GORST CREEK WATERSHED CHARACTERIZATION REPORT

Prepared for

And

Prepared by

Parametrix
411 108th Avenue NE, Suite 1800
Bellevue, WA 98004-5571
T. 425.458.6200 F. 425.458.6363
www.parametrix.com

In collaboration with

Washington Department of Ecology

And

Washington Department of Fish and Wildlife

June 2012 | 233-1896-096 (01/05)

CITATION

City of Bremerton. 2012. Gorst Creek Watershed Characterization Report. Washington Department of Ecology and the Washington Department of Fish and Wildlife in collaboration with Parametrix, Bellevue, Washington. May 2012.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS (CONTINUED)

LIST OF MAPS

APPENDICES

ACRONYMS

AU	Assessment Unit
BMP	best management practice
DNR	Washington State Department of Natural Resources
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
LID	Low Impact Development
PHS	Priority Habitats and Species
PSAMP	Puget Sound Ambient Monitoring Program
PSNERP	Puget Sound Nearshore Ecosystem Restoration Project
SMP	Shoreline Master Program
UGA	Urban Growth Area
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

EXECUTIVE SUMMARY

The Gorst Creek Watershed Characterization project analyzes existing conditions of the watershed with respect to water flow and habitat. Watershed Characterization, an analytical framework developed by the Department of Ecology, provides the basis for understanding the relative value of assessment units for water flow processes, water quality, and habitat within the Gorst Creek Watershed (Stanley et al, in preparation, 2011). Local agencies, such as the City of Bremerton and Kitsap County, are responsible for land use planning and protection within the watershed. The intent of this report is to inform future land use development with the combined analysis provided by watershed characterization and local habitat area assessments (provided by Washington Department of Fish and Wildlife). Based on this analysis, local jurisdictions can plan to accommodate future growth in a way that preserves, protects, and restores natural systems, habitats, and species, while at the same time identifying areas that are more suitable for additional development and growth. Protecting and restoring areas that are important to maintaining water flow and habitat will save time and money in the long-run, as fully functioning natural systems contribute significantly to reduced flooding and erosion, and support water flows and water quality important to people, wildlife, and aquatic species within the watershed. Additionally, understanding where to develop at the least environmental cost, creates certainty for both local jurisdictions seeking to accommodate growth, and for developers seeking to minimize time and costs associated with permitting development.

WHAT THE METHODS DO:

Watershed characterization models operate at a coarse scale and are intended to be used as decision support tools. They provide information. They prioritize areas on the landscape for restoration, protection, conservation and development. Local governments may choose to base their land use regulations on consideration of this information, in combination with more specific information. In the case of Gorst, the City of Bremerton intends to use the analysis provided in this report to develop a number of zoning and development alternatives which will be further analyzed in a programmatic Environmental Impact Statement on the Gorst Creek Watershed.

WHAT THE METHODS DO NOT DO:

The methods do not provide sufficient detail to be used to support individual restoration or protection actions. Neither do the methods provide prescriptive measures for what constitutes restoration, protection, or development. Rather, they are intended to provide high level guidance as to the type of restoration or protection action that is appropriate in a given area. General guidance as to appropriate types of actions is provided within appropriate sections of the report, but it is understood that this information will need to be supplemented with site specific information.

WHY GORST CREEK IS IMPORTANT:

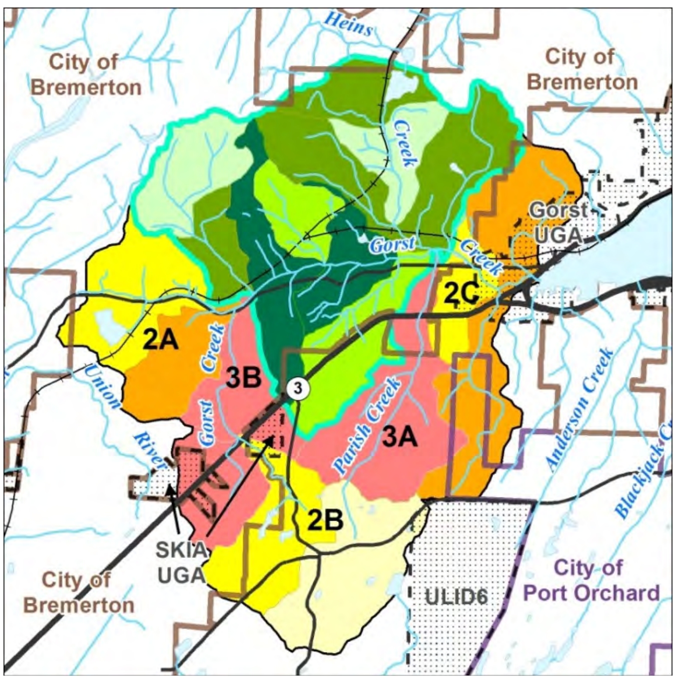
The Gorst Creek watershed is significant for a number of reasons:

- Public ownership and management of the forest land in the central portion of the watershed has protected water flow processes, which remain in relatively good condition, with respect to other portions of the landscape.
- Gorst Creek and its tributaries, including Sinclair Inlet at the mouth of Gorst Creek, support trout and anadromous salmonids and their habitat.
- The Gorst Creek watershed is described as "one of the largest and most productive watersheds in the east WRIA-15 subregion" in the 2003 Kitsap Salmonid Refugia Report (May and Peterson, 2003).

- Jarstad Creek has the greatest value for salmonid conservation in the watershed (May and Peterson, 2003).
- Heins Creek rated 'generally good' habitat conditions (May and Peterson, 2003).
- Gorst Creek, above river mile 1.0, rated 23rd of 95 salmonid refugia areas scored within Kitsap County (May and Peterson, 2003).
- The estuary (Sinclair Inlet) supports waterfowl, shorebirds, great blue herons, bald eagles, and is an important rearing and refuge area for juvenile Chinook salmon.
- The forested area that comprises the north and central portion of the Gorst Creek watershed is publicly owned, and lies within a contiguous area that also contains Green Mountain and Tahuya State Forest. Taken together, this area comprises the largest open-space block in the Puget Trough Ecoregion of the Puget Sound Basin.

While the Gorst Creek watershed contains significant natural resources, it is also an area which is anticipated to develop over the next several decades. Applying the results of watershed characterization yields the following map:

Watershed Management Zones



1 Protection Zone (Green). This area is key to recharge and discharge processes for Gorst Greek. Permitted uses must preserve forest cover and not result in conversion.

2. Restoration Zone (Yellow). Lower intensity uses.

A – Restore recharge, discharge, and delivery process, limit urban development, maintain in open space uses.
B – Residential uses but protect/restore storage functions of wetlands.
C – Restore recharge/discharge processes using LID measures.

3. Development Zone (Pink & Orange). Moderate to higher intensity urban uses.

A – Protect against erosion & sediment export with adequate setbacks, buffers & vegetation cover. Cluster development
B – Restore stream corridor; cluster development.

These results are overlain onto the habitat assessment, in Section 3.3 of this report. Generally, the recommendation is to protect the north central portion of the watershed, the tributaries, and the estuary, while allowing for additional growth and development in the south, and southeastern portions of the watershed, subject to existing protection measures and best management practices. Specifics on the integrated results are provided in Table 3-3, Section 3.3 of this report. These results provide high level guidance which will be used by the City of Bremerton to inform land use development alternatives in a programmatic Environmental Impact Statement as the City seeks to establish the groundwork for planning for growth, while at the same time protecting and conserving the significant natural resources of the Gorst Creek Watershed.

1. WHAT IS THE GORST CREEK WATERSHED CHARACTERIZATION PROJECT?

The Gorst Creek watershed characterization project represents a collaborative effort by state, federal, and local agencies and the Suquamish Tribe to use an integrated and holistic approach to watershed planning that benefits not only Gorst Creek but also provides long-term benefits to the region by creating a template to accommodate growth while restoring, protecting, and conserving existing natural resources which contribute to the quality of life in the region. The Puget Sound region's population has doubled from 2 million to 4 million since 1960, and is expected to reach 6.3 million by 2030 (OFM, 2007).

The intent of this report is to lay the ground work to accommodate additional growth while identifying areas within which key ecological processes and habitats that should be restored, protected, and conserved. By understanding where these processes occur on the landscape, and identifying areas within which more development can be accommodated with minimal harm to underlying ecological processes, patterns for development can be established that both accommodate projected growth, and restore, protect, and conserve the natural resources of the region. The focus of this report is the Gorst Creek watershed, a tributary to the Puget Sound. The Gorst Creek watershed is partially located within the City of Bremerton's Urban Growth Area (UGA), and partially within Kitsap County (Figure 1-1 shows a vicinity map, Map 2-1 shows UGAs within the project area).

Growth projections for Kitsap County indicate a projected increase of nearly one hundred thousand residents between 2010 and 2030 (OFM, 2007). Existing transportation infrastructure within the watershed includes state highways 3 and 16, which intersect along the shores of Sinclair Inlet at the mouth of Gorst Creek. These major transportation corridors convey traffic from Seattle, Tacoma, and Olympia to the Kitsap Peninsula and its major Navy facilities including Bangor, Keyport, and the Puget Sound Naval Shipyard.

Growth projections for Kitsap County indicate a projected increase of nearly one hundred thousand residents between 2010 and 2030 (OFM, 2007). Based on regional planning efforts:

- Approximately 20% of the new population is allocated to Bremerton city limits and its UGAs;
- A similar 21% of new population is allocated to Port Orchard city limits and the UGA
- Rural areas of the county are expected to absorb 24%.

Thus growth and development is anticipated over the next several decades in the Gorst Creek watershed to accommodate projected population increase. Growth in the Bremerton and Port Orchard city limits is anticipated on private lands. While the Gorst UGA by itself is expected to have a small share of new population growth (less than 1%) given its regional commercial focus, there is opportunity for more urbanization and land alteration according to County and City plans. Further development in unincorporated rural areas is also expected outside of the UGA and within the watershed.

As a significant waterbody in the watershed, Gorst Creek contains significant natural resources and supports runs of Chinook (*Oncorhynchus tshawytscha*) (supported by hatchery production), coho (*O. kisutch*), chum (*O. keta*), steelhead (*O. mykiss*), and sea-run cutthroat trout (*O. clarki clarki*). The Suquamish Tribe co-manages the hatchery on Gorst Creek and takes an active role in managing the natural resources within the watershed. The tribe harvests shellfish from Sinclair Inlet.

Implementing the recommendations of this report is anticipated to contribute to restoring and protecting Gorst Creek, Sinclair Inlet, and the natural resources which rely on the water flow and water quality of this watershed. By analyzing this information, the City of Bremerton and its partners can base future growth on an integrated approach to protecting and restoring ecological processes and habitat within the watershed, while integrating stormwater design and retrofits with green infrastructure to accommodate more development in those areas that are less sensitive to development.

1.1 HOW DOES THIS STUDY RELATE TO REGIONAL GOALS?

Significant technical analyses have already occurred, both in the Gorst Creek Watershed and in Kitsap County, as well as at the state, federal, and tribal level. Broad regional goals relating to environmental protection and development have been established at all levels of government. At the federal level, the U.S. Environmental Protection Agency (EPA) has developed a Strategic Plan for the Puget Sound. This project provides the basis for a planning framework to analyze a variety of growth scenarios (via a programmatic Environmental Impact Statement), as well as to prioritize projects that would improve and restore water quality on a watershed basis, and facilitate ecosystem-scale protection and restoration, in compliance with a number of goals articulated in EPA's Strategic Plan.

At the state level, the project is responsive to several goals identified by the Puget Sound Partnership in their Action Agenda. Specifically, those goals are: "to protect intact ecosystem processes, structures, and functions" and "to restore ecosystem processes, structures, and functions". In addition, the project is supported both by the Department of Ecology, the primary author of the watershed characterization analysis, and the Washington Department of Fish and Wildlife, the primary author of the fish and wildlife habitat assessment within the report. The Washington Salmon Recovery Funding Board (SRF Board) identified Gorst Creek as a priority area for Chinook restoration.

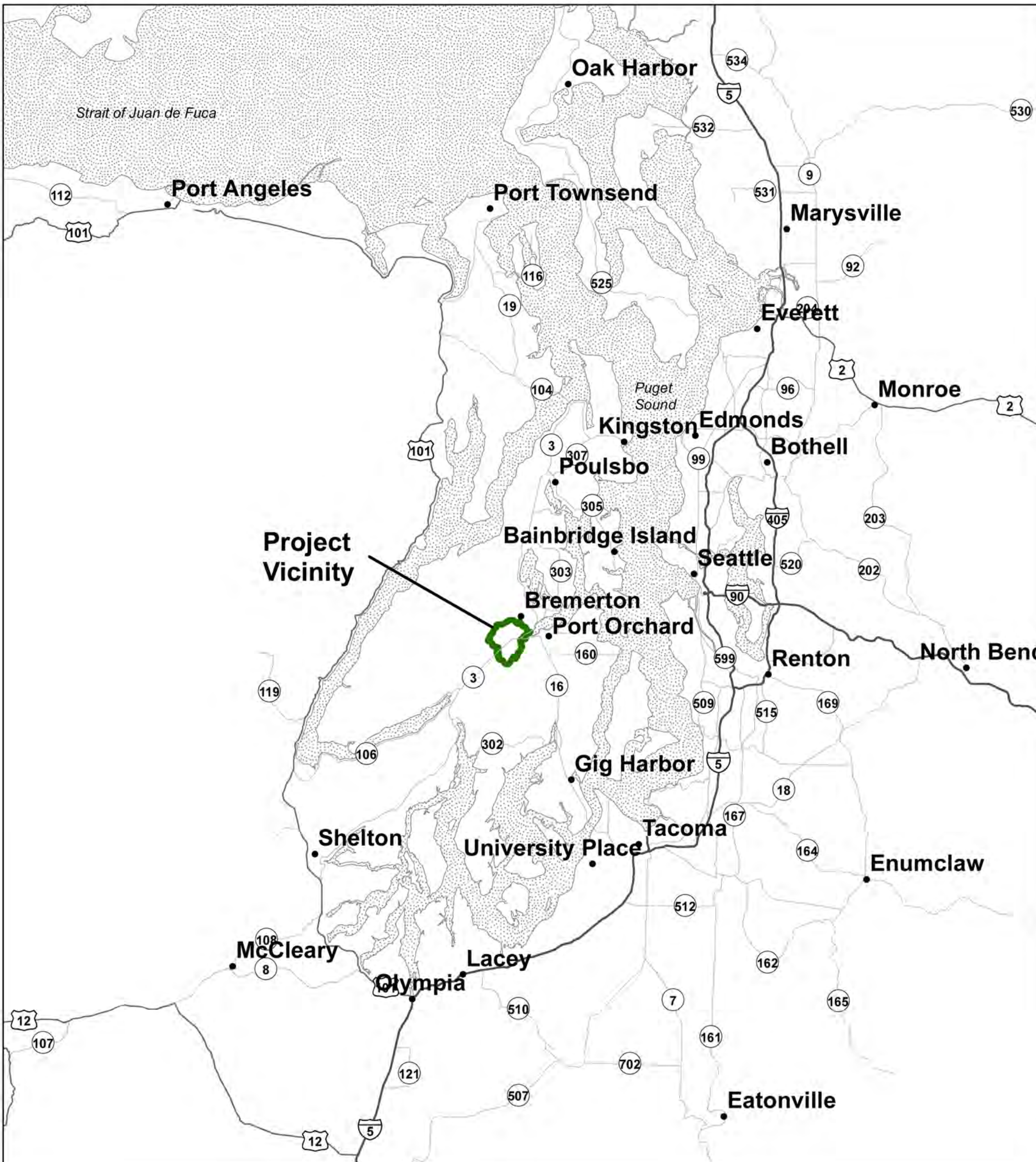
At the County level, the 2003 Kitsap Salmonid Refugia report (May and Peterson, 2003) also identified the creek as being of important regional significance. In addition, Kitsap County identified the following goals in its LID Initiative (2008): "protect water quality, preserve wetland and stream functions, encourage aquifer recharge, and provide cost-effective stormwater management". In response, this characterization will further inform analysis of existing stormwater infrastructure (in a separate technical memorandum) such that the siting of new facilities or stormwater retrofits complements the naturally occurring processes related to water flow within the watershed.

The Suquamish Tribe identified tribal goals in the Suquamish Tribal Resource Management (2008). The Gorst Creek Watershed Characterization Project can help achieve tribal goals in that, if the report recommendations are followed, and result in the protection and restoration of the most important areas for habitat and water flow, these actions would supportthe stated Tribal goals of providing the greatest diversity of species and habitats for wildlife on forest lands; providing long-term protection of habitat productivity for wild fish stocks; protecting the water quality needs of people, fish, and wildlife; and ensuring sustainable growth (Treaty Indian Tribes in Western Washington 2008).

City of Bremerton and Kitsap County: The information in this report will add to the City of Bremerton and Kitsap County's progressive use of best available science to inform local development regulations and ordinances, such as Critical Areas Ordinances, Shoreline Master Program updates, and Stormwater and Growth Management Comprehensive Plans including a Gorst UGA Subarea Plan that has been intiated through the current planning process.

1.2 WHAT IS THE SPECIFIC PURPOSE OF THIS REPORT?

This report creates a road map to achieve the regional and local goals identified above. The City of Bremerton and its stakeholders will develop growth scenarios premised on this report. Alternatives will be developed and analyzed in a programmatic environmental impact statement (EIS). Local land use will be premised on science-based understanding of protecting and restoring watershed processes and fish and wildlife habitat, while targeting new development and redevelopment towards less environmentally sensitive areas, and applying specific stormwater best management practices (BMPs), including LIDs to specific areas identified through this process.



Gorst Creek Watershed Characterization
City of Bremerton

Vicinity Map
Figure 1-1

Aug, 2011

0 10 Miles

N

Legend

Gorst Creek Watershed / Project Boundary

Interstate Route

US Route

State Route

City

Data Sources: Kitsap County, Washington Department of Transportation,

CITY OF BREMERTON

Path: K:\gis\1896-CoBremerton\232-1896-096_GorstMasterPlan\MapDocs\11x17Figs\WCR-1-1_Vicinity.mxd

2. WHAT IS WATERSHED CHARACTERIZATION?

Watershed Characterization refers to a GIS-based decision support tool that has been developed for the entire Puget Sound and its contributing drainages by the Washington Department of Ecology (Ecology) and its partner agencies, including the Puget Sound Partnership, Washington Department of Fish and Wildlife, and the Federal Environmental Protection Agency. The model can be scaled to analyze all of the drainages within the Puget Sound, or just one, as in the case of the Gorst Watershed Characterization Report. Application of the Watershed Characterization model provides information to support watershed planning for federal, state, and local agencies in the region. The primary focus of the model presented in this report is water flow. Models to assess water quality and fish and wildlife habitat are currently in process (Stanley et al. in preparation; Wilhere et al. in preparation).

