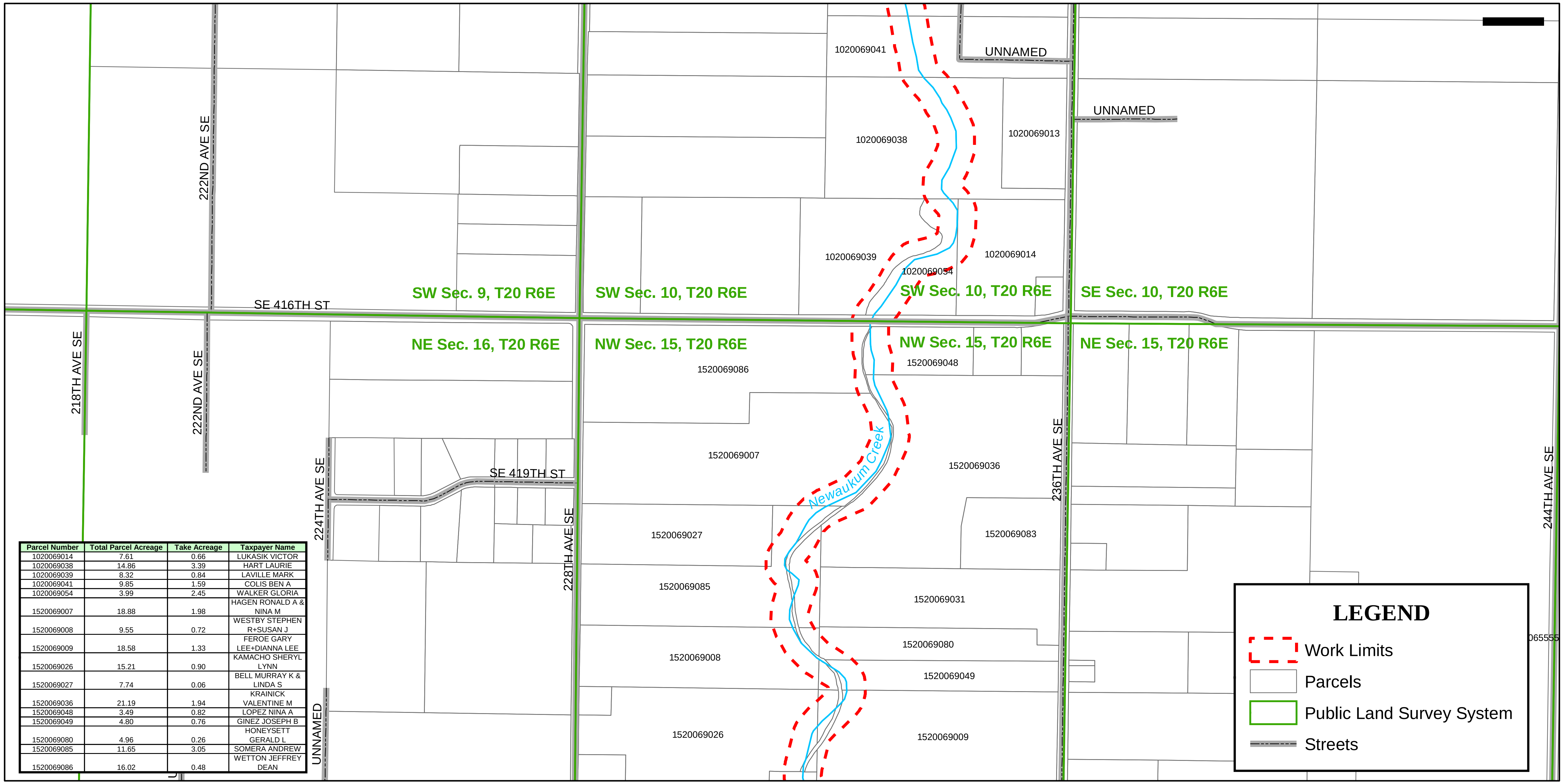
0 600 1,200 2,400

1 Inch = 600 Feet

Newaukum Creek South Central King County		**PHASE III PARCEL & VICINITY MAP**	
DATE: 12/15/2005	**AUTHOR:** S. Jesse	**DEPT:** IMO	**DIVISION:** Planning



Parcel Number	Total Parcel Acreage	Take Acreage	Taxpayer Name
1020069014	7.61	0.66	LUKASIK VICTOR
1020069038	14.86	3.39	HART LAURIE
1020069039	8.32	0.84	LAVILLE MARK
1020069041	9.85	1.59	COLIS BEN A
1020069054	3.99	2.45	WALKER GLORIA
1520069007	18.88	1.98	HAGEN RONALD A & NINA M
1520069008	9.55	0.72	WESTBY STEPHEN R+SUSAN J
1520069009	18.58	1.33	FEROE GARY LEE+DIANNA LEE
1520069026	15.21	0.90	KAMACHO SHERYL LYNN
1520069027	7.74	0.06	BELL MURRAY K & LINDA S
1520069036	21.19	1.94	KRAINICK VALENTINE M
1520069048	3.49	0.82	LOPEZ NINA A
1520069049	4.80	0.76	GINEZ JOSEPH B
1520069080	4.96	0.26	HONEYSETT GERALD L
1520069085	11.65	3.05	SOMERA ANDREW
1520069086	16.02	0.48	WETTON JEFFREY DEAN