The water flow assessment is based on the major watershed-scale hydrologic processes that naturally contribute to and affect stream flows; the subcomponents of the water flow process include an analysis of surface water delivery, storage, discharge, and recharge capacity (Stanley et al, 2010). The watershed characterization framework presumes an understanding of the iterative dynamics between ecosystem process, structure, and function. The underlying assumptions of these concepts are that ecosystems are influenced by the broad physical and chemical fluxes (the driving PROCESSES) of water, nutrients, sediment, heat, and organic material. In turn, these processes (such as river flow) lead to STRUCTURE (such as trees in a floodplain, as well as oxbows that provide off-channel salmonid-rearing habitat) and FUNCTION (habitat formed by both process, in this case river flow, and structure (vegetation and geomorphology) of these environments).

The intent of the water flow assessment is to understand the condition of these water flow processes across a given landscape, and to guide land use development actions so that these watershed-scale processes may be maintained or restored. The watershed therefore defines the unit of analysis for the water flow process. While the watershed characterization model can be run for the entire Puget Sound, it can also be scaled to subareas of interest, such as the Gorst Creek Watershed. Utilizing a different scale allows a user to focus on regionally significant issues (at the Puget Sound scale) or locally significant issues (at the subarea scale, such as the Gorst Watershed, which encompasses a roughly 20-square-mile area).

While fish habitat adapts easily to the scale of watershed analysis, wildlife are not constrained to watersheds. Terrestrial wildlife habitats exist across a landscape irrespective of watershed boundaries. The unit and method of analysis for terrestrial wildlife therefore differ from the approach used to characterize water flow processes.

While the methods and approach for each assessment are described in more detail in this report, the fundamental purpose of both analyses is to inform land use planning questions:

1) Where on the landscape should land use management efforts be focused?

2) What types of actions will be most effective to restore, protect and conserve?

3) Where should more development be sited?

In addition to providing information on water flow processes and fish and wildlife habitat in the Gorst Creek watershed, a separate technical report analyzes baseline stormwater conditions in the watershed. The combined analysis of water flow, habitat, and existing stormwater infrastructure actions are intended to identify areas for protection, and areas for more development, and thus support sustainable development within the Gorst Creek Watershed.

2.1 HOW WAS THE GORST CREEK WATERSHED CHARACTERIZED?

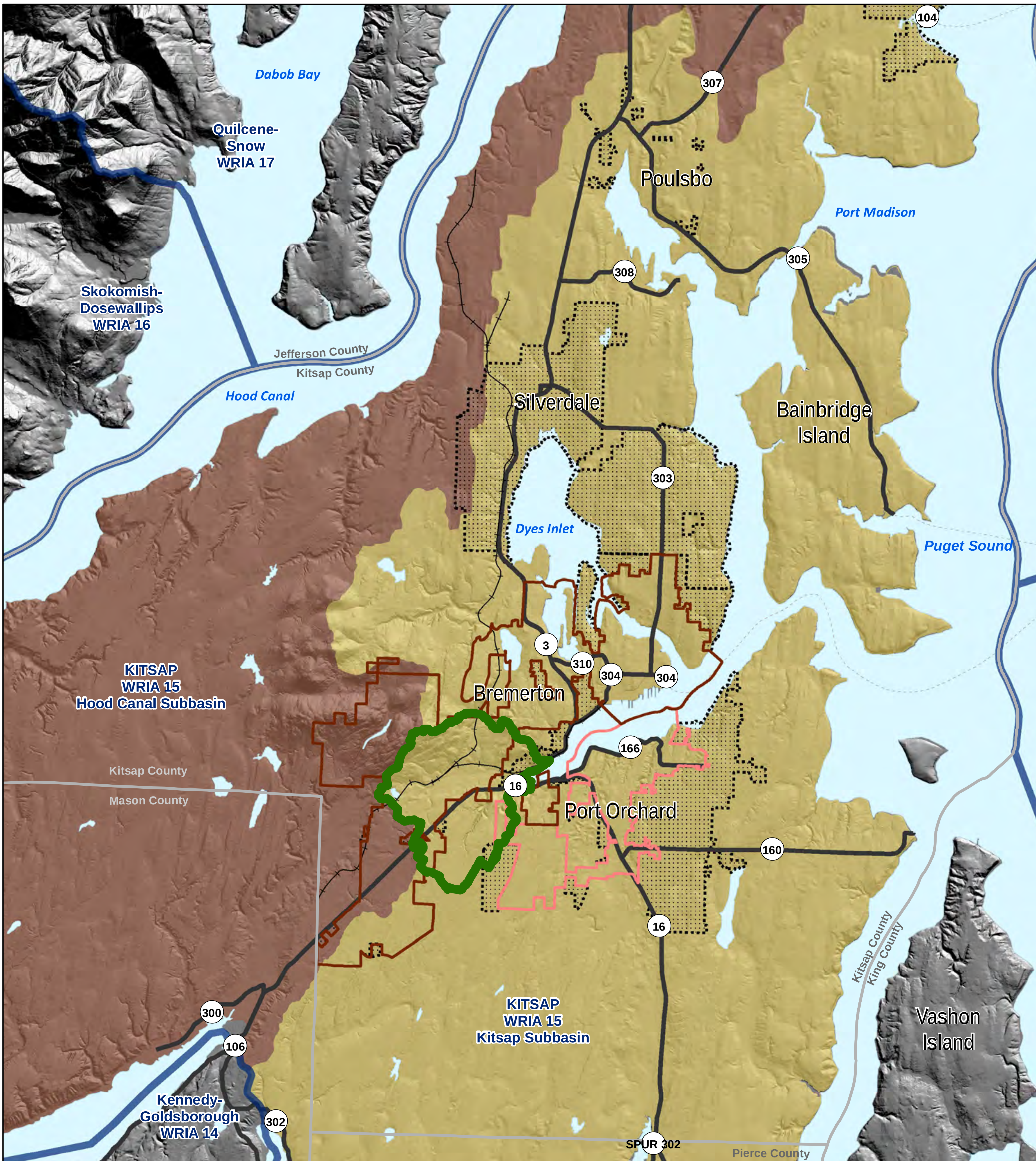
Application and analysis of the Gorst Creek Watershed Characterization is undertaken by a project team from the Department of Ecology. The initial step involves identifying the geographic area upon which the analysis will be run, and selecting GIS map units that correspond to the area of interest. The GIS model brings together the attributes that contribute to water flow in the landscape. The subcomponents of the water flow model include models for water delivery, surface storage, recharge, and discharge. More information on the model is found in The Puget Sound Characterization Methods, Models and Analysis (Stanley et al, 2009).

2.1.1 Project Area

The Gorst Creek watershed encompasses a portion of the City of Bremerton's city limits and UGA, a small portion of the Port Orchard city limits, and unincorporated Kitsap County on the western side of Puget Sound, in the central portion of Kitsap County, (Map 2-1). The project area lies within Water Resource Inventory Area (WRIA) 15, which encompasses all of Kitsap County and portions of Mason, Pierce, and King Counties (Vashon Island). Bremerton is located in the eastern portion of WRIA 15, or the East Kitsap Watershed, and most of the area comprises numerous small drainages flowing directly into Puget Sound (Map 2-2).

2.1.2 Watershed Description

The watershed covers approximately 7,000 acres in the southwestern portion of Kitsap County (Map 2-3). Approximately 3,000 acres are forested land owned by the City of Bremerton; approximately 3 percent of the remaining 4,000 acres include commercial, industrial, and residential zoned land developed with buildings and other impervious surfaces (Map 2-4). The watershed boundary and current zoning are shown on Map 2-5. The conditions in the upper Gorst Creek Watershed are largely undeveloped, with low levels of impervious surfaces, and wetland complexes in the headwaters that provide moderate to high functions, including floodwater retention, water quality, and habitat functions (Map 2-3). Gorst Creek drains into Sinclair Inlet. At the mouth of Gorst Creek is an estuary that has been degraded by shoreline armoring, fill, removal of shoreline vegetation, and the poor water quality of Gorst Creek More detailed information on the existing conditions of the watershed are found in the Inventory and Characterization Technical Memorandum, also prepared for this project (City of Bremerton, May 2011).



Gorst Creek Watershed Characterization
City of Bremerton

Regional Context
Map 2-1

Aug, 2011

0 2.5
Miles

N

Data Sources: Kitsap County, City of Bremerton, Washington Department of Natural Resources, Washington Department of Ecology, Washington Department of Transportation,

CITY OF BREMERTON

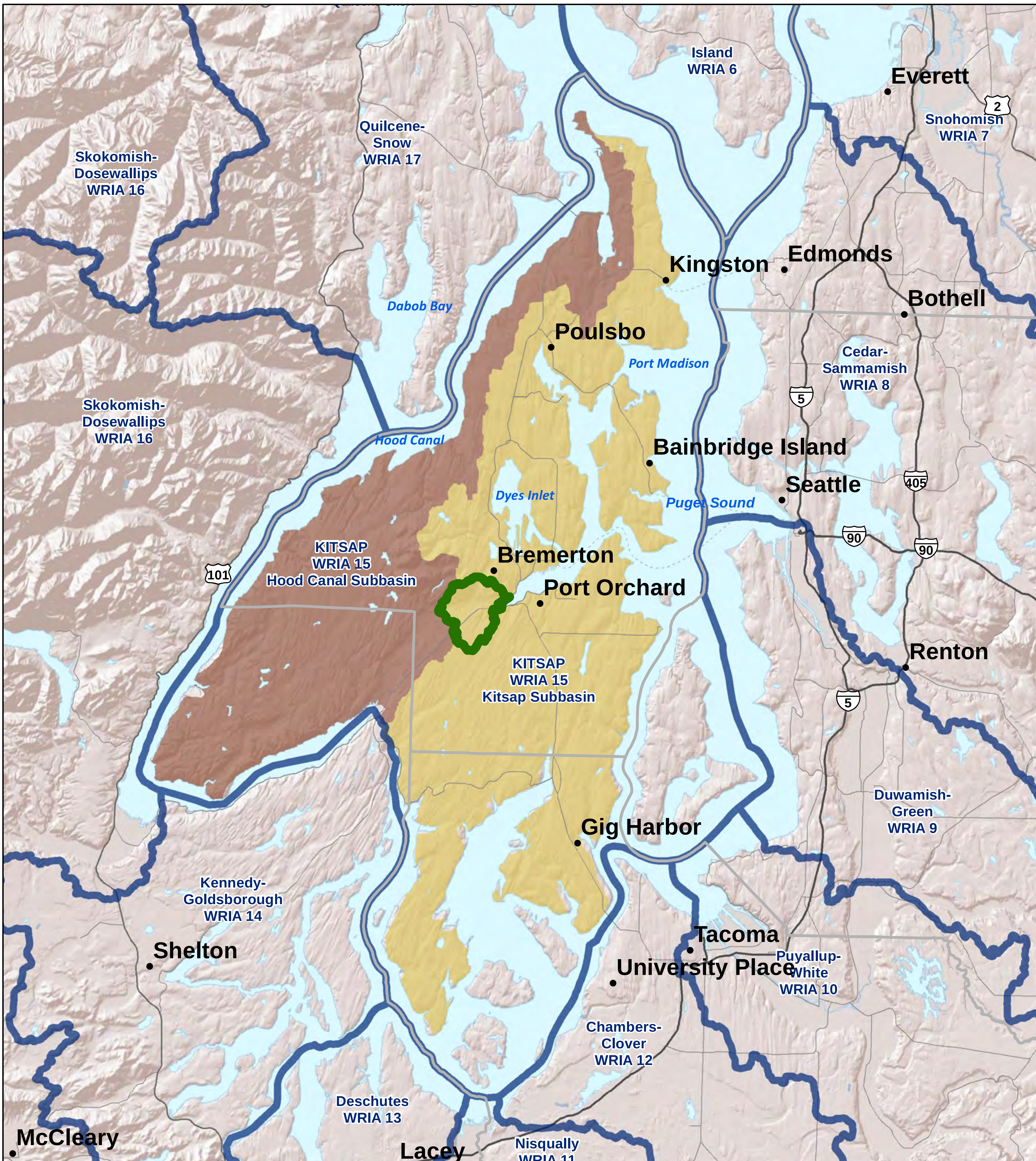
Legend

- Gorst Creek Watershed / Project Boundary
- County Boundary
- Water Resource Inventory Area (WRIA)
- City of Bremerton
- City of Port Orchard
- Railroad
- State Route
- Urban Growth Area
- Waterbody

WRIA 15 Subbasins (Hydrologic Unit Code (HUC) Subbasin)

- Hood Canal
- Kitsap

Path: K:\gis\1896-CoBremerton\232-1896-096_GorstMasterPlan\MapDocs\11x17Figs\WCR-2-1_RegionalContext.mxd



Gorst Creek Watershed Characterization
City of Bremerton

Puget Sound WRIAs
Map 2-2

Aug, 2011

0 6
Miles

N

Legend

- Gorst Creek Watershed / Project Boundary
- County Boundary
- Water Resource Inventory Area (WRIA)
- Interstate Route
- US Route
- State Route
- Waterbody

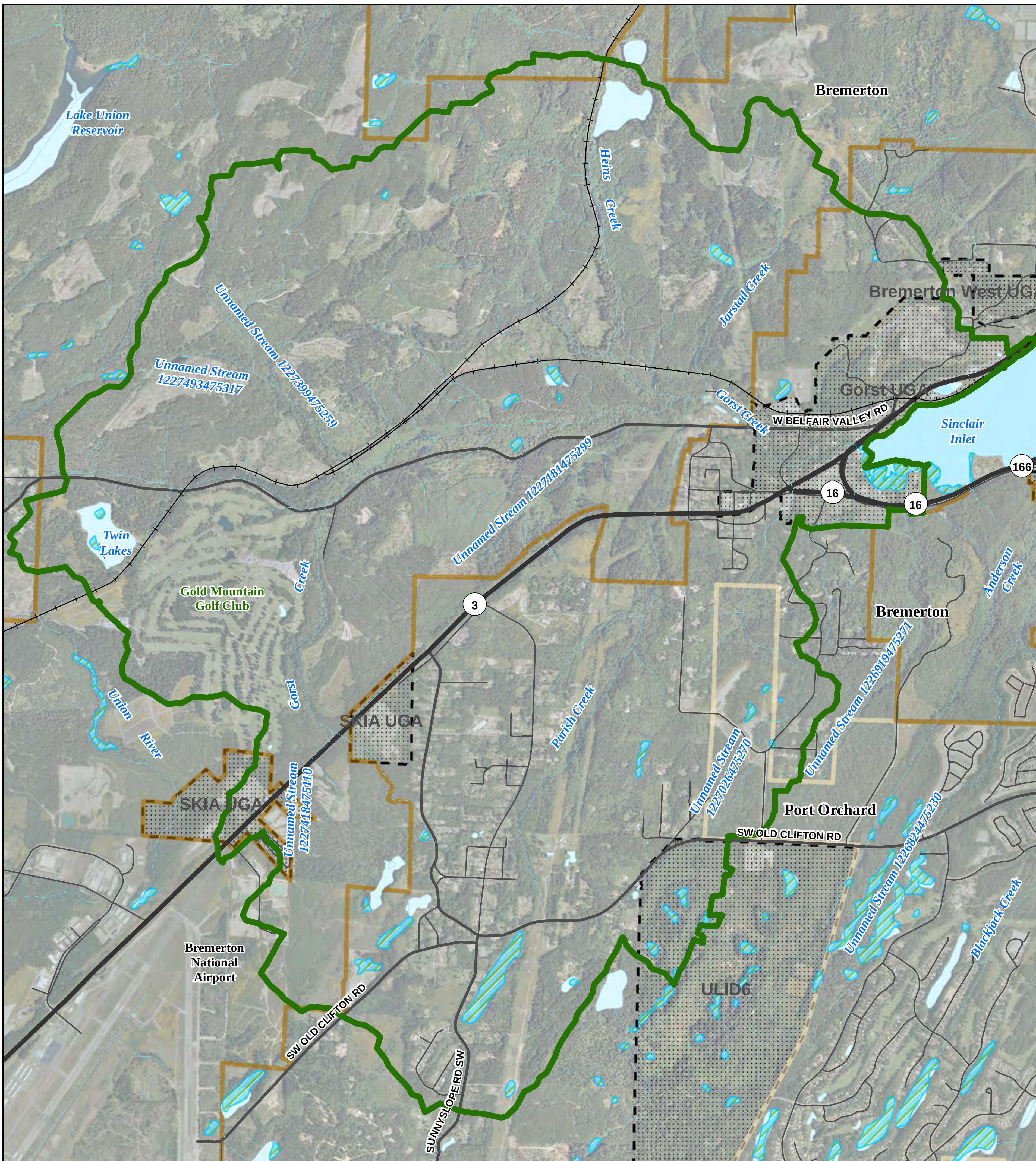
WRIA 15 Subbasins (Hydrologic Unit Code (HUC) Subbasin)

- Hood Canal
- Kitsap

Data Sources: Kitsap County, City of Bremerton, Washington Department of Natural Resources, Washington Department of Ecology, Washington Department of Transportation,

CITY OF BREMERTON

Path: K:\gis\1896-CoBremerton\232-1896-096_GorstMasterPlan\MapDocs\11x17Figs\WCR-2-2_WRIA.mxd



Gorst Creek Watershed Characterization
City of Bremerton

Gorst Creek Watershed Planning Area
Map 2-3

Aug, 2011

0 2,200

Scale in Feet

N

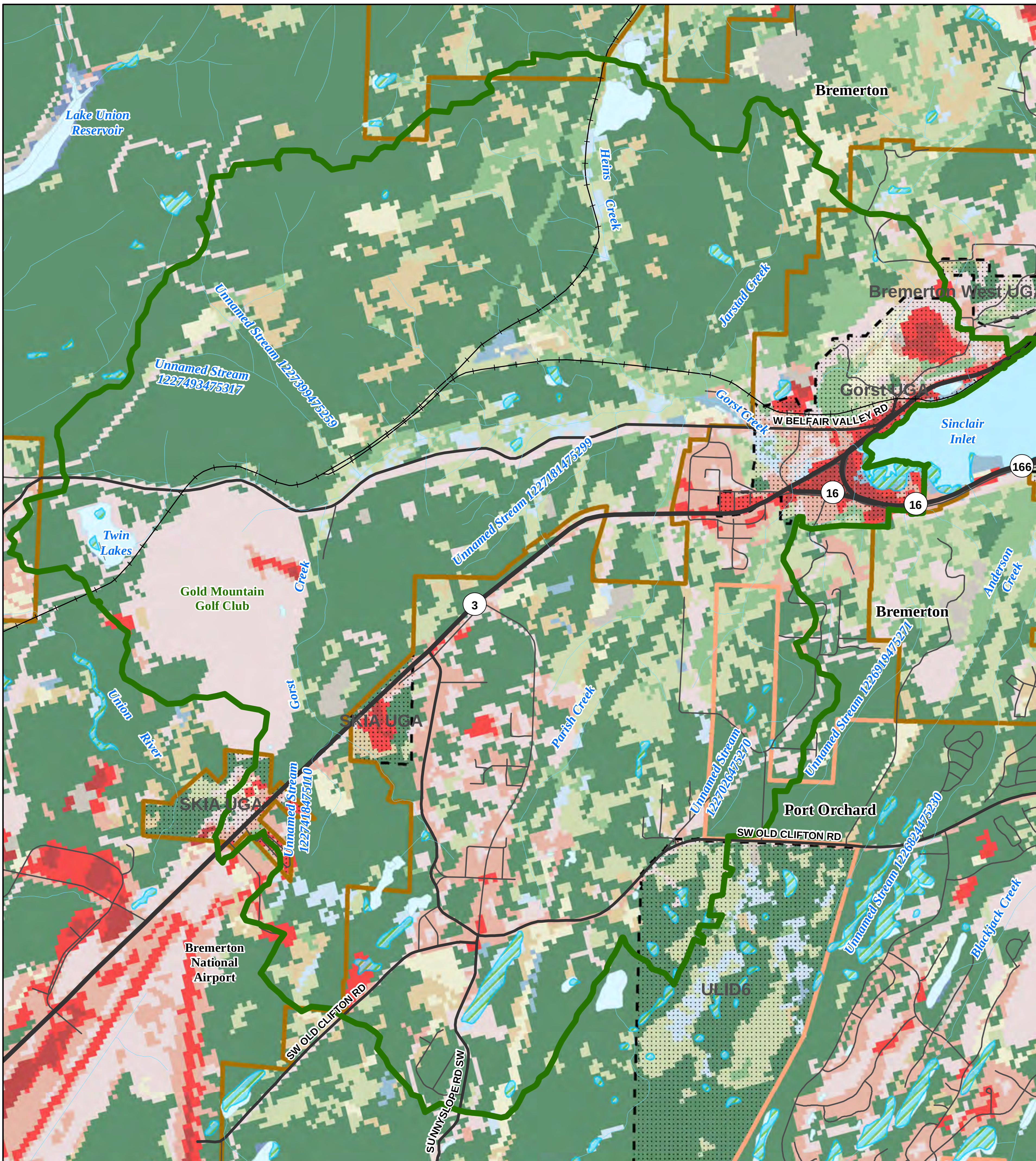
Legend

- Gorst Creek Watershed / Project Boundary
- Urban Growth Area
- City of Bremerton
- City of Port Orchard
- Road
- Railroad
- Stream
- Wetland (WDFW/NWI)
- Waterbody

Data Sources: Kitsap County, City of Bremerton, Washington Department of Natural Resources, Washington Department of Transportation, Washington Department of Fish and Wildlife (WDFW), National Wetland Inventory (NWI).

CITY OF BREMERTON

Path: K:\gis\1896-CoBremerton\232-1896-096_GorstMasterPlan\MapDocs\11x17Figs\WCR-2-3.mxd



Gorst Creek Watershed Characterization
City of Bremerton

Landcover
Map 2-4

Aug, 2011

0 2,200
Scale in Feet

N

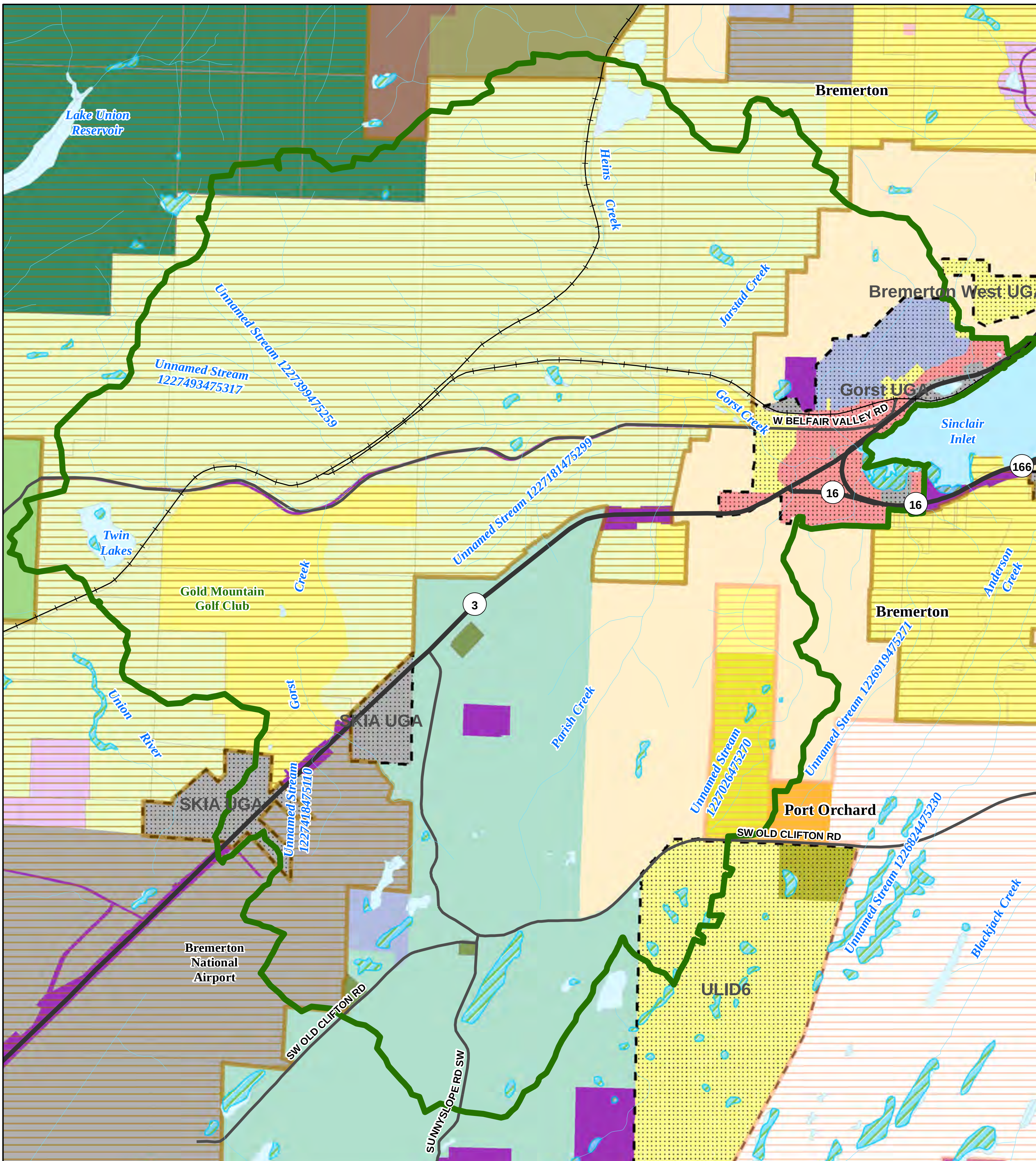
Data Sources: Kitsap County, City of Bremerton, Washington Department of Natural Resources, Washington Department of Transportation, Washington Department of Fish and Wildlife (WDFW), National Wetland Inventory (NWI), United States Geological Survey (USGS)

CITY OF BREMERTON

Legend

- Gorst Creek Watershed / Project Boundary
- Urban Growth Area
- City of Bremerton
- City of Port Orchard
- State Route
- Primary Road
- Secondary Road
- Railroad
- Stream
- Wetland (WDFW/NWI)
- Waterbody
- Open Water
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Bare rock, sand, quarry, strip mine, gravel pit, transitional barren
- Deciduous forest
- Evergreen forest
- Mixed forest
- Scrub/Shrub
- Grasslands, herbaceous
- Pasture, hay
- Cultivated Crops

Path: K:\gis\1896-CoBremerton\232-1896-096_GorstMasterPlan\MapDocs\11x17Figs\WCR-2-4_Landcover.mxd



Gorst Creek Watershed Characterization City of Bremerton

Land Use
Gorst Creek Watershed Planning Area
Map 2-5

July, 2011

0 2,200

Scale in Feet

N

Data Sources: Kitsap County, City of Bremerton, Washington Department of Natural Resources, Washington Department of Transportation, Washington Department of Fish and Wildlife (WDFW), National Wetland Inventory (NWI).

CITY OF BREMERTON

Legend

- Gorst Creek Watershed / Project Boundary
- Urban Growth Area
- City of Bremerton
- City of Port Orchard
- Road
- Railroad
- Stream
- Wetland (WDFW/NWI)
- Waterbody
- City Parcel

Landuse (City and County)

- Low Density Residential
- Medium Density Residential
- Medium/High Density Residential
- High Density Residential
- High Intensity Commercial Mixed Use
- Neighborhood Business
- Freeway Corridor
- Forest Resource Lands
- Incorporated City
- Industrial
- Industrial Park
- Mineral Resource
- Rural Protection
- Rural Residential
- Rural Commercial
- Rural Wooded
- Urban Reserve
- Watershed
- City Utility Lands
- Tranportation and Public Facilities

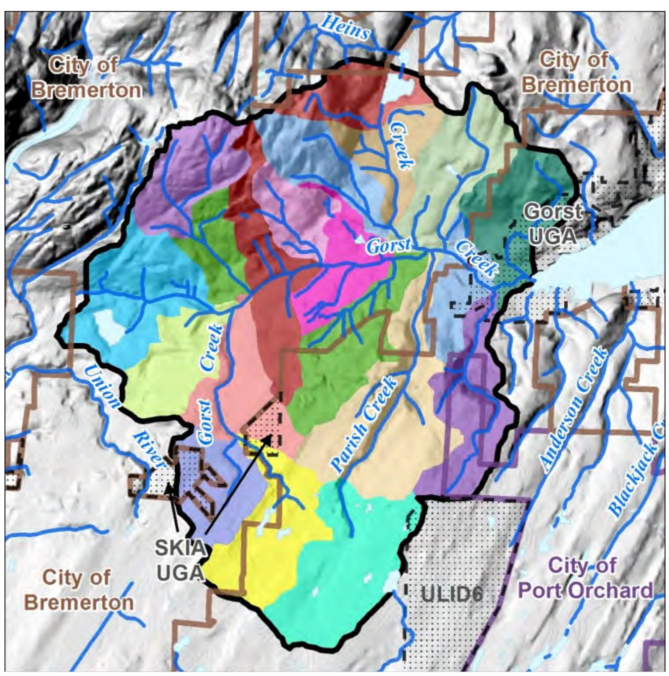
Path: K:\gis\1896-CoBremerton\232-1896-096_GorstMasterPlan\MapDocs\11x17Figs\WCR-2-5_Landuse.mxd

2.1.3 Primary Purpose and Elements of the Watershed Characterization

The watershed characterization consists of evaluating the water flow processes for delivery, storage, and recharge/discharge, an assessment of existing conditions of fish and wildlife habitats, including the marine nearshore of the Gorst Creek estuary, and the synthesis of that information into broad-scale recommendations for management of the watershed. The information on the watershed and fish and wildlife habitat forms the basis of recommendations to inform a land use development plan, which will be further analyzed through a programmatic EIS for the watershed, including a planned action component for the Gorst UGA. Additionally, in a separate technical memorandum, information regarding stormwater infrastructure will be analyzed as an overlay to the watershed and fish and wildlife habitat conditions. Areas for stormwater retrofits, LID, and BMP implementation will be identified to support development of green infrastructure. Green infrastructure can complement other land use management actions that support protection and conservation of existing natural processes related to water flow and fish and wildlife habitat. Green infrastructure, and areas for LID and stormwater retrofits should be sited in portions of the watershed that are less sensitive to change, as determined both by the watershed characterization and local habitat assessment.

Benedict and McMahon (Weber and Allen 2010) define green infrastructure as "*strategically planned and managed networks of natural lands, working landscapes, and other open space that conserve ecosystem functions and provide associated benefits to human populations.*" By first considering existing landscape processes related to water flow, then integrating information on fish and wildlife habitat, and applying an overlay of stormwater infrastructure, the City of Bremerton and Kitsap County can move forward with an analysis of development alternatives that is science-based. This report thus provides a roadmap to inform future land use planning that accommodates new development, redevelopment, as well as green and grey infrastructure (stormwater, roads, sewers) in such a way to preserve and protect existing ecological processes, resulting in long-term, sustainable development within the watershed.

2.1.4 Approach to Watershed Characterization



Units (colored sub-basins).

Figure 2-1. Study Area for Gorst Creek Watershed

> ***Watershed Processes:*** In this document, *watershed processes* refer to the dynamic physical and chemical interactions that form and maintain the landscape at the geographic scales of watersheds to basins (from hundreds to thousands of square miles).
>
> These processes include the movement of water, sediment, nutrients, pathogens, toxins, and wood as they enter, move through, and eventually leave the watershed.

The central assumption to the watershed characterization approach is that the health of aquatic resources is dependent upon intact, upgradient watershed processes. Research has demonstrated that analysts must consider the watershed processes that occur outside of aquatic ecosystems if the lakes, rivers, wetlands, and estuaries are to be protected and restored (National Research Council 2001; Dale et al. 2000; Bedford and Preston 1988; Roni et al. 2002; Poiani et al. 1996; Gersib 2001; Gove et al. 2001).

Management and regulation of these aquatic ecosystems have typically concentrated on the biological, physical, and chemical character of the individual lake, wetland, stream reach, or estuary, but not on the larger watershed that controls these characteristics.

Scientific studies have shown that watershed processes interact with landscape features, climate, and each other to produce the structure and functions of aquatic ecosystems that society is interested in protecting (Beechie and Bolton 1999). For example, flooding along streams can create off-channel habitat that is important for fish. Much of the research concludes that protection, management, and regulatory activities could be more successful if they incorporated an understanding of watershed processes.

2.1.5 Watershed Characterization Model Outputs and Application

When watershed data are applied to the watershed characterization model, a map is produced that displays the model outputs of each subcomponent of water flow (delivery, storage, recharge, and discharge). In addition to the subcomponent maps, the model also produces a synthesized map that illustrates priorities for protection and restoration and further identifies recommended management zones, which can be used by the City of Bremerton and Kitsap County to develop a watershed-based management plan. In addition to the maps (one for each model subcomponent as well as an integrated map), a list of watershed actions and recommendations to protect and restore key processes and functions is presented (see Section 3.4). Focal restoration areas (identified to the Assessment Unit or AU scale, which is .2 to 1 square mile for the Gorst Creek Watershed analysis) can include aquatic resources such as wetlands and riparian areas, as well as upland areas that are important to maintaining processes for these aquatic resources.

In addition to providing the basis for regulatory updates, such as Shoreline Master Programs (SMPs), Critical Areas Ordinances (CAOs), and Comprehensive Plans, the watershed characterization results can also provide the basis for programmatic watershed mitigation programs such as mitigation banking, in-lieu fee programs, and transfer of development rights. This is true because the synthesized maps identify specific assessment units (areas of .2 to 1 square mile) within which discrete actions can be taken to restore water flow processes. While additional information on site-specific actions and designs would need to be developed, the watershed characterization shows both **where**, on the landscape, to focus land use management efforts, and **what** ecological processes should be targeted for restoration.

2.2 FISH AND WILDLIFE HABITAT ASSESSMENTS- UNDERSTAND EXISTING RESOURCES AND PLAN ACCORDINGLY

Fish and wildlife are valuable public resources. In general, conversion of agricultural or commercial forests to residential and commercial uses degrades or destroys the habitats that support fish and wildlife. Effective land use zoning can result in “smart” growth that minimizes the loss and degradation of fish and wildlife habitats. To realize effective zoning, comprehensive land use plans must be based on objective, accurate information, including information on the value of local fish and wildlife habitats.

This report also assesses the current relative importance of places in the Gorst Creek Watershed for the conservation of fish and wildlife habitats. The main products of the fish and wildlife habitat assessments are maps of the Gorst Creek Sub-basin that show current relative value expressed as a quantitative index. This assessment will be integrated with assessments for water flow, which can be used by the City of Bremerton and Kitsap County to develop a programmatic EIS for the Gorst Creek Sub-basin.

2.2.1 Fish and Wildlife Habitat Assessment Methods

Because of differences in dimensions, scale, data quality, and ecosystem-level processes, the fish and wildlife assessment was subdivided into three separate assessments: terrestrial, marine nearshore, and freshwater. Detailed explanations of methods for the terrestrial and marine nearshore assessments are presented in Wilhere et al. (in preparation). For the freshwater assessment, the results of the 2003 Kitsap Salmonid Refugia Report (May and Peterson 2003) were relied upon.

2.2.2 The Challenges of Assessing Importance

The primary task of this assessment is to evaluate the relative importance of areas on the landscape with respect to their value for fish and wildlife habitat. Certain places in a region are readily identified as important or even irreplaceable because they contain rare habitat types, imperiled species, or abundant wildlife. For instance, in the Puget Trough Ecoregion, the prairies of Fort Lewis, the tidelands at the Nisqually River delta, and the waterfowl over-wintering areas of the Skagit River delta are universally recognized by fish and wildlife biologists as crucial places for habitat conservation. The importance of such places is obvious and absolute—experts are certain that these places should be protected for their ecological values. Most other places lack rare habitats, imperiled species, or abundant wildlife. Such places may have importance for the conservation of wildlife habitats, but they lack those qualities that would make their protection obvious. The importance of places with “common” habitats can be assessed, but only in a relative sense, and decisions regarding the protection of these places must be based on relative importance. Hence, for the multitude of places that contain only common habitats, this assessment cannot determine whether site A or site B should be protected; it can only determine that site A is relatively more valuable than site B and, therefore, site A should be given a higher priority for protection than site B.

The spatial scale at which an assessment is conducted affects one’s interpretation of relative importance. For instance, a site could have moderate relative importance in the Puget Trough Ecoregion but have the highest relative importance in WRIA 15. A land use plan for WRIA 15 might target that site for protection, but a conservation plan for the Puget Trough Ecoregion probably would not. Assessments at multiple scales help to determine protection priorities. A site with high regional importance would be considered more important to regional authorities than a site that has high local importance but only low or moderate regional importance. For this project, WDFW analysts calculated relative importance scores at multiple scales, which were different for terrestrial, marine nearshore, and freshwater assessments.

Measures of “importance” are normative. There is no purely objective “importance” that can be empirically validated. “Importance” is based on one’s belief of about what is valuable; therefore, it is influenced by personal values. How various data should be assembled into a measure of value may be different for each person. Nevertheless, scientists, policymakers, and stakeholders can reach consensus on what factors should be used to indicate importance and on the relative influence of those factors.