0 600 1,200 2,400

1 Inch = 600 Feet

Newaukum Creek
South Central King County

PHASE IV PARCEL & VICINITY MAP

DATE: 12/15/2005 | **AUTHOR:** S. Jesse | **DEPT:** IMO | **DIVISION:** Planning

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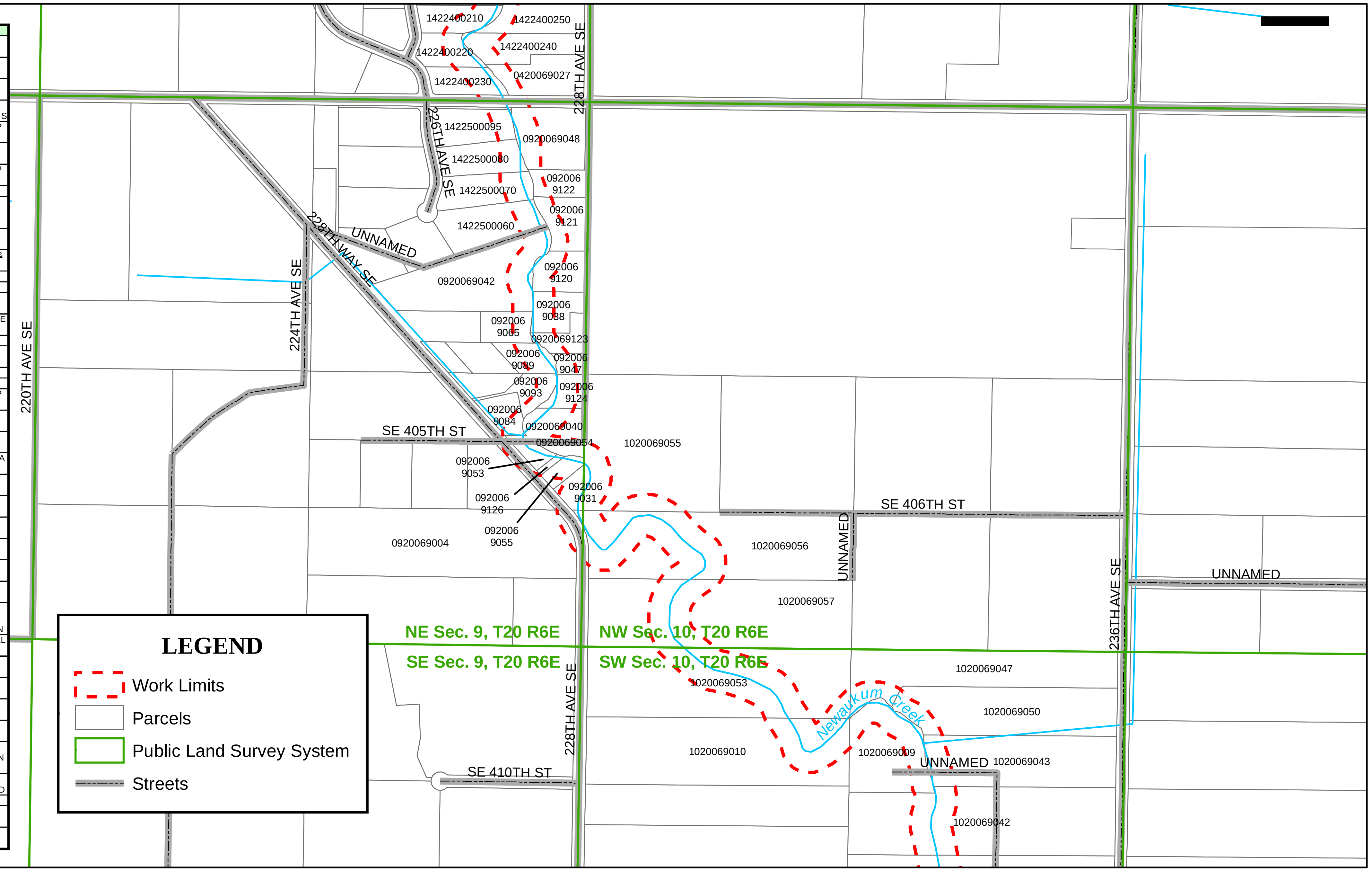
Parcel Number	Total Parcel Acreage	Take Acreage	Taxpayer Name
0420069027	1.74	0.31	CLARK DONALD W+GLENDA LEE
0920069004	9.81	0.12	BUCKNER DONAL+BLANCHE
0920069031	0.44	0.41	SCHARER DEBBIE A
0920069038	1.04	0.49	JORGENSEN RANDALL S
0920069040	1.15	0.80	BARTENETTI FRANK P JR
0920069042	4.75	1.08	DUCKEN JEFFREY W
0920069047	0.34	0.21	BARTENETTI FRANK P JR
0920069048	2.28	0.71	UHDE JANET A
0920069053	0.35	0.35	PICKERING HOWARD J+NANCY L
0920069054	0.28	0.28	RIEDERER DWIGHT E+CARMEN M
0920069055	0.40	0.32	MCFATRIDGE JERRY & KAREN
0920069065	0.87	0.33	JACOBSON J E
0920069084	0.73	0.22	POPE SCOTT L
0920069089	0.78	0.50	NO OWNER INFO LISTED
0920069093	0.74	0.39	ADAMS SAM J+MICHELE K
0920069120	1.15	0.50	DODGE AARON L
0920069121	1.27	0.50	STAPLES ROBERT & BARBARA
0920069122	0.98	0.19	CORDS DAVID
0920069123	0.70	0.24	HORAN SUSAN K
0920069124	0.63	0.47	BARTENETTI FRANK P JR
0920069126	0.09	0.09	MCFATRIDGE JERRY T+PADILLA
1020069009	3.43	1.57	HUFFMAN RONALD P
1020069010	9.68	1.84	BRETT WILLIAM R+LIDA M
1020069042	9.67	1.50	GLAZIER CATHERINE
1020069043	5.29	0.62	FITZPATRICK JOHN A
1020069047	5.81	0.54	WILLNER ANDREW N+NANCY C
1020069050	5.59	0.52	ASHLEY HOUSE THERAPEUTIC FO
1020069053	9.96	3.19	TUOHY CRAIG D+MARILYN M
1020069055	10.13	1.27	RIEDERER DWIGHT E+CARMEN M
1020069056	9.77	3.60	PETERSEN ROBERT+DEWILDE LIN
1020069057	9.86	1.83	MCLAUCHLIN MITCHELL S
1422400210	1.11	0.53	ARBOGAST JACK H+MARILYN M
1422400220	0.97	0.49	ARBOGAST JACK H+MARILYN M
1422400230	1.04	0.49	ELSTON DONALD LEON+CAROLYN
1422400240	1.63	0.49	KENDALL EDWARD J
1422400250	1.54	0.34	HAUFF TARA R+DERAN JEFFREY D
1422500060	2.14	0.45	BUCKENDAHL CAROL D
1422500070	1.58	0.48	WALCZAK STELLA
1422500080	1.41	0.40	DE SANTO WILLIAM D+KATHY JO
1422500095	1.50	0.34	DE SANTO WILLIAM D+HELMOLD



0 600 1,200 2,400

1 Inch = 600 Feet

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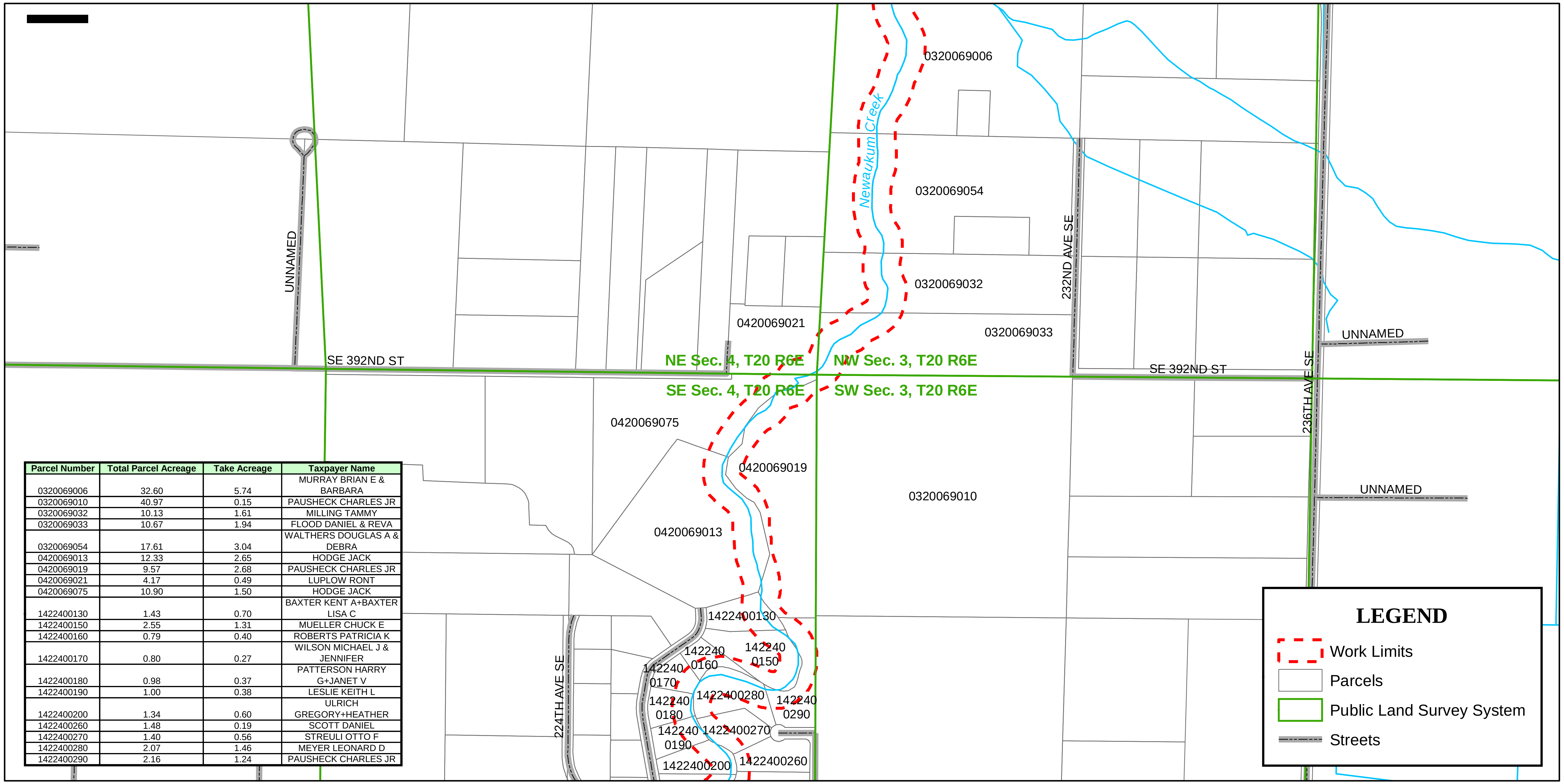
Newaukum Creek South Central King County		**PHASE V PARCEL & VICINITY MAP**	
DATE: 12/15/2005	**AUTHOR:** S. Jesse	**DEPT:** IMO	**DIVISION:** Planning