The relative importance of a place for the conservation of fish and wildlife habitats can be based on a variety of factors (Wilhere et al. 2008): rarity of species or habitat-types, richness of species or habitat types, the presence of imperiled species (i.e., listed as threatened or endangered), species endemism, local abundances of particular species or habitat types, metrics of habitat quality, or ecological integrity. These factors quantify different aspects of importance and therefore a truly comprehensive assessment would include all of them; however, WDFW lack the data needed to estimate most of them.

Empirical data on the locations of wildlife species collected by WDFW and other agencies generally focus on imperiled species or harvested species. For the majority of other wildlife species, site-scale location data are based on incidental observations or incomplete surveys or are out of date. Furthermore, data accuracy tends to be a function of a species' sightability; location data for highly visible species (e.g., large bodied in open habitats) tend to be more accurate than data for less visible species (e.g., small bodied with cryptic markings in densely vegetated habitats). For nearly all vertebrate species, comprehensive data on wildlife locations are available as range maps, but these can be highly inaccurate at spatial scales of about 1 square mile or less. For the locations of habitat types, satisfactory empirical data are available for rare or imperiled habitat types, such as oak woodlands and prairies. Location data for other habitat types are available as landcover maps derived from remotely sensed satellite images. These landcover data tend to have either low classification accuracy (e.g., 35 percent error or worse) or low thematic precision, i.e., a small number of landcover categories. Both shortcomings preclude an accurate mapping of habitat types, species-specific habitats, or habitat quality.

In summary, practical measures of importance are constrained by the types, quantity, and quality of available data. The challenge was to develop an assessment that respected the limitations imposed by the spatial data but still served as a useful, credible indicator of relative importance at a spatial scale relevant to the Gorst Creek Watershed Characterization Stud.

2.2.3 Terrestrial Habitat Assessment

WDFW analysts assessed the relative importance of places for the conservation of terrestrial wildlife habitats at three spatial scales: within the Gorst Creek Watershed, WRIA 15, and the Puget Trough Ecoregion. The smallest scale assessment shows the relative importance of places within the Gorst Creek Watershed. The two larger scale assessments indicate the importance of places in the watershed compared to other places in the region. The two larger scales were done with the same assessment method, but the regions over which places were compared were different. The smallest scale was done with a different method.

2.2.3.1 Regional Assessments

To make the most of comprehensive data which were available, WDFW analysts looked for ways to simplify the regional assessments. They started with a conceptual model of terrestrial habitats and land use in the Puget Sound Basin.

The water flow assessment was based on the major watershed-scale hydrological processes that naturally contribute to and affect stream flows; the subcomponents of the water flow process included an analysis of surface water delivery, storage, discharge, and recharge capacity. Unlike the water flow assessment, the conceptual model for the terrestrial habitats assessment was not process-based. It was not processed-based because in the lower-elevation landscapes of the Puget Sound Basin where city and county governments have principal jurisdiction over land use, there are no natural landscape-scale processes related to habitat formation that have not been severely altered by existing land use patterns.

Prior to European settlement, the most important landscape-scale terrestrial process in the Puget Sound Basin was fire. The moist western hemlock forests of the western Cascades had a fire return interval of 200 to 500 years (Agee 1993). Stand-replacing fires occurred after periods of prolonged drought and burned over many thousands of acres. Over the past century, however, wildfire has been controlled for the purposes of protecting property and valuable forest resources; consequently, fire has been effectively eliminated from the Puget Sound lowlands and Cascades foothills.

Smaller-scale (on the order of ¼ to 100 acres) natural disturbances caused by wind or landslides still occur, but the dominant large-scale disturbances are now those related to human land uses (Figure 2-2). Residential, commercial, industrial, and agricultural land uses convert natural or semi-natural habitats to non-natural habitats. Many of these non-natural habitats, particularly in commercial and industrial land uses, have almost no value as habitats for native species. In nearly all cases, conversion to residential, commercial, industrial, and agricultural land uses results in the permanent loss or degradation of native habitats.

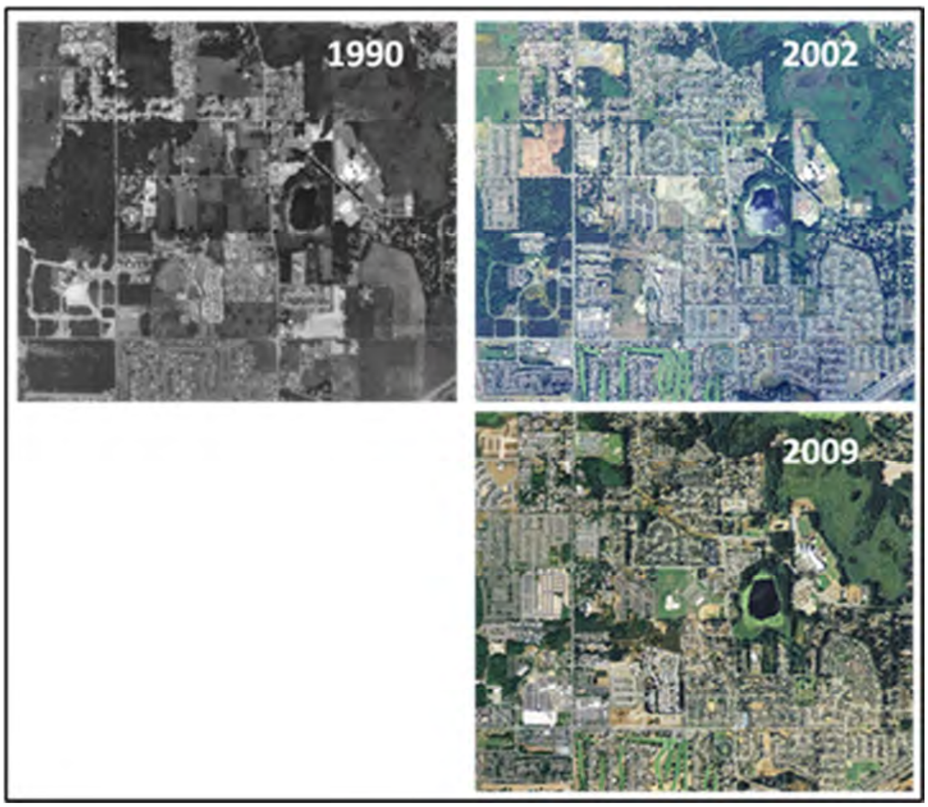


Figure 2-2. The Dominant Process in Terrestrial Landscapes of Puget Sound Basin—the Conversion of Lands to Different Land Uses

These aerial photographs were taken in Lacey, Washington over a period of 19 years.

Private forestry is arguably an exception to the habitat loss that occurs through most other anthropogenic (caused by human activities) land use conversions. Private commercial forests of the Puget Trough Ecoregion are mostly third-, fourth-, and fifth-growth forests managed for timber. Forestry can, to a limited degree, mimic some aspects of natural disturbance and succession because while it changes both the structure and function of the forest, the end result still allows for the continued existence of habitats for many native species. Although private commercial forests are lacking in number and diversity of species, they contain key structural components of late-successional forests that historically dominated the Puget

Sound lowlands and Cascades foothills (such as large trees, large snags, and large logs). Moreover, this type of forestry supports a wide variety of native common wildlife species, including several species of large mammals such as black-tailed deer (*Odocoileus hemionus columbianus*), black bear (*Ursus americanus*), cougar (*Felis concolor*), and bobcat (*Lynx rufus*). Landscapes comprising private commercial forests are relatively similar in character, but differences in forest stands occur due to differences in management practices.

In the Puget Sound Basin, agricultural land uses—in particular, pasture, orchards, and grain fields—can provide high value habitats for certain species. For instance, pastures provide habitat for elk (*Cervus canadensis roosevelti*), and harvested grain fields provide winter-feeding and resting areas for snow geese (*Chen caerulescens*) and other migratory water fowl.

In the WDFW conceptual model there are four main land uses: private forestry, private agriculture, residential-commercial-industrial, and public natural resources. Private forestry, private agriculture, and public natural resources were considered "open space," and all open space was assumed to have habitat value. Agricultural and commercial forest lands are collectively known as working lands. WDFW analysts assumed that the residential-commercial-industrial land use has no habitat value for native species. This is not entirely true, especially for residential land uses, but the data needed to determine the habitat value of different residential areas were not available. Furthermore, residential land uses can be subject to substantial changes in land use intensity, and the analysts could not accurately project where residential areas would undergo increased development (and a consequent decrease in habitat value). Furthermore, the WDFW analysts lacked the spatial data needed to make distinctions among different types of agriculture, such as pasture, orchard, and row crops. In addition, the analysts lacked the data needed to make distinctions among different management practices in private forests, such as differences in stand rotation age or differences in structural retention. Consequently all private agriculture was treated as equivalent and all private commercial forest land was treated as equivalent.

The WDFW conceptual model reduces importance to two main components: 1) the presence of Priority Habitats and Species (PHS), and 2) the degree of open-space fragmentation (Figure 2-3). Priority habitats are habitat types with unique or significant value to a diverse assemblage of species. A priority habitat may consist of a unique vegetation type (e.g., prairie) or dominant plant species (e.g., oak woodland), a described successional stage (e.g., old-growth forest), or a specific habitat feature (e.g., cliffs). Priority species require protective measures for their survival due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal value. Priority species include state endangered, threatened, sensitive, and candidate species; as well as animal aggregations considered vulnerable (e.g., heron colonies, bat colonies). Much of the PHS data are site-scale (e.g., nest and den sites, communal roosts), which do not match the scale of the assessment. WDFW analysts used only PHS data that were "regional-scale" occurrences, defined as occurrences greater than 100 acres. In the Puget Sound Basin, oak-prairie habitats are highly imperiled; hence, they were given special consideration in the model.

As discussed above, the conceptual model assumes that all private agricultural land uses are equivalent and all private commercial forest land uses are equivalent. A lack of information in the available spatial data forced these assumptions. However, available data did enable the WDFW analysts to model other differences in relative habitat values among open-space lands: fragmentation, land use, and vegetation zones. For the conservation of wildlife, size matters. In fact, the area of contiguous habitat may be the single most important variable determining the long-term viability of wildlife populations (Diamond 1975; Soule and Simberloff 1986). Other landscape-scale metrics of fragmentation, such as habitat patch compactness, habitat patch isolation, and habitat patch density, also influence the relative importance of wildlife habitats (Figure 2-4). For the region-wide assessment, open-space fragmentation was primarily a function of contiguous habitat area modified by these other fragmentation metrics.

The WDFW analysts felt confident about making expert judgments about the relative impacts of various land uses on relative habitat value. WAC 458-53-030 (from Chapter 458-53 WAC, Property Tax Annual Ratio Study) lists 83 different land uses that are used for the Washington State tax code. A parcel database (RTI 2010) contains the land use for all private land parcels in Puget Sound Basin, including Kitsap County[1]. The analysts grouped the 83 land uses into six general categories (residential-commercial-industrial, recreational open space, open space, agriculture, mining, forestry) and assigned habitat impact values to those categories. The relative habitat value of a place was in part a function of the land uses occurring in and around that place.

The conceptual model divided the Puget Sound Basin into six vegetation zones (Figure 2-5). The rate of habitat conversion and amount of habitat protection within each zone is very different among vegetation zones. For instance, 89 percent of high elevation zones in Puget Sound Basin (2.9 million acres) have some level of protection on public lands. However, only 11 percent of low elevation vegetation zones in Puget Sound Basin—prairie and oak woodland, Puget Sound Douglas-fir (*Pseudotsuga menziesii*), and Sitka spruce (*Picea sitchensis*)—are protected on public lands. Low elevation zones contain imperiled habitats such as oak woodlands and prairies, uncommon habitats such as stands of mixed Douglas-fir and madrone (*Arbutus menziesii*), and biologically rich and productive habitats such as large wetland complexes and river floodplain forests. Habitats in low elevation zones are more at risk than habitats in higher elevation zones; therefore, in the conceptual model open space in low elevation zones were considered more important than open space at higher elevations.

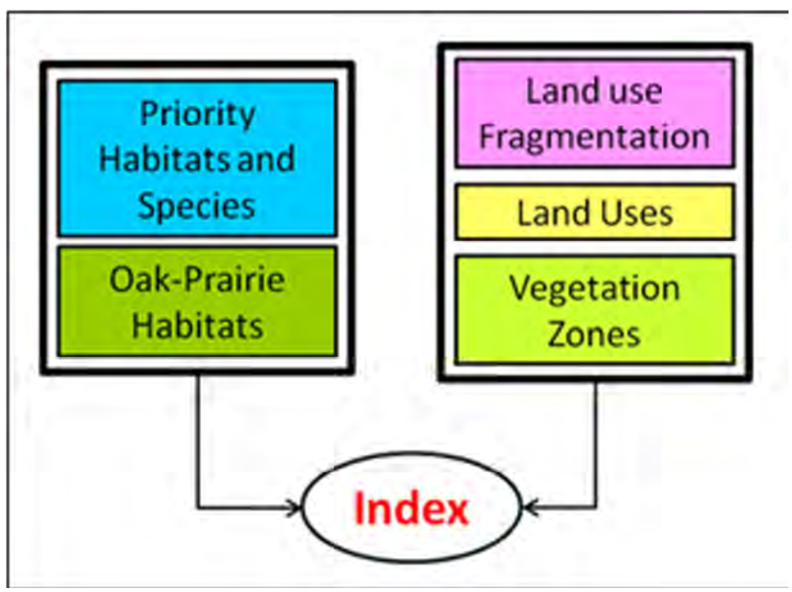


Figure 2-3. Major Components of the Terrestrial Habitat Assessment for the Puget Sound Basin

The index score is assigned to each open-space block. Land use fragmentation index is based on conceptual model in Figure 2-4 and vegetation zones are shown in Figure 2-5.

[1] An exception is Island County.

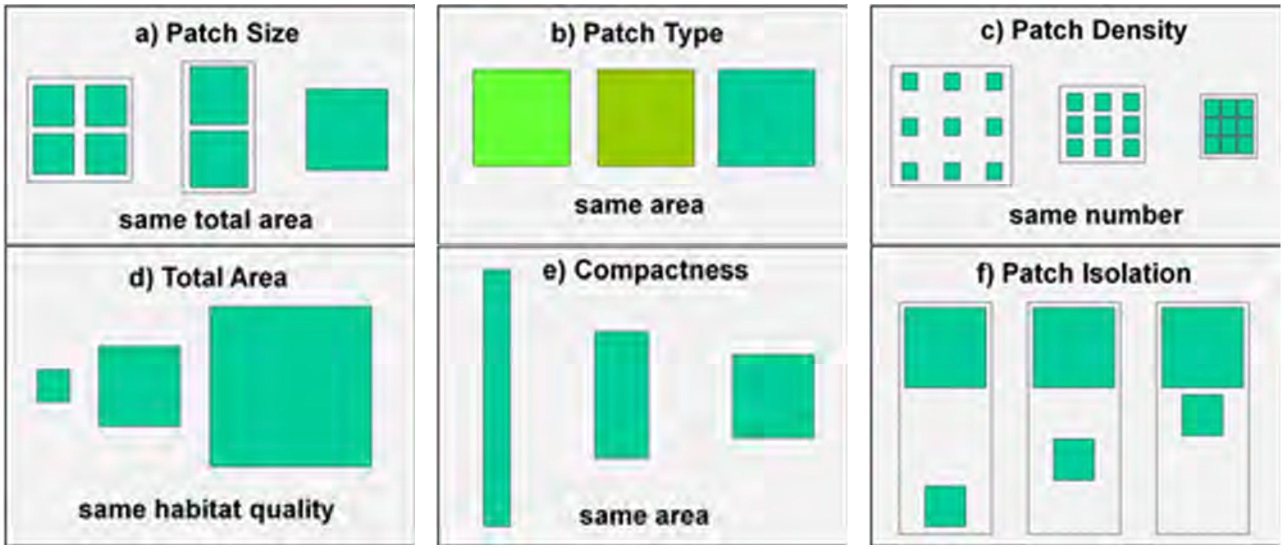


Figure 2-4. Conceptual Model for Measures of Landscape Fragmentation used in Terrestrial Habitat Assessments

Landscape condition improves from left to right in each gray box.

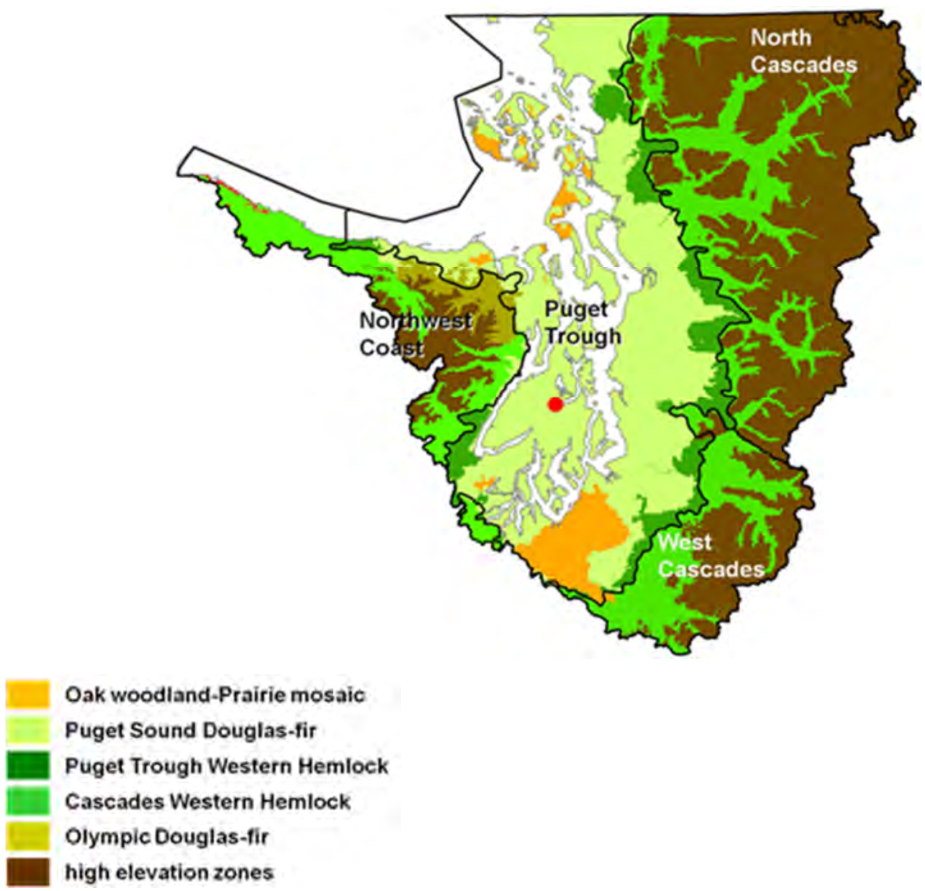


Figure 2-5. Vegetation Zones of the Puget Sound Basin (modified from Cassidy et al. 1997)

Six high elevation zones were consolidated into one zone (see Appendix A for definitions of vegetation zones). Black lines divide the four ecoregions of the Puget Sound Basin. Red dot is the approximate location of the Gorst Creek Watershed.

The importance index (Figure 2-3) was calculated for open-space blocks. An open-space block is a contiguous area containing land uses—such as commercial forest, agriculture, parks, and designated open-space—that maintain natural or semi-natural habitats or serve as habitats for native wildlife. The first major step in the regional assessment for the entire Puget Sound Basin was to delineate open-space blocks, which is described in Appendix C.

A regional assessment was done for the entire Puget Sound Basin. A regional assessment provides useful information for local assessments by indicating the relative regional importance of local fish and wildlife habitats. Local habitats of high regional importance should be high priorities for local protection. To make the results more relevant to the Gorst Creek Watershed, the regional results were normalized so that comparisons could be made within the Puget Trough Ecoregion and within WRIA 15.

The regional assessment of open-space blocks assigned one overall score to each block; it did not map variations in habitat quality within each block. The local assessment assigned value scores within blocks at the resolution of 30 x 30 meter-square grid cells. Scores were based on three factors: road density, land use, and parcel density (Figure 2-6). These factors are similar to factors used by Quigley et al. (2001), Leu et al. (2008), and Theobald (2010). Habitat quality within a block was affected by nearby conditions outside the block. This was accomplished by averaging the relative impacts of land use (Table 2-1) with a 195-meter-radius moving window. All grid cell scores were normalized to the maximum and minimum grid cell scores in the open-space blocks. More detailed explanation is provided in Appendix C.

2.2.3.2 Local Scale Assessment of Terrestrial Habitats

WDFW also performed a local assessment of terrestrial habitats. The local assessment had three components: wildlife and habitats occurrence data from WDFW's GIS databases, conferences with local WDFW wildlife biologists, and a local assessment of the open-space blocks identified in the regional assessment. The local assessment enhanced the regional assessment by improving the accuracy of the open-space block boundaries through interpretation of aerial photographs, incorporating finer spatial-scale PHS data (i.e., point data and polygons < 100 acres), and increasing the resolution of the assessment within the open-space blocks to 30 x 30 meters (¼ acre).

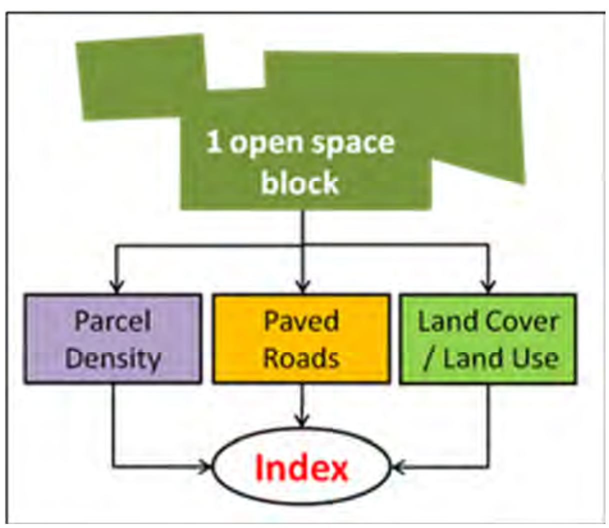


Figure 2-6. Factors Combined to Assess Habitat Value within Open-space Blocks

Index score is assigned to each 30 x 30 meter grid cell within an open-space polygon.

2.2.4 Marine Nearshore Assessment

Along the marine shorelines of Puget Sound, the most important physical process is the movement of sediment. Sediment movement occurs within spatially distinct littoral drift cells (Figure 2-7). Drift cells consist of sediment sources, typically bluffs, where erosion provides sediment for beaches, sediment sinks, areas where sand and gravel accumulate, and transport reaches where littoral drift connects sources to sinks. Puget Sound's shorelines comprise 812 drifts cells, which have an average length of 3.3 miles with a range from 225 feet to 40 miles (Anchor QEA 2009).

Within drift cells variation in wave exposure, sediment sources and local geomorphology have created a variety of shoreforms, such as bluff-backed beach, barrier beach, pocket beach, barrier estuary, open coastal inlet, closed lagoon, closed lagoon marsh, rocky shore, and river delta (Shipman 2008). Bluff-backed beaches are sediment sources; barrier beaches and barrier estuaries are sediment sinks; and all beaches play a role in sediment transport. Littoral drift is the process that shapes and maintains most shoreforms and the habitats associated with them. Therefore, in order to protect or restore nearshore habitats for shellfish and fish, such as herring and salmon, the essential processes within drift cells must also be protected or restored.

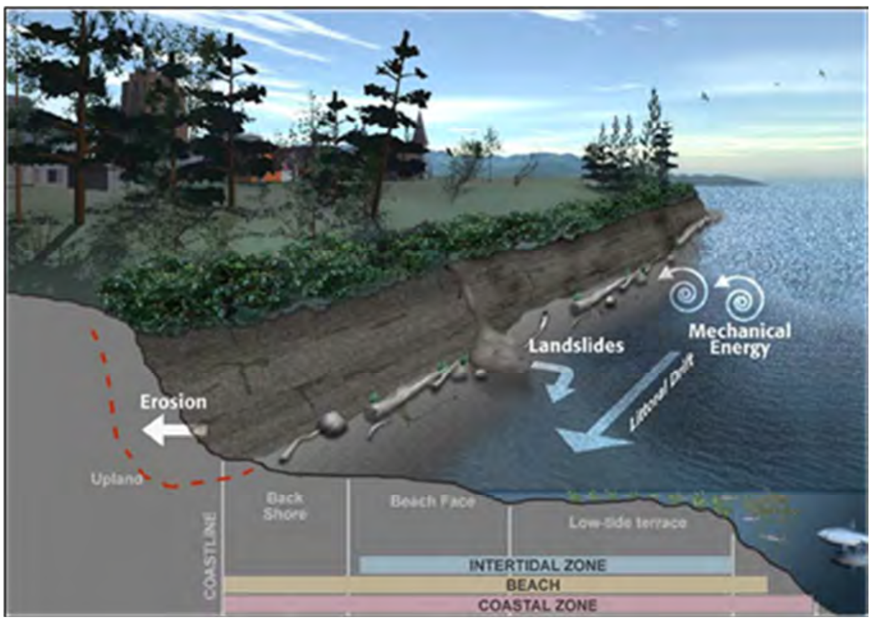


Figure 2-7. The Movement of Sediment within a Littoral Drift Cell
Source: Simenstad et al. (2006)

The marine nearshore habitat assessment was done at two spatial scales. At the smaller scale, shoreline segments were assessed based on the presence, absence, and abundance of fish, wildlife, and marine vegetation. At the larger scale, drift cells were assessed and prioritized for restoration and protection. As indicated in Cereghino et al. (in preparation), that assessment was done by the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP).

The approach used for nearshore habitats was much different than that used for terrestrial habitats. Unlike the data for terrestrial wildlife and habitats, data for nearshore fish, wildlife, and habitats are more comprehensive and accurate. Therefore, the index derived was based entirely on biological data.

All biological datasets managed by WDFW were reviewed for their relevance to marine shorelines in Puget Sound and their likely accuracy. WDFW's subjective evaluation of likely accuracy considered the dataset's age, how the data were collected, and the detectability of the taxa surveyed. Occurrence data for fish and wildlife are more prone to false negatives than to false positives; hence, WDFW analysts were particularly concerned about the potential frequency of false negatives in each dataset. They also included a subset of marine vegetation data from the Washington State Department of Natural Resources (DNR) shorezone database (Berry et al. 2001; DNR 2001) because aquatic vegetation is a key component of many nearshore habitats. After filtering the data sets, data sets that covered more than 38 species or species groups were selected (Figure 2-8).

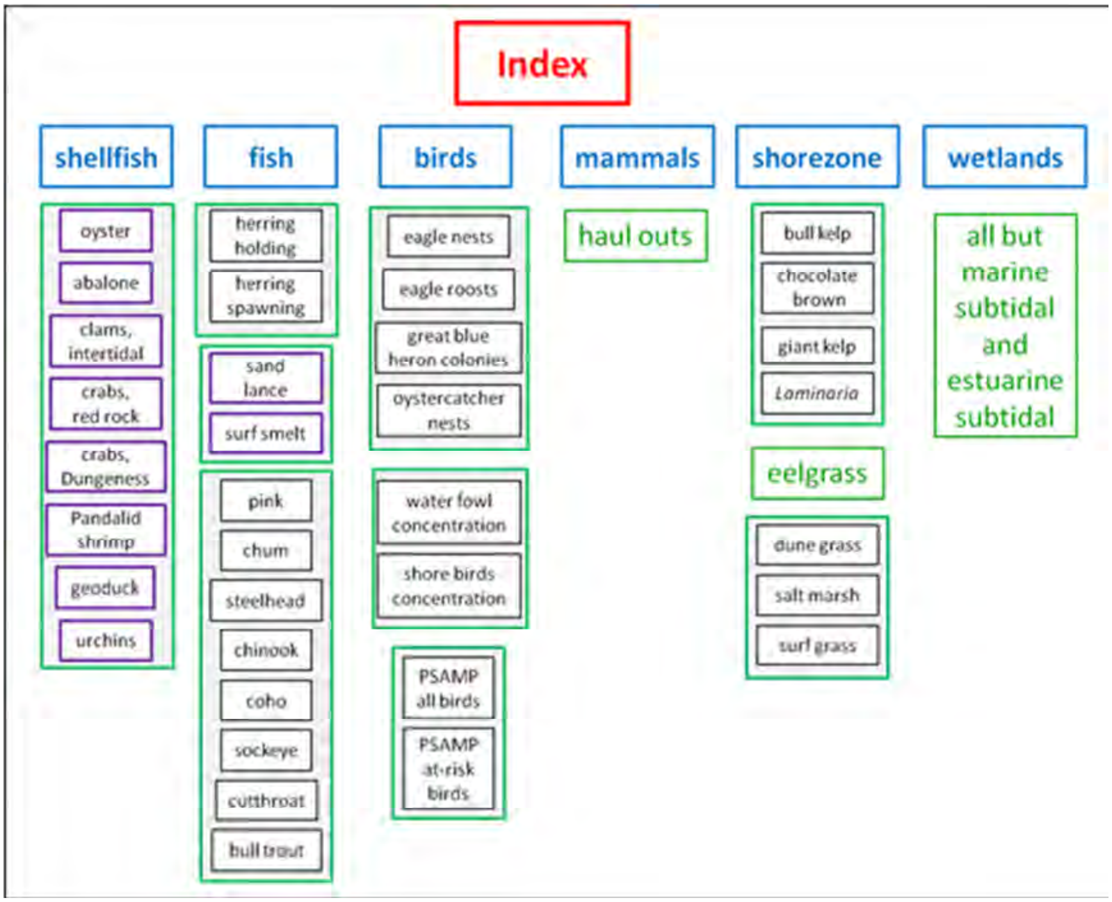


Figure 2-8. Species and Species Groups Used in the Marine Nearshore Habitats Index

Species in purple boxes are those that had data of questionable quality and a presence/absence index was created.

Compared to terrestrial and freshwater environments, the variety of species and habitats for which occurrence or abundance data are available is relatively broad: kelp, eelgrass, surfgrass, estuarine wetlands, eight species of molluscs and crustaceans of commercial or recreational interest, urchins, three species of forage fish, eight species of salmonids, bald eagle (*Haliaeetus leucocephalus*), great blue heron (*Ardea herodias*), black oystercatcher (*Haematopus bachmani*), a multi-species bird survey, waterfowl concentration, shorebird concentrations, and haul outs for seals and sea lions.

The measurement precision for most of these data is at the level of presence/absence. Only Puget Sound Ambient Monitoring Program (PSAMP) bird survey data enabled an estimate of local density or abundance. The accuracy of the data for this marine nearshore assessment is affected by the data's age and the methods of data collection. Some data sets are 20 years old.

Most data were collected through field surveys but few were systematic, and the data in certain data sets are "based on 'best professional judgment' of the biologist." For species that had data of questionable quality, WDFW analysts created a presence/absence index that indicated the relative likelihood that the species would exist in a shoreline segment given the oceanographic sub-basin, shoreform, and habitat type (Dethier 1990; Berry et al. 2001) of the shoreline segment.

Biological data were combined into an index in a manner similar to that of Diefenderfer et al. (2009). The relative influences of each species or species group on the index were equal, i.e., the weights in the index equation all equaled 1. Index scores for shorelines in Sinclair Inlet were compared to other shorelines in the Central Puget Sound oceanographic sub-basin, which is one of nine sub-basins defined by PSAMP.

PSNERP's assessment assigned two recommendations to each drift cell—one for beaches and one for embayments. There were six possible recommendations based on historical potential to provide ecosystem services and current degradation of those services (Table 2-1). The recommendations were based on a potential degradation relative to other drift cells in Puget Sound. A detailed explanation of PSNERP's methods can be found in Cereghino et al. (in preparation).

Table 2-1. Categories for Drift Cell Priorities and Management Recommendations from the Puget Sound Nearshore Ecosystem Restoration Project (Cereghino et al., in preparation)

	Low Degradation	Moderate Degradation	High Degradation
High Potential	Protect High Sites with substantial opportunities to protect large complex systems	Restore High Sites where there may be an opportunity to substantially increase ecosystem services	Enhance High Sites where strategic actions may enhance ecosystem services
Low Potential	Protect Low Sites with opportunities to protect systems	Restore Low Sites where there may be an opportunity to increase ecosystem services	Enhance Low Sites where strategic actions may enhance ecosystem services

2.2.5 Freshwater Habitat Assessment

In 2003, Kitsap County commissioned a detailed, in-depth assessment of salmon habitats: the Kitsap Salmonid Refugia Report (May and Peterson 2003). The authors of that report conferred with three local WDFW biologists and numerous other local experts. WDFW analysts used the findings of the Kitsap Salmonid Refugia Report to inform this report. Freshwater biota in the Gorst Creek Watershed are certainly more diverse than only salmonids. For example, a WDFW survey in 1997 found a Coast Range sculpin (*Cottus aleuticus*) and a prickly sculpin (*Cottus asper*) near river mile 0.5 of Gorst Creek. However, given the limited resources available for this assessment, the condition of salmonid habitats must suffice as a surrogate for the habitat conditions of other freshwater species. This report uses the watershed characterization results, Kitsap Salmonid Refugia Report, and Bremerton's water quality assessment as the basis for freshwater habitat conditions within the watershed.

May and Peterson (2003) assessed the conservation value of potential salmonid refugia (i.e., stream tributaries and stream reaches of mainstem waters) using an index consisting of four main components: watershed conditions, riparian conditions, in-stream habitat quality, and fish population characteristics (Figure 2-9). For more detail on their methods see May and Peterson (2003). Their findings for Gorst Creek and its tributaries are summarized in Section 3. Values in the Gorst Creek Watershed are compared to values for other watersheds in WRIA 15.

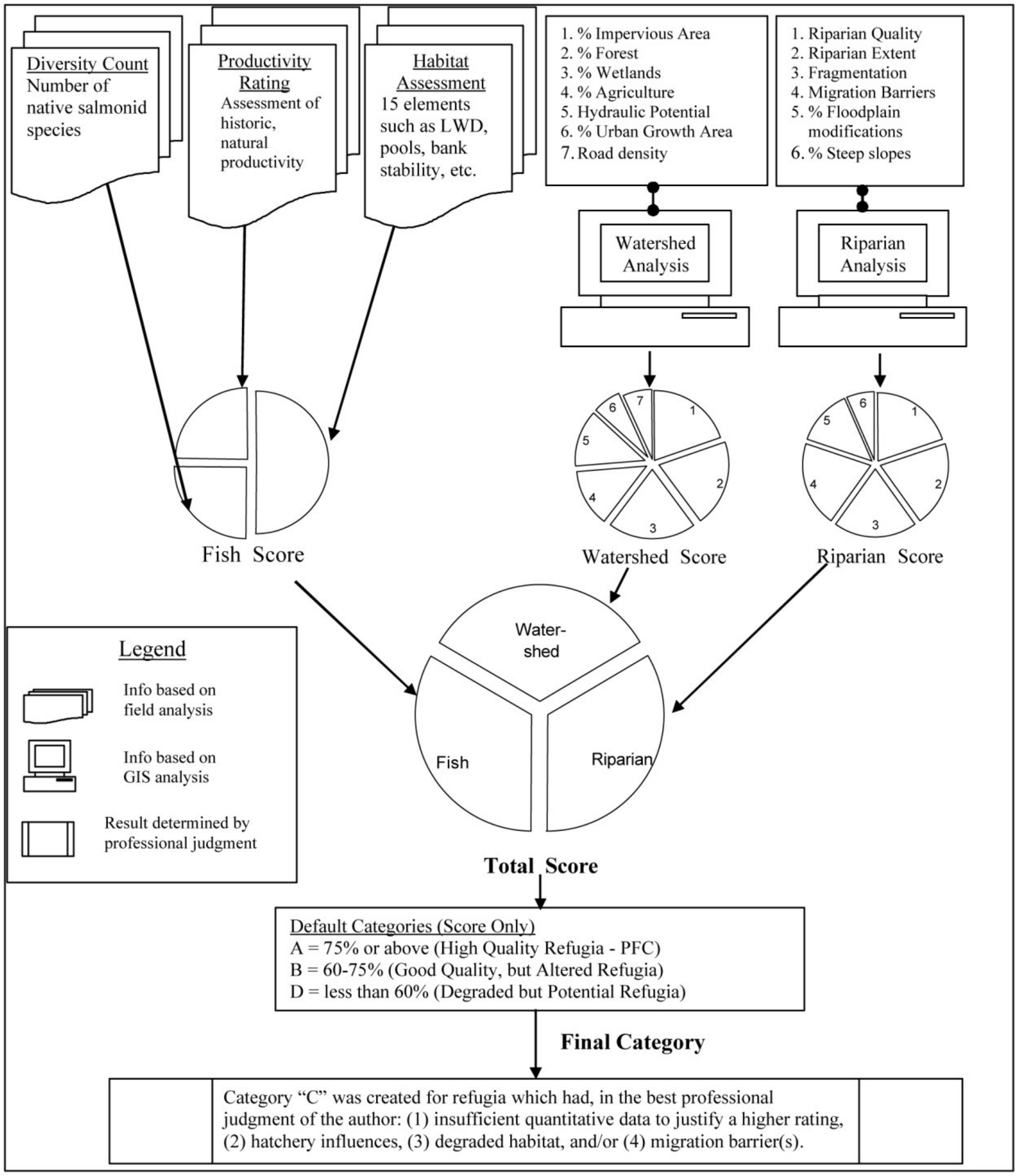


Figure 2-9. Calculation of the Value Index for Salmonid Conservation used in the 2003 Kitsap Salmonid Refugia Report

Source: May and Peterson (2003)

3. STUDY FINDINGS

This section of the report presents both a synthesized map, which combines results from the watershed characterization model with fish and wildlife habitat, and interpretation and ranking of those results for specific areas within the Gorst Creek watershed to restore, protect, conserve, or those areas which can accommodate more development. Watershed characterization model results are presented first, followed by fish and wildlife habitat assessment results.