PHASE VI PARCEL & VICINITY MAP

Newaukum Creek
South Central King County



Parcel Number	Total Parcel Acreage	Take Acreage	Taxpayer Name
0320069006	32.60	5.74	MURRAY BRIAN E & BARBARA
0320069010	40.97	0.15	PAUSHECK CHARLES JR
0320069032	10.13	1.61	MILLING TAMMY
0320069033	10.67	1.94	FLOOD DANIEL & REVA
0320069054	17.61	3.04	WALTHERS DOUGLAS A & DEBRA
0420069013	12.33	2.65	HODGE JACK
0420069019	9.57	2.68	PAUSHECK CHARLES JR
0420069021	4.17	0.49	LUPLOW RONT
0420069075	10.90	1.50	HODGE JACK
1422400130	1.43	0.70	BAXTER KENT A+BAXTER LISA C
1422400150	2.55	1.31	MUELLER CHUCK E
1422400160	0.79	0.40	ROBERTS PATRICIA K
1422400170	0.80	0.27	WILSON MICHAEL J & JENNIFER
1422400180	0.98	0.37	PATTERSON HARRY G+JANET V
1422400190	1.00	0.38	LESLIE KEITH L
1422400200	1.34	0.60	ULRICH GREGORY+HEATHER
1422400260	1.48	0.19	SCOTT DANIEL
1422400270	1.40	0.56	STREULI OTTO F
1422400280	2.07	1.46	MEYER LEONARD D
1422400290	2.16	1.24	PAUSHECK CHARLES JR

0 600 1,200 2,400

1 Inch = 600 Feet

DATE: 12/15/2005 | **AUTHOR:** S. Jesse | **DEPT:** IMO | **DIVISION:** Planning

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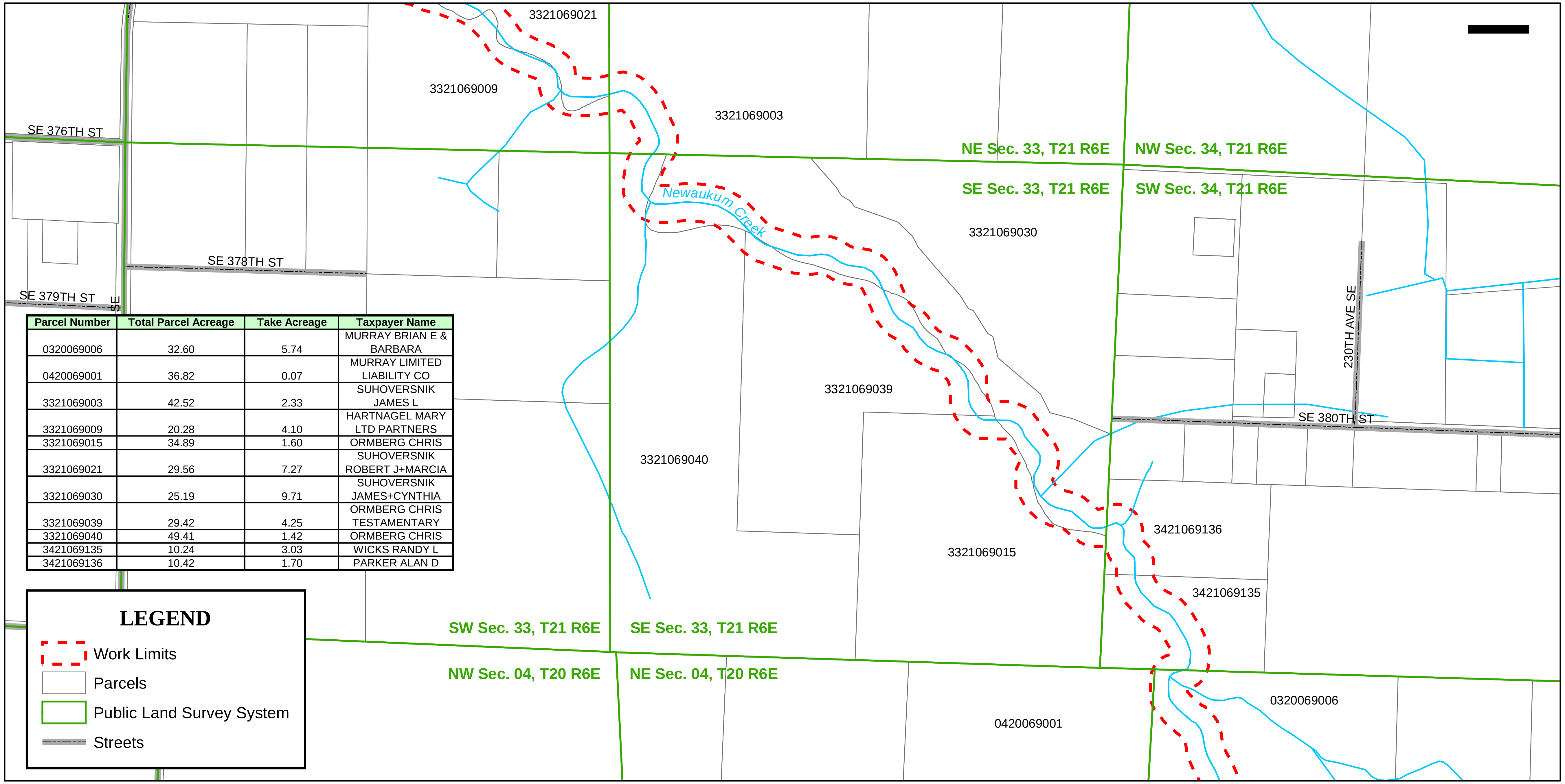