3.1 WATERSHED CHARACTERIZATION RESULTS

3.1.1 Areas of Protection, Restoration, Conservation, and Development

To be most effective, land use planning should be developed within a framework that first focuses on maintaining or restoring watershed processes (Hidding and Teunissen 2002; Dale et al. 2000; Gove et al. 2001). To assist land use planning efforts for the Gorst Creek Watershed, an initial watershed planning framework for protection, restoration, conservation, and development is presented in this section. These terms are used as specifically tied to watershed characterization model output results, as discussed below. The results present the areas that, according to the model, are most important for water flow processes, and the priority areas for protection, restoration, conservation, and development.

3.1.2 Water Flow and Sediment Processes Model Output

The output of the water flow model is a color-coded map. The color-coding is tied to results from a synthesis matrix derived from combining two models—one that identifies areas important to water flow processes and another that assesses the level of degradation to these areas of importance (Stanley et al. 2005, 2010). The synthesis matrix (Figure 3-1) uses the results of the importance and degradation model to categorize areas for protection, conservation, restoration, and development. The maps display Assessment Units(AUs) – areas between approximately .2 and 1 square mile in the case of this analysis. The categorized (and color-coded) results are then displayed as an overlay onto AUs within the watershed. Because the water flow model consists of four subcomponents—delivery, storage, recharge, and discharge, it is important that the assessment results for these components are first evaluated individually, and then analyzed collectively to inform management recommendations.

The analysis involves the following steps:

1. Review results of each component starting with delivery first, then storage, and finally recharge/discharge;
2. Evaluate the overall condition of the watershed for each component relative to its upper, middle, and lower portions;
3. Synthesize results into final recommendations for overall development patterns and protection/restoration measures based on a standardized list of management actions (referred to herein as land use management recommendations).

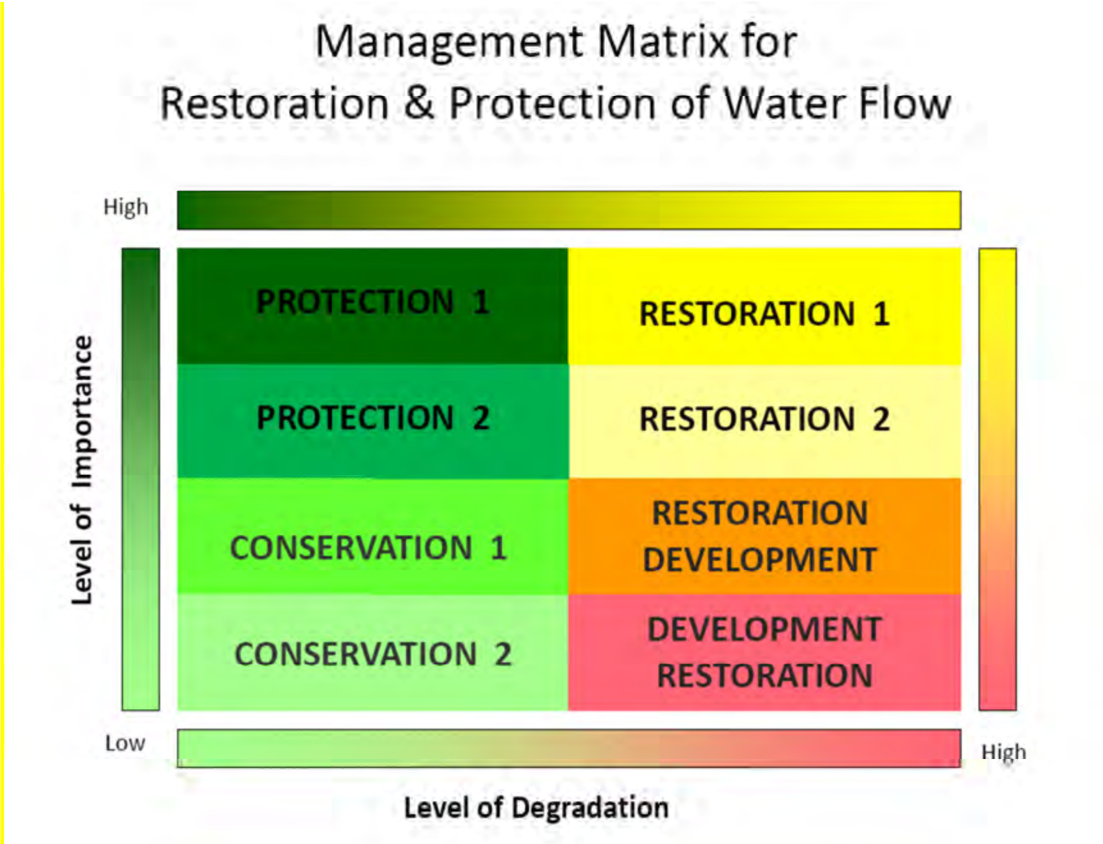


Figure 3-1. Watershed Characterization Results Matrix

The results are displayed in a color coded matrix (Figure 3-1) within which the x axis represent the level of degradation, while the y axis represents the level of importance. Because the assessment results are for individual AUs, there is a need to consider these results relative to adjoining AUs. For the Gorst Creek watershed the AUs are at a .2 to 1 square mile scale. The position of an AU within a watershed (upper, middle, or lower portion) can determine whether a restoration or protection action is advisable. For example, if upper watershed conditions are significantly degraded then downstream processes may not support stream restoration actions, such as the placement of large woody debris. The following evaluations show the condition of the upper, middle, and lower watersheds for the northern and southern half of the Gorst Creek Watershed.

Understanding Synthesis Matrix Terminology

Overall, the model output results allow local jurisdictions to prioritize land use actions within the matrix categories set forth in figure 3-1 and defined below.

Protection**:** Areas mapped as darker to lighter green. These areas are highly important for water flow processes (y axis in synthesis matrix) and have been subjected to relatively low level of degradation as measured by the assessment (x axis). Therefore, protection is defined as any activity that ensures that **the watershed process remains relatively unimpaired**. This can encompass traditional efforts of protecting land from human activities (e.g., open space, conservation easements), but it can also mean designing development in a way that allows the watershed process to continue with minimal impairment. For instance, an area important for recharge could be set aside from any development, or new development could be sited and designed to ensure recharge of the additional surface runoff generated by the development.

Conservation: Areas mapped as lighter green. These areas have lower relative importance for water flow processes but also have relatively low levels of degradation. Generally, due to these conditions, these areas require a relatively low level of active management, provided that land uses and activites are not allowed to degrade processes (moving from left to right on the synthesis matrix).

Restoration: Areas mapped as yellow to lighter yellow. These areas require the most active management. They denote areas which have a relatively high importance to water flow processes but are highly degraded. These are focal areas for active management. Restoration can be considered any activity that ensures that degraded subcomponents of **the watershed process are re-established or re-habilitated**. This can involve restoring the natural condition of an important area but it can also include activities that restore the capacity of the important area to support the process. For instance, an area important for recharge that is covered with impervious surfaces could be modified to accommodate recharge (i.e., implementing stormwater retrofits or green infrastructure) or it could be restored to natural conditions. The type of action should be tied to understanding components of the water flow process. Specific actions will require further analysis, at a scale beyond that employed by the watershed characterization.

Development: Areas mapped as orange to pink. The model maps these areas as of relatively low importance to the water flow process and high degradation. In the context of model output results, these are typically areas within which continued development will have the least effect on water flow processes, as compared to other locations within the watershed.

However, the specific design of any land use management activities must consider measures that protect and restore individual subcomponents of the water flow process (e.g. delivery, storage, recharge, discharge) that individually may have higher importance relative to the overall results. These measures should be developed in conjunction with further site-level analysis (e.g. storage is indicated as high importance; use more detailed hydrologic modeling, such as EPA's Hydrological Simulation Program - Fortran (HSPF) to identify degree of storage restoration to maintain normal range of downstream flows).

3.1.3 Delivery Results

The assessment of delivery includes evaluating precipitation type and quantity as well as land cover. An intact water flow delivery component is key to the proper functioning of a watershed because it helps regulate the type (subsurface or over land flow) and timing of the delivery of water downstream. If upper watershed delivery processes are not intact, then middle and lower watershed conditions will not function properly, typically resulting in more frequent higher flows that degrade the structure and function of habitats within the watershed. The northern half of the watershed (green polygons in Figure 3-2) for the upper and middle reaches is intact for this process, while most of the southern half (pink polygons in Figure 3-2) is altered by mixed development involving forest clearing, residential areas, a golf course, an airport, and industrial facilities. While the delivery results indicate that the southern portion of the watershed is of relatively lower importance and therefore suitable for development, measures to increase forest cover and decrease impervious surfaces should be implemented to improve water quality and reduce erosive surface water flows from this area. These measures could be considered in combination with other stormwater 'best management practices'. Other subcomponents such as storage and discharge provide more definition about the type of specific measures needed for restoration of processes in the southern portion of the watershed.

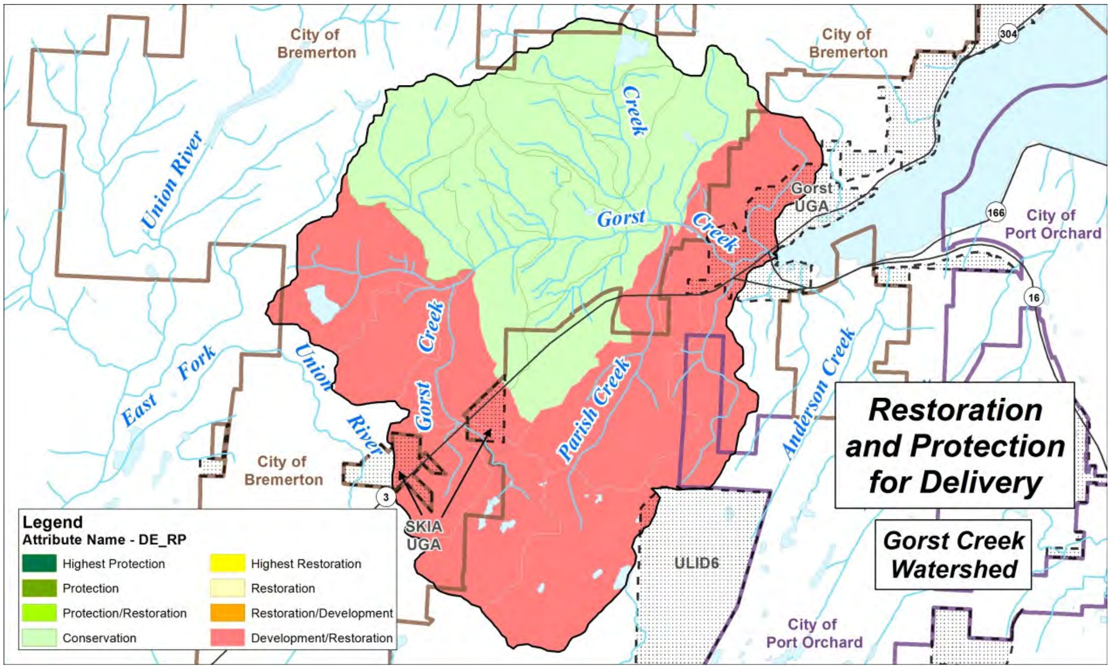


Figure 3-2. Delivery Results

Generally, the northern half (light green polygons) of the watershed is rated in good condition based on the presence of intact forest and low level of urban development. The southern half (red outline) is in poor condition for this process due to forest clearing, residential, golf course, and airport development. Removal of forest cover and urban development affects the timing and delivery of water to streams and wetlands.

3.1.4 Storage Results

The assessment of storage involves evaluating the relative area of depressional wetlands and floodplains present within the watershed. Storage areas, especially if located in the upper portion of a watershed, play an important role in desynchronizing surface flows and reducing downstream flooding and erosion.

For storage, the overall pattern of importance and degradation in the Gorst Creek Watershed are similar to those present for delivery, except that the relative level of importance for storage is higher overall (Figure 3-3). The northern watershed (green polygons) is in good condition and ranks high in importance and low for degradation.

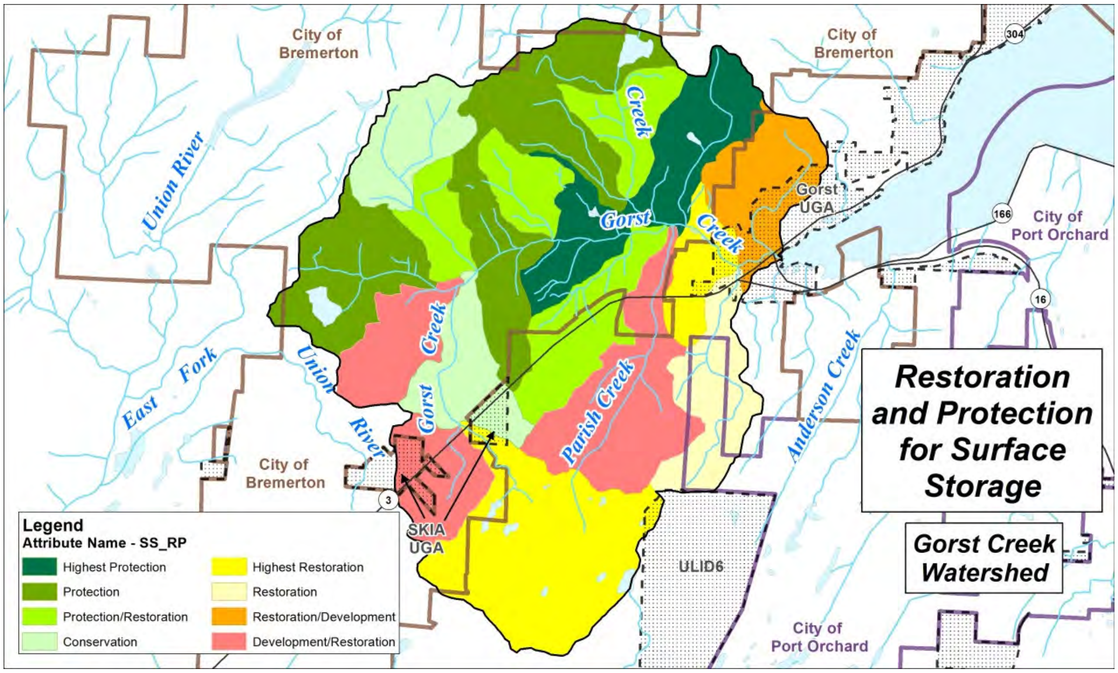


Figure 3-3. Storage Results

The northern half (green polygons) of the watershed is rated in good condition based on the present intact conditions for storage of water in northern and central portions of the watershed. The southern half (red and yellow polygons) is in poor condition due to forest clearing and residential, golf course, and airport development.

A large portion of the southern watershed is a high priority for restoration (dark yellow polygons, figures 3-3). This is a till terrace with a large mosaic of depressional wetlands. These wetlands should be restored first relative to other restoration areas lower in the watershed, given their greater influence over controlling downstream flooding and erosion. This would include headwater wetlands for Gorst and Parish Creeks. Restoration measures would involve re-establishing the natural hydrologic patterns by eliminating features designed to drain the wetlands (ditches, culverts), removing fill, and re-establishing upslope flows to these wetlands that have been re-routed around or away from them.

The northern and central portions of the watershed is generally in good condition with low to high importance for storage and low levels of degradation. These areas should be protected from development that would alter and degrade storage areas (e.g. filling, ditching and diking of wetlands and floodplains).

The model results for storage suggest that the mid to lower reaches of Parish Creek and two AU's west of the upper reaches of Gorst Creek are appropriate for urban development (pink color AUs) involving permanent change in land cover (buildings, roads, sewers). For the mid to lower reaches of Parish Creek, the results and recommendations of the sediment export assessment (section 3.1.6) should also be considered when locating and designing development.