Parcel Number	Total Parcel Acreage	Take Acreage	Taxpayer Name
0320069006	32.60	5.74	MURRAY BRIAN E & BARBARA
0420069001	36.82	0.07	MURRAY LIMITED LIABILITY CO
3321069003	42.52	2.33	SUHOVERSNIK JAMES L
3321069009	20.28	4.10	HARTNAGEL MARY LTD PARTNERS
3321069015	34.89	1.60	ORMBERG CHRIS
3321069021	29.56	7.27	SUHOVERSNIK ROBERT J+MARCIA
3321069030	25.19	9.71	SUHOVERSNIK JAMES+CYNTHIA
3321069039	29.42	4.25	ORMBERG CHRIS TESTAMENTARY
3321069040	49.41	1.42	ORMBERG CHRIS
3421069135	10.24	3.03	WICKS RANDY L
3421069136	10.42	1.70	PARKER ALAN D

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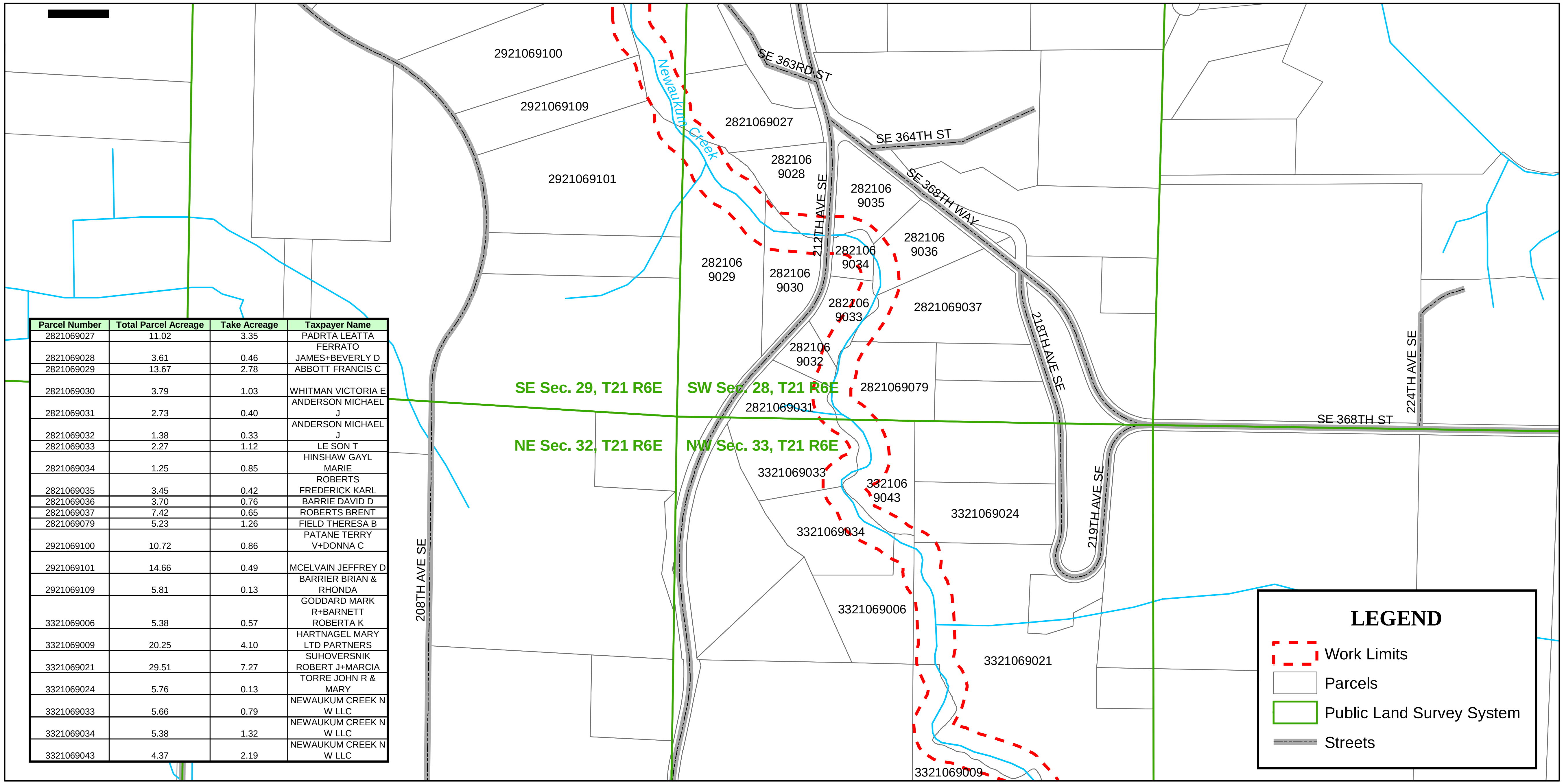
0 600 1,200 2,400

1 Inch = 600 Feet

Newaukum Creek
South Central King County

PHASE VII PARCEL & VICINITY MAP

DATE: 12/15/2005 **AUTHOR:** S. Jesse **DEPT:** IMO **DIVISION:** Planning



Parcel Number	Total Parcel Acreage	Take Acreage	Taxpayer Name
2821069027	11.02	3.35	PADRTA LEATTA
2821069028	3.61	0.46	FERRATO JAMES+BEVERLY D
2821069029	13.67	2.78	ABBOTT FRANCIS C
2821069030	3.79	1.03	WHITMAN VICTORIA E
2821069031	2.73	0.40	ANDERSON MICHAEL J
2821069032	1.38	0.33	ANDERSON MICHAEL J
2821069033	2.27	1.12	LE SON T
2821069034	1.25	0.85	HINSHAW GAYL MARIE
2821069035	3.45	0.42	ROBERTS FREDERICK KARL
2821069036	3.70	0.76	BARRIE DAVID D
2821069037	7.42	0.65	ROBERTS BRENT
2821069079	5.23	1.26	FIELD THERESA B
2921069100	10.72	0.86	PATANE TERRY V+DONNA C
2921069101	14.66	0.49	MCELVAIN JEFFREY D
2921069109	5.81	0.13	BARRIER BRIAN & RHONDA
3321069006	5.38	0.57	GODDARD MARK R+BARNETT ROBERTA K
3321069009	20.25	4.10	HARTNAGEL MARY LTD PARTNERS
3321069021	29.51	7.27	SUHOVERSNIK ROBERT J+MARCIA
3321069024	5.76	0.13	TORRE JOHN R & MARY
3321069033	5.66	0.79	NEWAUKUM CREEK N W LLC
3321069034	5.38	1.32	NEWAUKUM CREEK N W LLC
3321069043	4.37	2.19	NEWAUKUM CREEK N W LLC

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0 600 1,200 2,400

1 Inch = 600 Feet

Newaukum Creek
South Central King County

PHASE VIII PARCEL & VICINITY MAP

DATE: 12/15/2005 | **AUTHOR:** S. Jesse | **DEPT:** IMO | **DIVISION:** Planning

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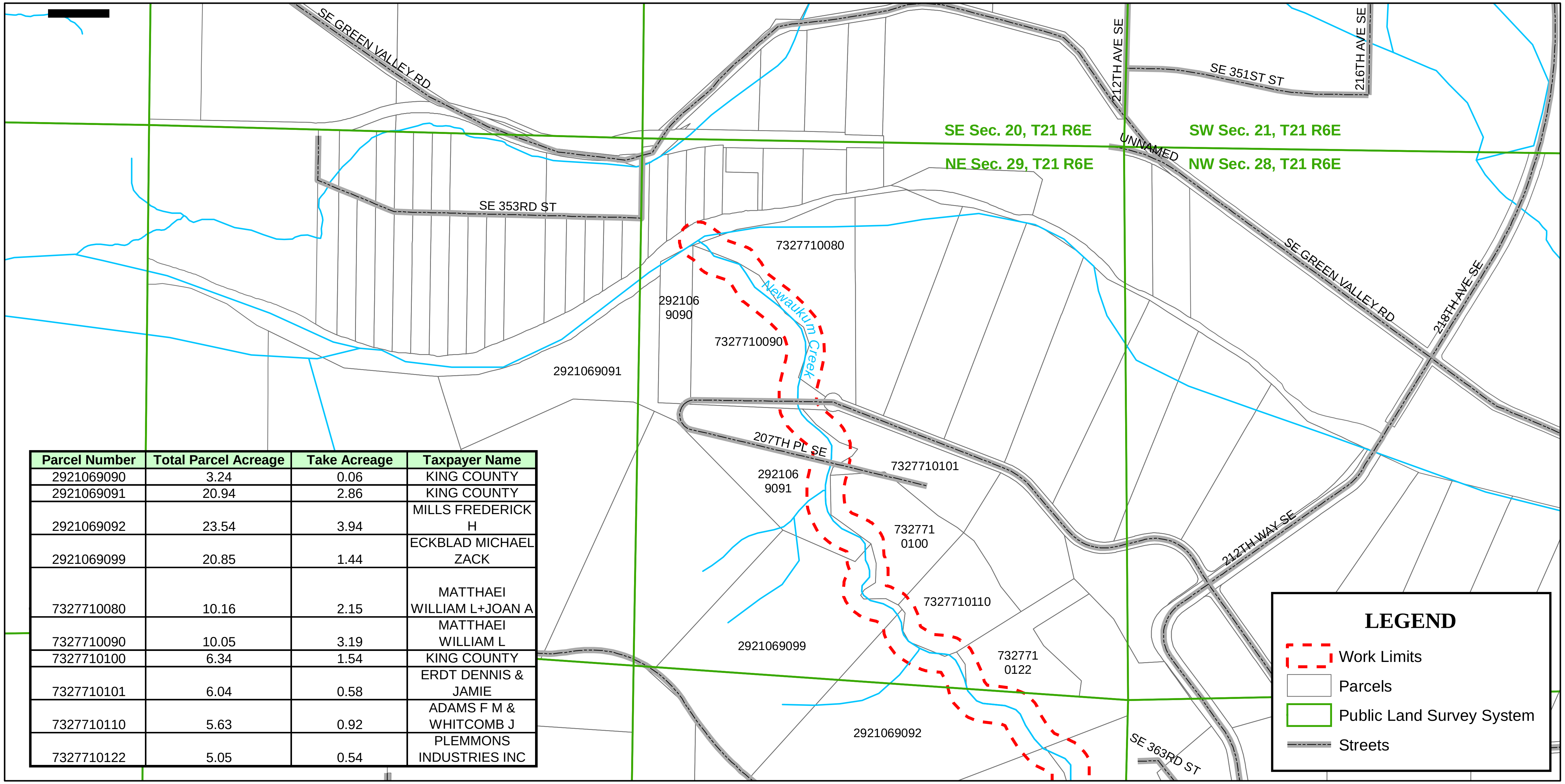

Parcel Number	Total Parcel Acreage	Take Acreage	Taxpayer Name
2921069090	3.24	0.06	KING COUNTY
2921069091	20.94	2.86	KING COUNTY
2921069092	23.54	3.94	MILLS FREDERICK H
2921069099	20.85	1.44	ECKBLAD MICHAEL ZACK
7327710080	10.16	2.15	MATTHAEI WILLIAM L+JOAN A
7327710090	10.05	3.19	MATTHAEI WILLIAM L
7327710100	6.34	1.54	KING COUNTY
7327710101	6.04	0.58	ERDT DENNIS & JAMIE
7327710110	5.63	0.92	ADAMS F M & WHITCOMB J
7327710122	5.05	0.54	PLEMMONS INDUSTRIES INC

0 600 1,200 2,400

1 Inch = 600 Feet

Newaukum Creek
South Central King County

PHASE IX PARCEL & VICINITY MAP

DATE: 12/15/2005 | **AUTHOR:** S. Jesse | **DEPT:** IMO | **DIVISION:** Planning

Appendix B – Parcel List for Project Area

Parcel	Project Area Map [1]	Zoned [2]	Taxpayer current as of 1/10/06 [3]	Notes
0720079013	I	R	MCMURRAY L L+JULIA J	
0720079015	I	R	Eugene Clegg	
0720079020	I	R	MALATESTA ELLEN	
0720079021	I	R	MALATESTA ELLEN	
0720079022	I	R	BRYANT RUSSELL J+JOAN E	
0720079023	I	A	Tacoma Water	
0720079033	I	R	CARD THOMAS R	
0720079060	I	R	LINGREN CHERYL ANNE	
0720079061	I	R	RIECK ROBERT R	
0720079068	I	R	URQUHART KIMBERLY	
0720079069	I	R	MYERS DOUGLAS F & JOYCE I	
0817000170	I	R	MCMURRY JULIA J	
0817000180	I	R	FALLEN LUCILLE	
0817000415	I	R	FALLEN LUCILLE	
0820079011	I	R	BRYANT RUSSELL J+JOAN E	
0820079094	I	R	JACOBS DONALD D +ANITA	
0820079100	I	R	BAUER DONN A JR	
1220069017	I	R	SPRAGUE BRUCE+JULIE	
1220069020	I	R	CAMENZIND ANNEMARIE	
1320069001	I	R	PIEROTTI RICHARD L	
1320069002	I	R	ROPER KEN & CYNTHIA	
1320069027	I	R	PIEROTTI RICHARD L	
1320069205	I	R	PIEROTTI RICHARD L	
1320069212	I	R	PIEROTTI RICHARD L	
1320069218	I	R	PIEROTTI RICHARD L	
1320069219	I	R	PIEROTTI RICHARD L	
1320069231	I	R	MCGARRY DONALD	
1320069235	I	R	PIEROTTI RICHARD L	
1820079080	I	A	King County	
1320069002	II	R	ROPER KEN & CYNTHIA	
1320069007	II	R	NORSTROM MICHELLE	
1320069008	II	R	IRWIN GEORGE T+PADDY C LEWIS	
1320069009	II	R	IRWIN GEORGE	
1320069087	II	R	ELWAY ROBERT	
1320069133	II	R	IRWIN GOERGE	
1320069208	II	R	HENRY KIMBERLY A	
1420069001	II	R	HUSSIEN SEMIRA	
1420069015	II	R	LITOWITZ DENNIS J	
1420069037	II	R	WILLIAMS JEANETTE	
1420069052	II	R	HALLER KLAUS D	
1420069053	II	R	FORTIN ANDRE L & LAURA S	
1420069057	II	R	INSLEE CHARLES S+PATRICIA A	
1420069059	II	R	SCHAEFER JASON J	