3.1.5 Recharge and Discharge Results

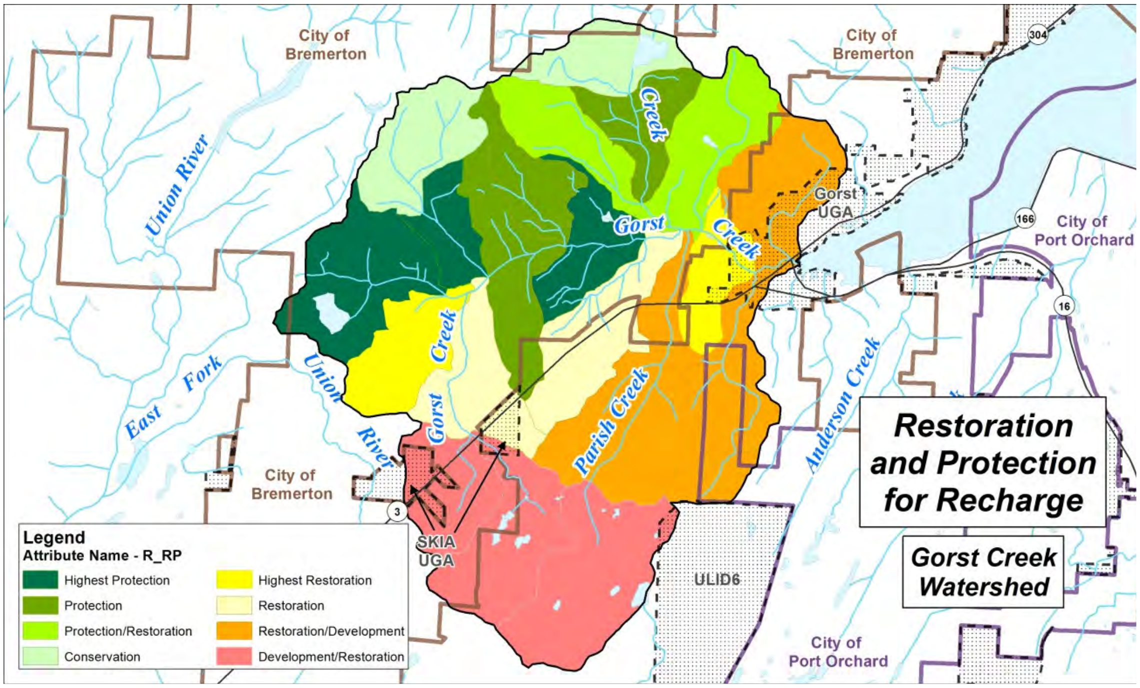
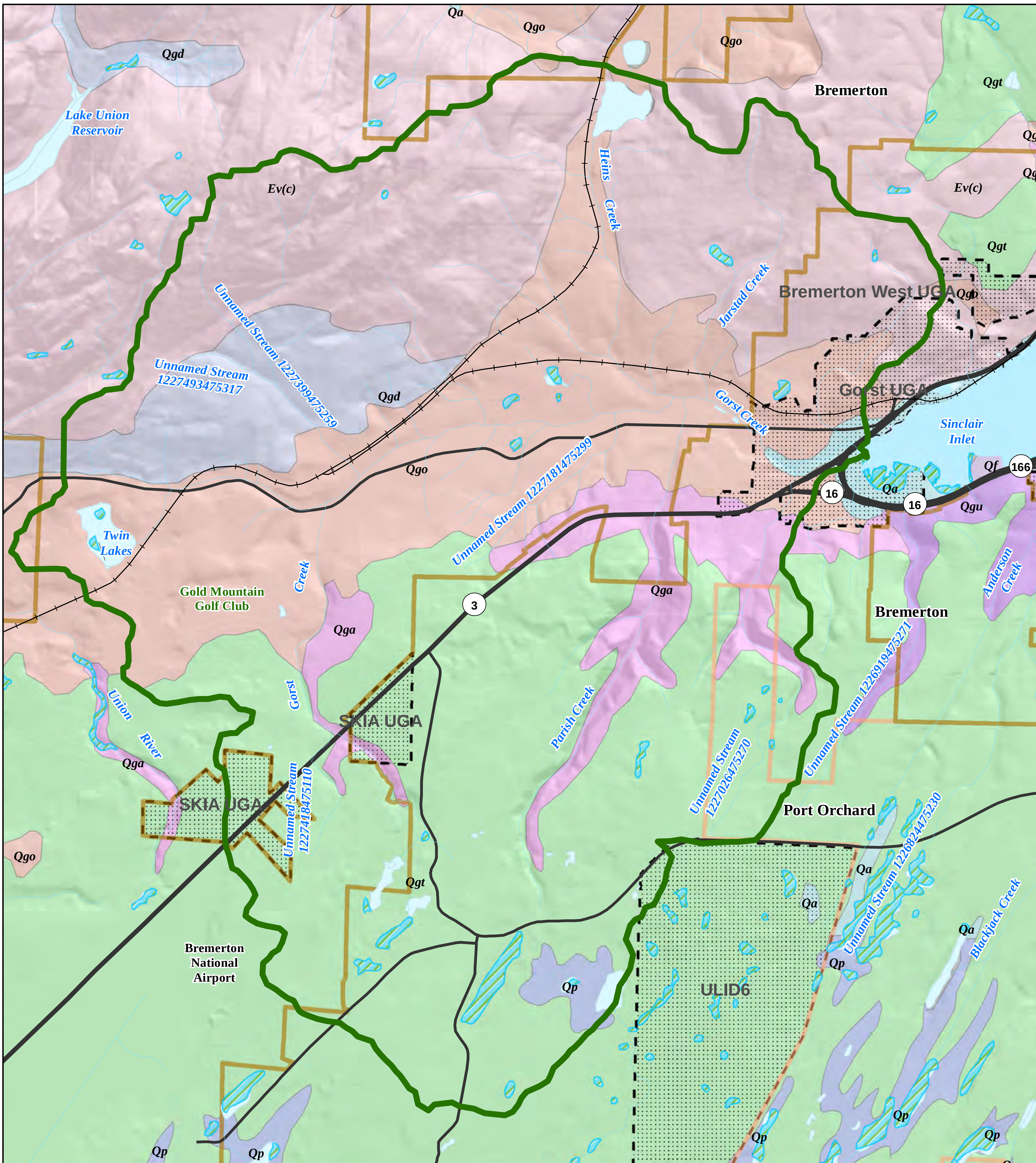


Figure 3-4. Recharge Results

Assessment units adjoining the mainstem of Gorst Creek in the northern and central portions of the watershed should be protected from development given their high importance to the recharge process and low level of degradation. The southern portion of the watershed has low permeability and is more suitable for high intensity development.

The assessment of recharge is based on the type and area of surficial deposit present (coarse or fine-grained), its rate of infiltration, and amount of annual precipitation. The assessment of discharge is based on the relative area of slope wetlands (indicates areas where groundwater discharges) and larger, low gradient floodplains. Typically, there is some relationship between upslope recharge areas and downgradient discharge areas, so development actions should evaluate the impact of impervious surfaces in recharge areas on downstream discharge areas that support stream and wetland hydrology.

A large deposit of recessional outwash consisting of fine-grained sand (Sceva 1957) dominates the northern portion of the Gorst Creek Watershed. This deposit, one of the largest in the Kitsap peninsula, stretches from Sinclair inlet southwest through the Union River trough (Map 3-1). Recessional outwash typically has excellent properties for the recharge, storage, and discharge of water and as a result supports streams with annual flows sufficient to support a diversity of aquatic life. The southern portion of the watershed consists primarily of Vashon Till, which due to its low permeability has low rates of recharge and discharge (Sceva 1957). These geologic conditions are the underlying factors that drive the recharge and discharge results.



Gorst Creek Watershed Characterization
City of Bremerton

Geology
Map 3-1

Apr, 2012

0 2,200

Scale in Feet

N

Data Sources: Kitsap County, City of Bremerton, Washington Department of Natural Resources, Washington Department of Transportation, Washington Department of Fish and Wildlife (WDFW), National Wetland Inventory (NWI), USDA Natural Resources Conservation Service (NRCS).

CITY OF BREMERTON

Legend

- Gorst Creek Watershed
- Urban Growth Area
- City of Bremerton
- City of Port Orchard
- Road
- Railroad
- Stream
- Wetland (WDFW/NWI)
- Water- body

WA DNR Geologic Unit Polygons

Code and Description

- Qa, alluvium
- Qga, advance continental glacial outwash, Fraser-age
- Qgo, continental glacial outwash, Fraser-age
- Qgt, continental glacial till, Fraser-age
- Qp, peat deposits
- Qgd, continental glacial drift, Fraser-age
- Qgu, glacial drift, undivided
- Qf, artificial fill, including modified land
- Ev(c), basalt flows and flow breccias, Crescent Formation

Path: K:\gis\1896-CoBremerton\232-1896-096_GorstMasterPlan\MapDocs\GCWatershedCharReportApril2012\WCR-3-1_SoilsGeology.mxd

The results indicate that AUs adjacent to the mainstem of Gorst Creek in the upper and middle portion of the northern half of the watershed are both highly important to the recharge process (Figure 3-4). The discharge maps (Figure 3-5) suggest that a significant area of groundwater discharge is located in the central portion of the watershed, which also happens to coincide with recharge areas of high importance (darker greens). Field investigations demonstrated that these areas of high importance were dominated by slope wetlands dominated by salmonberry (*Rubus spectabilis*), devil's club (*Oplopanax horridus*), and Western red cedar (*Thuja plicata*) in the ravines, and Western hemlock (*Tsuga heterophylla*) in the overstory of the adjacent uplands; these field investigations confirmed that this area is a groundwater discharge area.

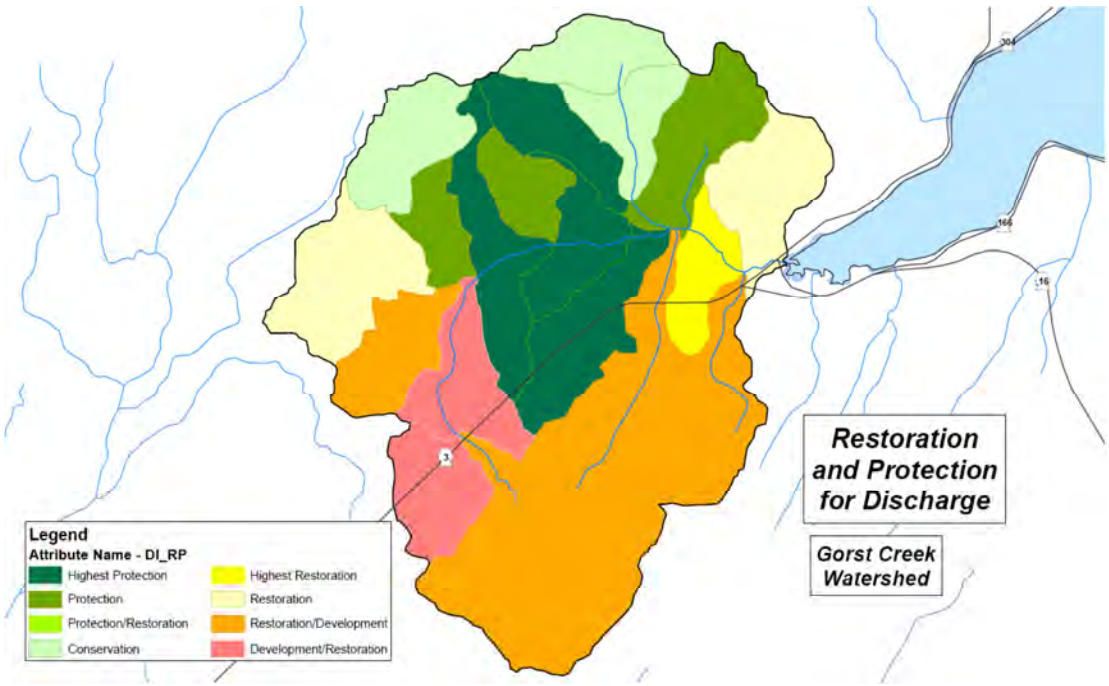


Figure 3-5. Discharge Results

Areas important for discharge are located in the central portion of the watershed (dark green). Discharge areas can play an important role in the support of base flows in streams. Development should not occur within these areas or significantly alter recharge areas that support them.

It is likely that recharge areas within and upslope of the areas of high importance for discharge are linked to and support groundwater discharge in these locations. Because recharge and discharge processes are significantly affected by impervious surfaces, buildings, roads, and drainage networks, it is important that urban development be very limited in these areas and employ best available infiltration measures if permitted. An AU located in the lower portion of the watershed on the mainstem of Gorst Creek is shown as high priority restoration (dark yellow) suggesting that it is a key area for discharge (Figure 3-5). Restoration actions for this AU could include removal of ditches and roads that alter natural groundwater discharge patterns, or upgrading some of these facilities to infrastructure that allows for normal patterns of discharge to occur.

3.1.6 Sediment Model Results

The sediment model assesses the relative potential of an AU to export sediment by assessing both the sources and sinks for sediment. For sources of sediment we evaluated areas of higher erosion (e.g. using RUSLE2), flow path density and areas of mass wasting. For sinks, we evaluated the area of storage provided by wetlands and floodplains.

Overall, the results indicated that the steeper portions of the watershed with larger areas of sediment sources and fewer areas of storage, had the greater potential to export sediment. This includes Parish, Heins and Jarstad Creeks and several unnamed tributaries to Gorst Creek (Figure 3-6). High export potential (brown and dark brown AUs) appears to be greatest in the north and eastern portions of the watershed and least in the southern, terrace portion. The terrace portion (yellow AUs) has a large area of depressional wetlands (sinks) and till soils which have a lower erosivity than outwash soils on steeper slopes.

The sediment model results suggest that development is most appropriate in the southern terrace areas (yellow AUs). Development activities in the high export potential AUs (brown and dark brown) must employ measures to minimize erosion, including appropriate setbacks from steep slopes, minimizing overland flow through use of infiltration techniques and plantings. In addition, the results from the assessment of storage should be used to develop appropriate priorities and measures for reducing downstream erosion. For example, wetlands in the upper watershed of Parish Creek play an important role in moderating the volume and velocity of downstream flows through mid and lower reaches of this watershed which has a high sediment export potential. This would indicate a high priority for protecting and restoring these headwater wetlands.

The model results also suggest protection of the existing forest cover in the northern half of the watershed, particularly in Heins Creek and unnamed watershed to the west (dark brown AUs).

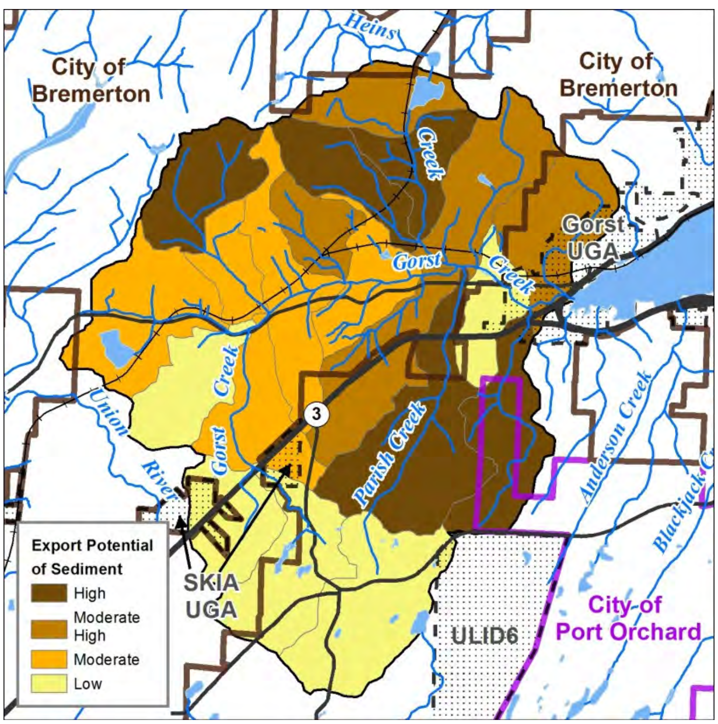
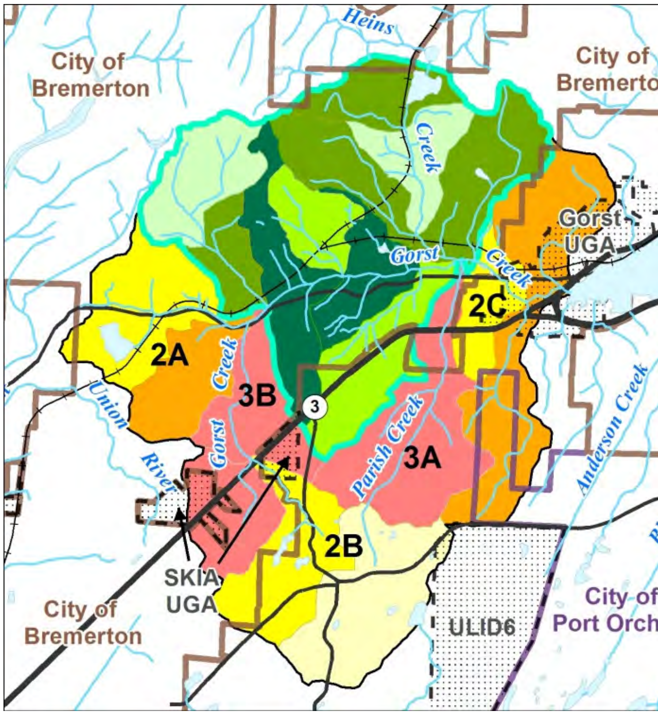


Figure 3-6. Sediment Export Results

Areas rated with the highest potential for export of sediment are located in eastern half of the watershed (tributaries to the lower reaches of Gorst Creek) and the upper reaches of the northern half of the watershed. The till terrace in the southern half of the watershed has a low potential for sediment export.

3.1.7 Recommended Actions

Based on the assessment results for the individual water flow components (delivery, storage, recharge, and discharge) and sediment process, AUs can be grouped into patterns that identify zones for restoration, protection, and development. Figure 3-7 presents the recommended management zones.



1 Protection Zone (Green). This area is key to recharge and discharge processes for Gorst Greek. Permitted uses must preserve forest cover and not result in conversion.

2. Restoration Zone (Yellow). Lower intensity uses.

A – Restore recharge, discharge, and delivery process, limit urban development, maintain in open space uses.

B – Residential uses but protect/restore storage functions of wetlands.
C – Restore recharge/discharge processes using LID measures.

3. Development Zone (Pink & Orange). Moderate to higher intensity urban uses.

A – Protect against erosion & sediment export with adequate setbacks, buffers & vegetation cover. Cluster development
B – Restore stream corridor; cluster development.

Figure 3-7. Watershed Management Zones based on Synthesis of Assessment Results.

This map represents the combined results of the preceding assessment of delivery, surface storage, recharge and discharge.

The **Protection Zone** supports recharge, discharge and storage processes which are critical to sustaining a natural range of flows in Gorst Creek, including adequate low flows during summer and fall. The unique properties of the Gorst Creek recessional outwash deposits are a principal factor in this high rating for hydrologic importance. Because recharge and discharge processes are sensitive to development and would be significantly degraded by impervious surfaces, buildings, roads, and drainage infrastructure, such development should be restricted in this zone.

The **Restoration Zone** primarily supports storage processes and some recharge/discharge processes. This zone may be appropriate for development but different actions in areas A, B, and C should be subject to the following provisions:

Area 2A: This area has moderate to moderate-high importance for storage and discharge and high importance for recharge. The delivery, recharge and discharge processes are degraded. Because of its location at the headwaters of Gorst Creek and importance for recharge, low intensity uses would be appropriate. This low intensity pattern is already set with the golf course, which likely has a lower impact upon recharge processes than higher intensity urban areas. However, restoration actions to improve recharge could be investigated, including infiltration swales or galleries adjacent to the lower permeability fairways and greens. For the discharge process, restoration measures would include re-establishment of the natural hydrology of depressional and slope wetlands. Accomplishing this restoration may involve plugging ditches that either drain these wetlands or re-aligning ditches that intercept upslope water away from wetlands (e.g., roads intercepting shallow groundwater flow), thereby altering water flow processes downstream. The delivery process could be improved through the re-establishment of additional forest cover.

Area 2B: Restoration of storage processes is the highest priority for this area; recharge processes have lower importance due to the presence of till. Higher intensity development would be appropriate provided that storage processes are protected and restored. This effort would include re-establishing the natural hydrology of depressional wetlands by plugging ditches that drain them, removing fill and re-routing natural drainage patterns back into these depressional wetlands. In particular, protection and restoration of wetlands in the Parish Creek AU will protect the mid and lower portions of this watershed from erosion and sediment export.

Area 2C: Located in the lower portion of the watershed, this area is important for its recharge and discharge processes. Given that this area is already developed with urban uses, restoration may be limited to stormwater retrofit actions. However, restoration of in-stream alterations (removal of channel armoring, berms) and re-establishment of natural stream structure (i.e., reducing channelization in the lower reaches of the stream) may be appropriate given that upstream processes for the northern half of the watershed are relatively intact.