Parcel	Project Area Map [1]	Zoned [2]	Taxpayer current as of 1/10/06 [3]	Notes
1420069077	II	R	ROGER TONY & JOAN	
1420069082	II	R	INSLEE CHARLES R+INSLEE PAT	
1420069083	II	R	MAGNUSSON CALVIN C	
1420069099	II	R	King County	
1420069108	II	R	King County	
1420069136	II	R	MILLER MILDRED HAZEL	
1420069013	III	R	NACHTSHEIM LINDA	
1420069014	III	R	BROWNE KRISTI LYNN+MICHAEL J and Melody A	
1420069025	III	R	KRUEGER TONY L	
1420069082	III	R	INSLEE CHARLES R+INSLEE PAT	
1420069083	III	R	MAGNUSSON CALVIN C	
1420069099	III	R	King County	
1420069105	III	R	BREWER BILLIEJ	
1420069108	III	R	King County	
1520069009	III	R	FEROE GARY LEE+DIANNA LEE	
1520069010	III	R	NGUYEN HOP	
1520069011	III	R	GWERDER HELEN T	
1520069012	III	R	NGUYEN HOP N+HA T	
1520069017	III	R	JOSIE WILLIAM R	
1520069021	III	A	CITY OF ENUMCLAW	
1520069022	III	A	CITY OF ENUMCLAW	
1520069032	III	R	BEACH RICHARD	Parcel listed twice on PDF - has to do with acreage
1520069032	III	R	BEACH RICHARD	Parcel listed twice on PDF - has to do with acreage
1520069034	III	R	EMERSON DONALD M	
1520069052	III	R	MILLER LOWELL E	
1520069056	III	A	CITY OF ENUMCLAW	
1520069067	III	R	Bachmeier, Caroline and August	
1520069074	III	A	CITY OF ENUMCLAW	
1520069076	III	A	CITY OF ENUMCLAW	
1520069079	III	R	MOODY ROSEMARY	
1520069098	III	R	ENGBERG PAT	
2220069001	III	A	CITY OF ENUMCLAW	
2220069002	III	R	CITY OF ENUMCLAW	
2220069032	III	R	CITY OF ENUMCLAW	Area defined as an "urban reserve"
2220069042	III	R	MCLARTY JOHN T+KARIN L	
2220069047	III	R	FURTWANGLER PEGGY A	
2320069012	III	R	ROSATTO ASSOCIATES	
2320069013	III	R	NOEL F WILLIAM	
2320069038	III	R	NACHTSHEIM LINDA	
1020069014	IV	R	LUKASIK VICTOR	
1020069038	IV	R	HART LAURIE	
1020069039	IV	R	LAVILLE MARK	
1020069041	IV	R	COLIS BEN A	

Parcel	Project Area Map [1]	Zoned [2]	Taxpayer current as of 1/10/06 [3]	Notes
1020069054	IV	R	WALKER GLORIA	
1520069007	IV	R	HAGEN RONALD A & NINA M	
1520069008	IV	R	WESTBY STEPHEN R+SUSAN J	
1520069009	IV	R	FEROE GARY LEE+DIANNA LEE	
1520069026	IV	R	KAMACHO SHERYL LYNN	
1520069027	IV	R	BELL MURRAY K & LINDA S	
1520069036	IV	R	KRAINICK VALENTINE M	
1520069048	IV	R	LOPEZ NINA A	
1520069049	IV	R	GINEZ JOSEPH B	
1520069080	IV	R	HONEYSETT GERALD L	
1520069085	IV	R	SOMERA ANDREW	
1520069086	IV	R	WETTON JEFFREY DEAN	
0420069027	V	R	CLARK DONALD W+GLENDA LEE	
0920069004	V	R	BUCKNER DONAL+BLANCHE	
0920069031	V	R	SCHARER DEBBIE A	
0920069038	V	R	JORGENSEN RANDALL S	
0920069040	V	R	BARTENETTI FRANK P JR	
0920069042	V	R	DUCKEN JEFFREY W	
0920069047	V	R	BARTENETTI FRANK P JR	
0920069048	V	R	UHDE JANET A	
0920069053	V	R	PICKERING HOWARD J+NANCY L	
0920069054	V	R	RIEDERER DWIGHT E+CARMEN M	
0920069055	V	R	MCFATRIDGE JERRY & KAREN	
0920069065	V	R	JACOBSON J E	
0920069084	V	R	POPE SCOTT L	
0920069089	V	A	NORMAN, LYLE E	Website said account had been "killed" [KCE, 2005]
0920069093	V	R	ADAMS SAM J+MICHELE K	
0920069120	V	R	DODGE AARON L	
0920069121	V	R	STAPLES ROBERT & BARBARA	
0920069122	V	R	CORDS DAVID	
0920069123	V	R	HORAN SUSAN K	
0920069124	V	R	BARTENETTI FRANK P JR	
0920069126	V	R	MCFATRIDGE JERRY T+PADILLA	
1020069009	V	R	HUFFMAN RONALD P	
1020069010	V	R	BRETT WILLIAM R+LIDA M	
1020069042	V	R	JOHNSON, MARK & SHANNON	
1020069043	V	R	FITZPATRICK JOHN A	
1020069047	V	R	WILLNER ANDREW N+NANCY C	
1020069050	V	R	ASHLEY HOUSE, THERAPEUTIC FOSTER CARE	
1020069053	V	R	TUOHY CRAIG D+MARILYN M	
1020069055	V	R	RIEDERER DWIGHT E+CARMEN M	
1020069056	V	R	PETERSEN ROBERT+DEWILDE LIN	
1020069057	V	R	MCLAUCHLIN MITCHELL S	
1422400210	V	R	ARBOGAST JACK H+MARILYN M	
1422400220	V	R	ARBOGAST JACK H+MARILYN M	

Parcel	Project Area Map [1]	Zoned [2]	Taxpayer current as of 1/10/06 [3]	Notes
1422400230	V	R	ELSTON DONALD LEON + CAROLYN	
1422400240	V	R	KENDALL EDWARD J	
1422400250	V	R	HAUFF TARA R+DERAN JEFFREY D	
1422500060	V	R	BUCKENDAHL CAROL D	
1422500070	V	R	WALCZAK STELLA	
1422500080	V	R	DE SANTO WILLIAM D+KATHY JO	
1422500095	V	R	DE SANTO WILLIAM D+HELMOLD	
0320069006	VI	R	MURRAY BRIAN E & BARBARA	
0320069010	VI	R	PAUSHECK CHARLES JR	
0320069032	VI	R	MILLING TAMMY	
0320069033	VI	R	FLOOD DANIEL & REVA	
0320069054	VI	R	WALTHERS DOUGLAS A & DEBRA	
0420069013	VI	R	HODGE JACK	
0420069019	VI	R	PAUSHECK CHARLES JR	
0420069021	VI	R	LUPLOW RONI	
0420069075	VI	R	HODGE JACK	
1422400130	VI	R	BAXTER KENT A+BAXTER LISA C	
1422400150	VI	R	MUELLER CHUCK E	
1422400160	VI	R	ROBERTS PATRICIA K	
1422400170	VI	R	WILSON MICHAEL J & JENNIFER	
1422400180	VI	R	PATTERSON HARRY G+JANET V	
1422400190	VI	R	LESLIE KEITH L	
1422400200	VI	R	ULRICH GREGORY+HEATHER	
1422400260	VI	R	SCOTT DANIEL	
1422400270	VI	R	STREULI OTTO F	
1422400280	VI	R	MEYER LEONARD D	
1422400290	VI	R	PAUSHECK CHARLES JR	
0320069006	VII	R	MURRAY BRIAN E & BARBARA	
0420069001	VII	A	MURRAY LIMITED LIABILITY CO	Designated forest land by RCW 84.33.120 OR 84.33.130
3321069003	VII	R	SUHOVERSNIK JAMES L	
3321069009	VII	R	HARTNAGEL MARY LTD PARTNERS	has open space exemption (appears on maps VII and VII)
3321069015	VII	R	ORMBERG CHRIS	
3321069021	VII	R	SUHOVERSNIK ROBERT J+MARCIA	
3321069030	VII	R	SUHOVERSNIK JAMES+CYNTHIA	
3321069039	VII	A	ORMBERG CHRIS TESTAMENTARY	This parcel classified as open space "farm and agricultural" pursuant to RCW 84.34.
3321069040	VII	R	ORMBERG CHRIS	
3421069135	VII	R	WICKS RANDY L	
3421069136	VII	R	PARKER ALAN D	

Parcel	Project Area Map [1]	Zoned [2]	Taxpayer current as of 1/10/06 [3]	Notes
2821069027	VIII	R	PADRTA LEATTA	
2821069028	VIII	R	FERRATO JAMES+BEVERLY D	
2821069029	VIII	R	ABBOTT FRANCIS C	
2821069030	VIII	R	ROGERS, JOHN	
2821069031	VIII	R	ANDERSON MICHAEL J	
2821069032	VIII	R	ANDERSON MICHAEL J	
2821069033	VIII	R	LE SON T	
2821069034	VIII	R	HINSHAW GAYL MARIE	
2821069035	VIII	R	ROBERTS FREDERICK KARL	
2821069036	VIII	R	BARRIE DAVID D	
2821069037	VIII	R	ROBERTS BRENT	
2821069079	VIII	R	HARKNESS JASON B+ELISABETH	
2921069100	VIII	R	PATANE TERRY V+DONNA C	
2921069101	VIII	R	MCELVAIN JEFFREY D	
2921069109	VIII	R	BARRIER BRIAN & RHONDA	
3321069006	VIII	R	GODDARD MARK R+BARNETT ROBERTA K	
3321069009	VIII	R	HARTNAGEL MARY LTD PARTNERS	Has open space exemption (appears on maps VII and VII)
3321069021	VIII	R	VERSNIK ROBERT J+MARCIA	
3321069024	VIII	R	TORRE JOHN R & MARY	
3321069033	VIII	A	NEWAUKUM CREEK N W LLC	Vacant land, zoned for agriculture
3321069034	VIII	A	NEWAUKUM CREEK N W LLC	Vacant land, zoned for agriculture
3321069043	VIII	A	NEWAUKUM CREEK N W LLC	Vacant land, zoned for agriculture
2921069090	XI	A	KING COUNTY	
2921069091	XI	A	KING COUNTY	
2921069092	XI	R	MILLS FREDERICK H	
2921069099	XI	R	ECKBLAD MICHAEL ZACK	
7327710080	XI	R	MATTHAEI WILLIAM L+JOAN A	
7327710090	XI	R	MATTHAEI WILLIAM L	
7327710100	XI	A	KING COUNTY WTR & LAND	
7327710101	XI	R	ERDT DENNIS & JAMIE	
7327710110	XI	R	ADAMS F M & WHITCOMB J	
7327710122	XI	A	PLEMMONS INDUSTRIES INC.	Vacant land, zoned for agriculture

1 – Corresponding maps of parcels can be found in Appendix A.
2 – Zoning can be residential (R), commercial (C), or agricultural (A), though A is considered a form of residential. The properties owned by the city or county are generally zoned residential or agricultural [KC, 2006].
3 – Tax payer may not be the same as the property owner currently residing on-site.

Appendix C - Historical Photos / Maps

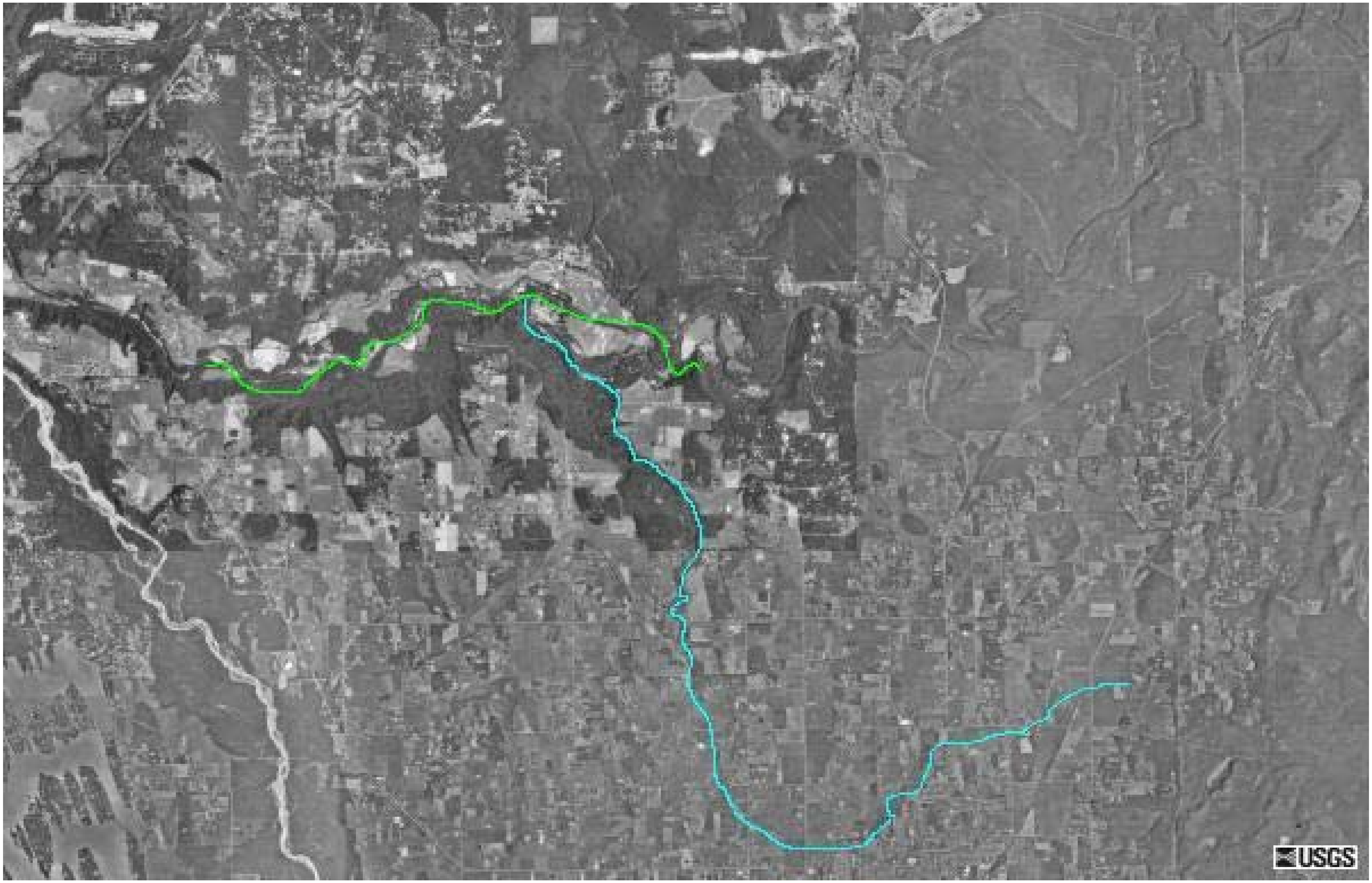

Figure C1. Map of Newaukum Creek (blue) and Segment of Green River (green)

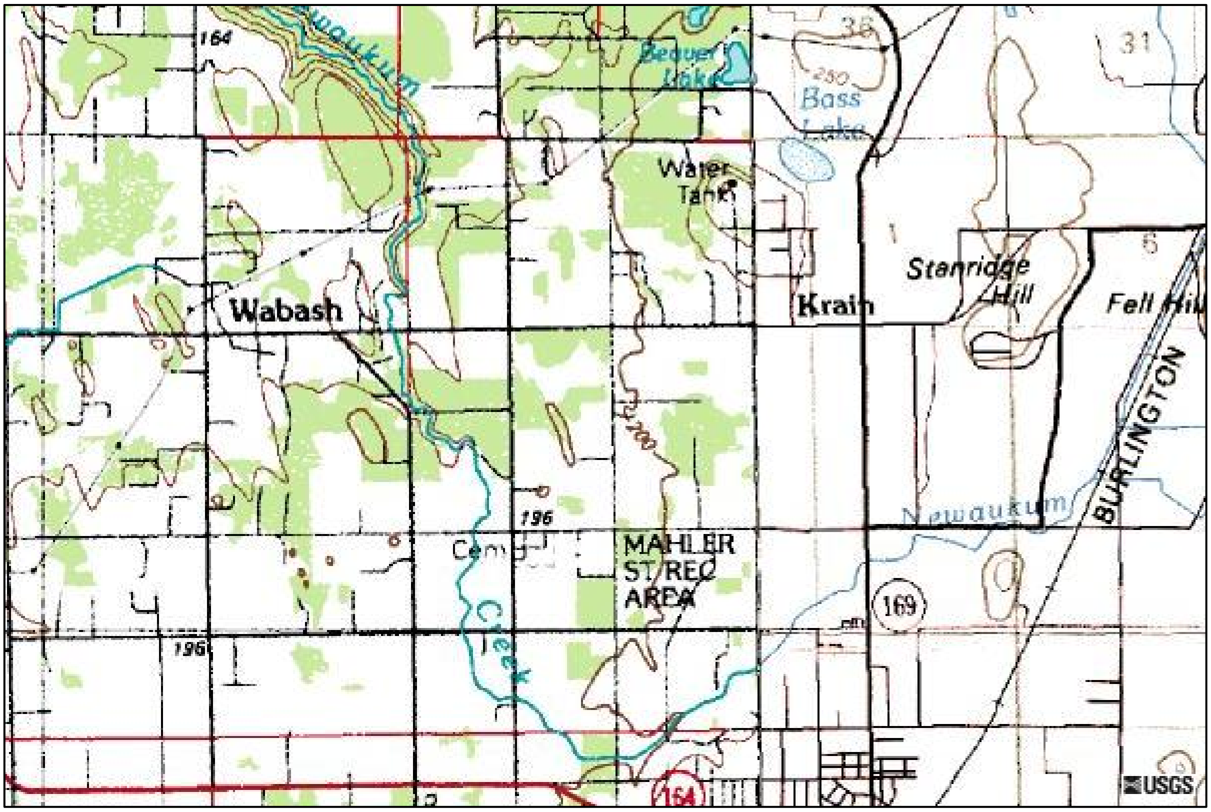

Figure C2. 1980 Topographical Map [Terraserver©, 2006]

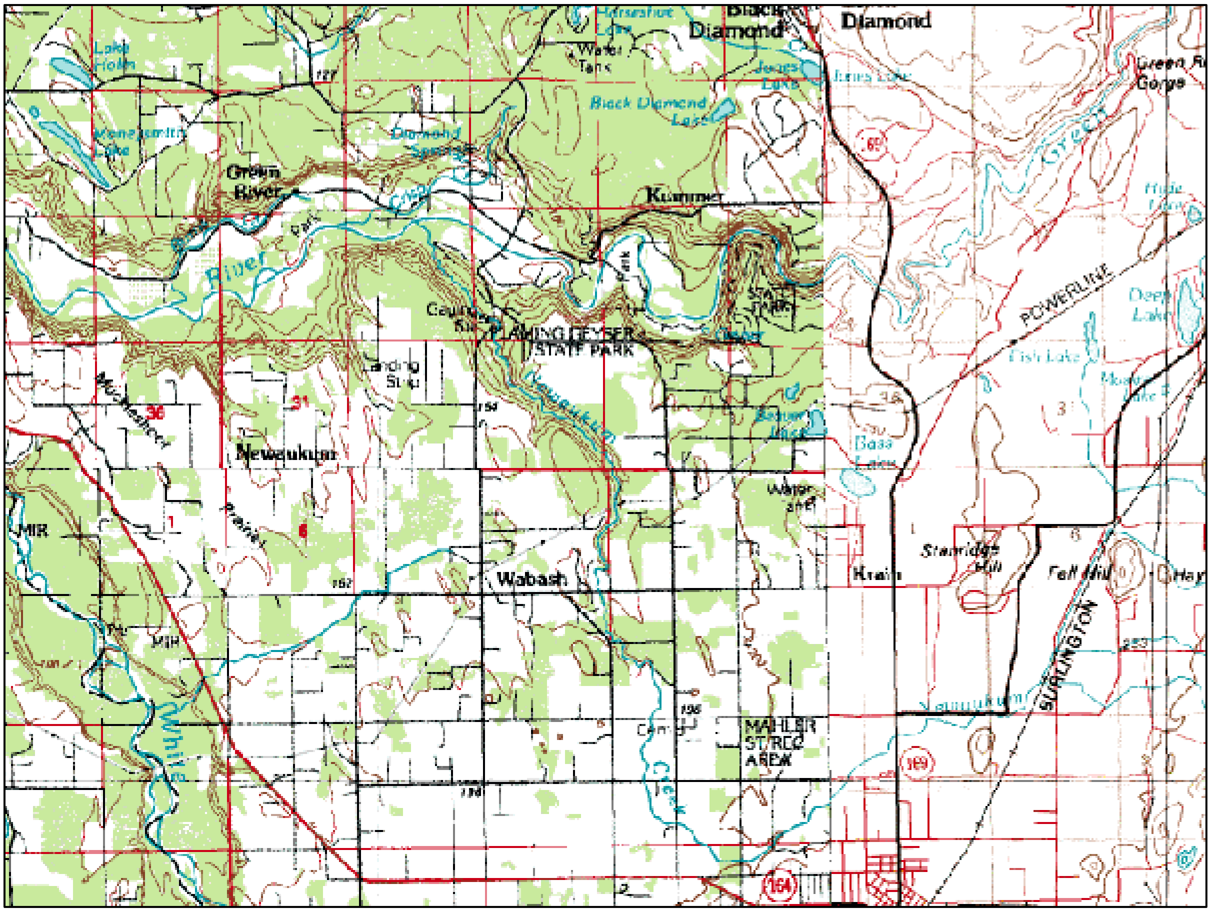

Figure C3. 1993 Topographical Map [Topozone, 2006]