The **Development Zone** (pink and downstream orange AU adjacent to Sinclair Inlet) is suited for the highest intensity development (such as high density residential or commercial) provided appropriate measures for protecting streams, wetlands, and water quality are followed, including those for area 3A and 3B below.

Area 3A: The sediment model indicated that this AU had a high potential for export of sediment which would argue for protecting this area. However, the water-flow assessment shows this area as appropriate for higher intensity development, leading to an integrated measures that would reduce erosion and sediment export through clustering of development, adequate setbacks from steep slopes, restoration of suitable buffers, control of runoff through LID techniques and planting of cover designed to slow and infiltrate overland flows.

Area 3B: The sediment model indicated that this AU had a moderate potential for export of sediment. This area is shown as appropriate for higher intensity development for both the delivery, and surface storage subcomponent models for water-flow, although the corridor along Gorst Creek is shown as important for conservation for restoring and protecting surface storage, while the headwaters are shown as important for wetland restoration to protect the surface storage function. This area is capable of accepting higher intensity development provided that the stream corridors are maintained, development is clustered, and adequate setbacks from steep slopes, appropriately sized buffers, and runoff control as noted in Area 3A are followed.

3.2 FISH AND WILDLIFE HABITAT ASSESSMENT RESULTS

3.2.1 Terrestrial Assessment

Occurrence data for terrestrial wildlife and habitats from WDFW's GIS databases (Figure 3-8) indicated only one PHS occurrence—a bald eagle nest near the south shore of Sinclair Inlet and its associated territory located throughout the west end of the estuary. This was identified in the existing conditions technical memorandum (City of Bremerton, 2011). The great blue heron colony identified in the existing conditions technical memorandum was destroyed circa 2006 (J. Skriletz, WDFW, pers. comm.). Local WDFW biologists knew of no other extant occurrences of terrestrial priority habitats or species in the Gorst Creek Watershed. However, the forests managed by the City of Bremerton may be inhabited by the following priority species: western toad (*Anaxyrus boreas*), wood duck (*Aix sponsa*), sooty grouse (formerly blue grouse, *Dendragapus fuliginosus*), band-tailed pigeon (*Columba fasciata*), Vaux's swift, (*Chaetura vauxi*), pileated woodpecker (*Dryocopus pileatus*), Keens' long-eared myotis (*Myotis evotis keenii*), big brown bat (*Eptesicus fuscus*), and black-tailed deer (Johnson and O'Neil 2001). Significant marine habitats affected by land use in the Gorst Creek Watershed are described in Section 3.2.2.

Over 70 percent of the Gorst Creek Watershed is forested, and about four-fifths of this forest is managed for timber. These forests are unremarkable except for two characteristics: the area which they encompass and the vegetation zone in which they are located. The regional assessment for the Puget Sound Basin identified four open-space blocks that overlap the Gorst Creek Watershed (Table 3-1, Figure 3-9). There were no regional-scale PHS features or oak-prairie habitats in the open-space blocks that overlap the watershed.

The exceptionally large area of two open-space blocks resulted in these areas attaining high scores compared to other open-space blocks in the Puget Trough Ecoregion and WRIA 15. According to the regional assessment, the open-space blocks overlapping the north and south portions of the Gorst Creek Watershed were in the top 10 percent for importance in the Puget Trough Ecoregion. The large, contiguous open-space blocks overlapping the watershed comprise the most important open space in WRIA 15.

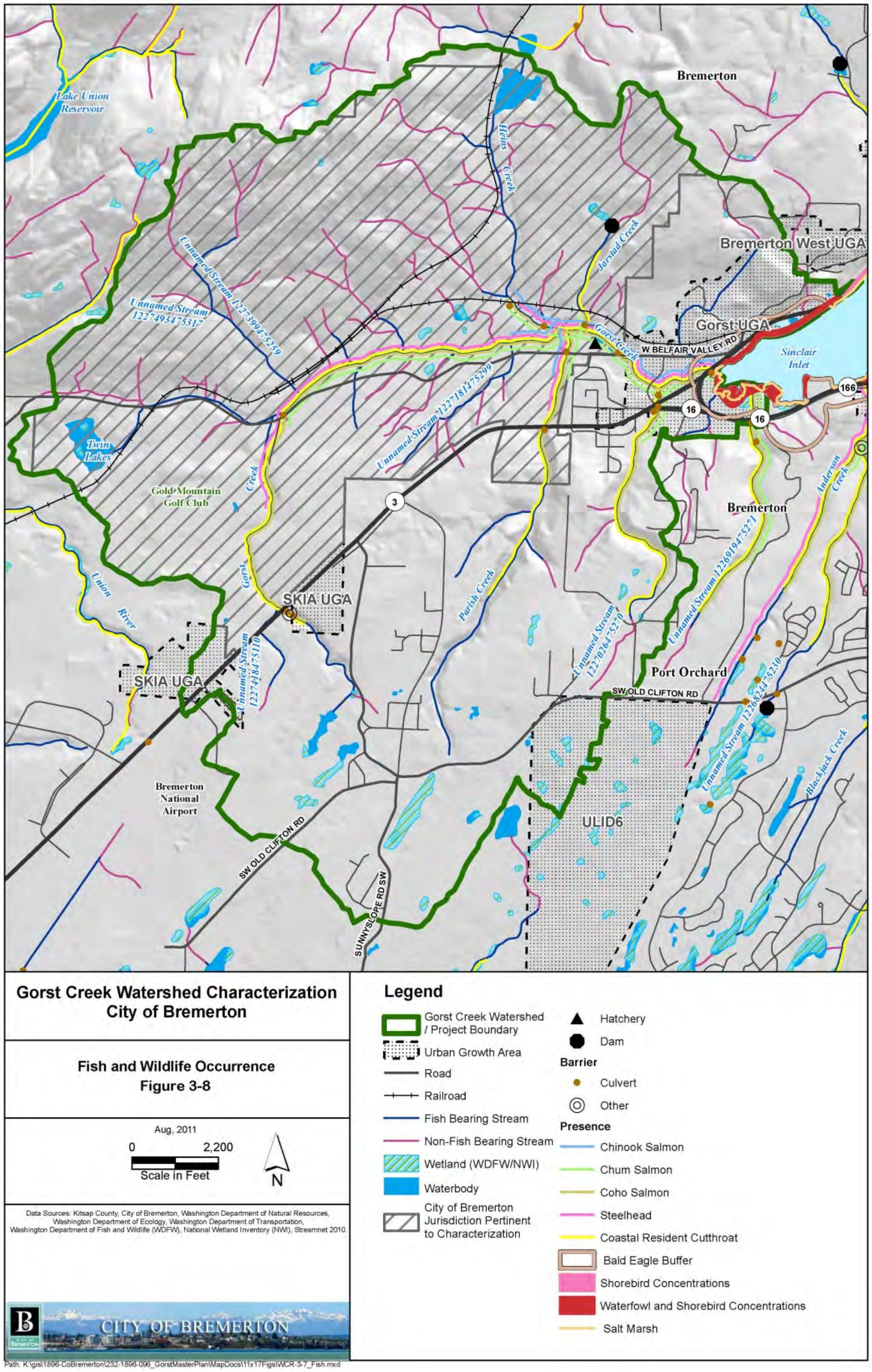
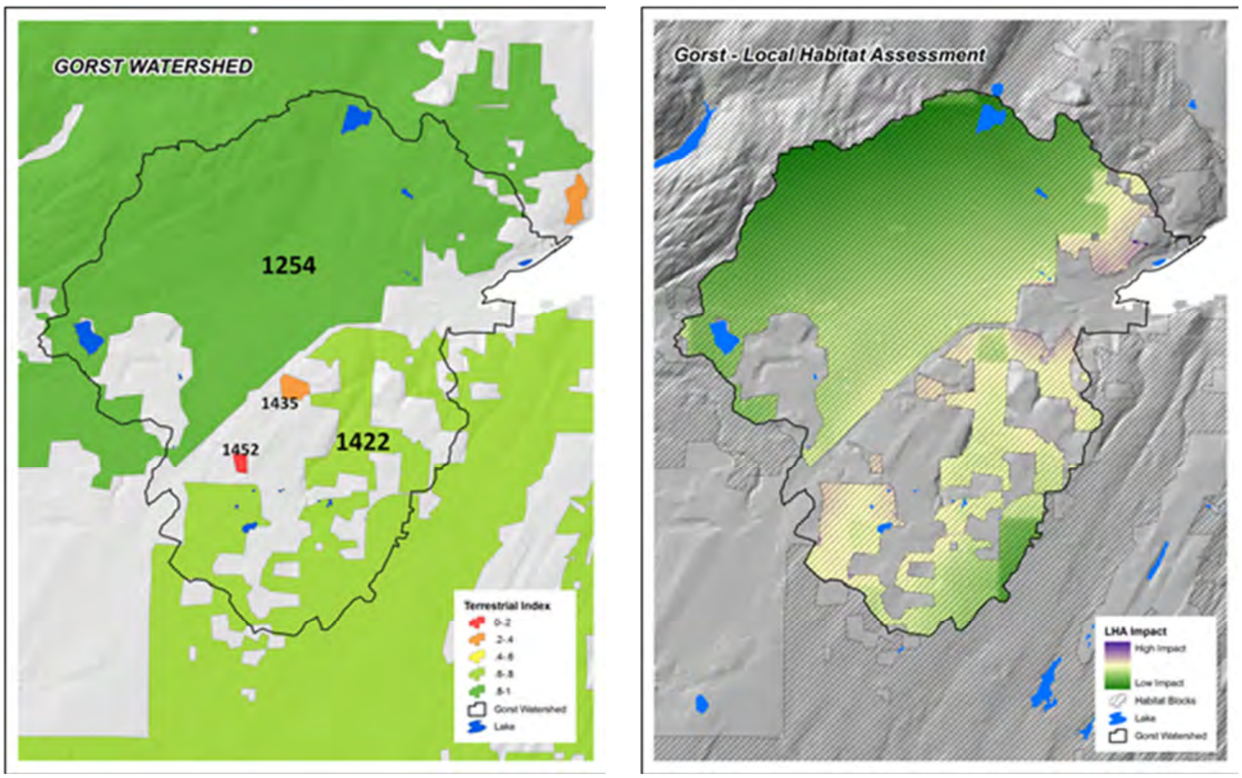


Figure 3-8. Fish and Wildlife Occurrence Data for Gorst Creek Watershed and the Gorst Creek Estuary of Sinclair Inlet

Table 3-1. Open-space Blocks Identified in the Puget Sound Basin Regional Assessment that Overlap the Gorst Creek Watershed

Block ID	Total Area (acres)	Area in Gorst Creek Watershed	Index Score	Percent Rank in Puget Trough Ecoregion (2,615 blocks)	Rank in WRIA 15 (531 blocks)
1254	106,414	3,126	0.953	94 %	1
1422	25,418	1,019	0.703	91 %	2
1435	22	22	0.175	73 %	58
1452	11	9	0.165	53 %	172

Note: Rank refers to rank of the block's index score.



A **B**

Figure 3-9. (A) Four Open-space Blocks Overlapping the Gorst Creek Watershed

Colors show habitat value compared to other open-space blocks in the Puget Sound Basin. Black line is watershed boundary. See Table 3-1 for more information on each block

Figure 3-9. (B) Habitat Value Within Each Open-Space Block.

Impact refers to adverse impacts from human activities. Low impact has high habitat value.

The local habitat assessment indicates the habitat value within open-space blocks (Figure 3-9). The large block overlapping the northern portion of the watershed has a low edge-to-area ratio; hence, neighboring land uses have less influence on its habitat value. The northern block also has a low paved-road density and has not been platted for development. It includes the Bremerton municipal watershed and other lands owned by the City of Bremerton. The open-space block to the south has a much higher edge-to-area ratio;

therefore, it is more affected by nearby land uses. It also has a higher paved-road density, and well over half the block has been subdivided into numerous 5- and 20-acre parcels. The effects of these factors are evident in the habitat value mapped in Figure 3-9 (B).

3.2.2 Marine Nearshore Habitat Assessment

The estuary at the mouth of Gorst Creek contains intertidal wetlands and salt marsh that support shorebird and waterfowl concentrations. A bald eagle nest and territory occur near the south shore. A great blue heron colony was formerly located (circa 2006) near the west end of Sinclair Inlet, and over the past decade two separate great blue heron colonies have existed near the south shore of the inlet. This high concentration of colonies suggests that the estuary is used by herons as foraging habitat.

Juvenile Chinook salmon from Gorst Creek and at least 14 other watersheds, including as far away as the Fraser River in British Columbia, use Sinclair Inlet as rearing habitat (Fresh et al. 2006). Gorst Creek hatchery fish comprise nearly 100 percent of the juvenile Chinook in Sinclair Inlet until midsummer, dropping to only 40 percent of the total recoveries after mid-summer through early fall.

Compared to other shorelines in the Central Puget Sound sub-basin, the 2 miles of marine shoreline along the Gorst Creek estuary have an average index score at the 65th percentile. In other words, the importance is greater than 65 percent of other shorelines in the Central Puget Sound sub-basin. Three shoreline segments had importance values at the 83rd percentile (Figure 3-10). These relatively high scores were due to the presence of shorebird and waterfowl concentrations, salt marsh vegetation, and for one of the segments a nearby great blue heron colony.

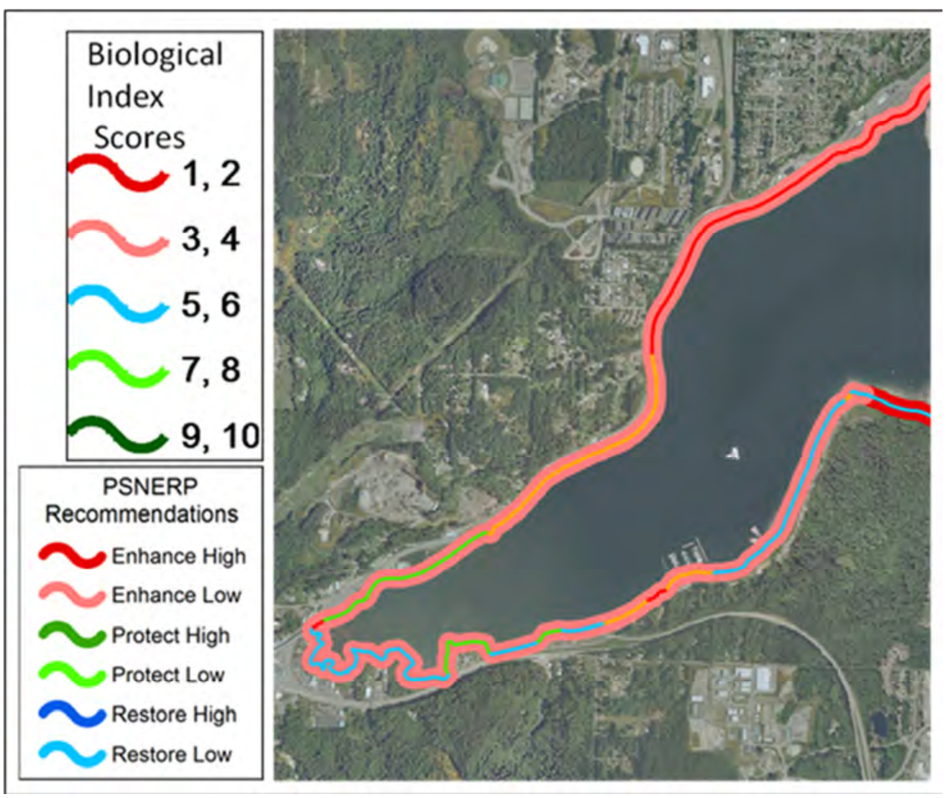


Figure 3-10. Results of the Nearshore Habitat Assessment (inner line) and PSNERP's Assessment of Drift Cells (two outer lines)

10 is highest importance and 1 is lowest importance. See Table 1 for definitions of PSNERP recommendations.

Gorst Creek is a shallow estuary in which little tidal energy or exchange occurs. Indicative of this condition, two drift cells overlap in the estuary in a zone within which no appreciable beach sediment transport occurs. For both beaches and embayments within the estuary, the PSNERP recommendations are "enhance low" (Cereghino et al. in preparation). An enhance recommendation means that improving critical ecosystem functions is the emphasis and that substantive restoration of ecosystems processes is unlikely.

The 2003 Kitsap Salmonid Refugia Report (May and Peterson 2003) also assessed the condition of marine nearshore salmon habitats. Sinclair Inlet received a score of 19 percent—the lowest score of the 31 sites assessed in Kitsap County. (See Figure 2-9 for a breakdown of the relative weighting of factors considered relative to fish habitat, riparian condition, and watershed for each of these areas). See also May and Peterson (2003) for detailed information on their assessment model. In contrast, the Point No Point nearshore received the highest score of 83 percent. Borde et al. (2009) also assessed nearshore conditions within the estuary and found that Sinclair Inlet has some of the most highly affected drift cells in eastern Kitsap County.

3.2.3 Freshwater Habitat Assessment

Gorst Creek is inhabited by Chinook, chum, and coho salmon, including steelhead and cutthroat trout (Figure 3-8), and is a major source of naturally produced and hatchery Chinook salmon in Sinclair Inlet (Fresh et al. 2006). In Sinclair Inlet the highest abundances of juvenile Chinook salmon are found in the area closest to the mouth of Gorst Creek and generally decline with increasing distance from Gorst Creek (Fresh et al. 2006).

The 2003 Kitsap Salmonid Refugia Report (May and Peterson 2003) designated Gorst Creek a class C salmonid refugia. Class C refugia have been altered from natural conditions and do not fully support native salmonid populations. The report described the watershed as "one of the largest and most productive watersheds in the east WRIA-15 subregion." Most notably, the report stated that without the hatchery influence, portions of the watershed would likely qualify as class B refugia. A class B refugia has been altered from natural conditions but at least some salmonid populations appear to be self-sustaining and resilient.

According to the Kitsap Salmonid Refugia Report, Jarstad Creek, a tributary of Gorst Creek, has the greatest value for salmonid conservation in the watershed. It scored 73 percent (Table 3-2, Figure 3-11), which is quite high considering that the highest score in Kitsap County was 83 percent for Stavis Creek. Jarstad Creek tied for the 20th highest score of the 95 refugia areas assessed in Kitsap County. Habitat conditions in Jarstad and Heins creeks are "generally good" (May and Peterson 2003). Because these sub-watersheds are owned and managed by the City of Bremerton, which leaves significant riparian buffers along streams, habitat conditions in these sub-watersheds are expected to improve.

Gorst Creek above river mile 1.0 also scored rather high: 72 percent, which was the 23rd highest score of the 95 refugia. Lower Gorst Creek, between river miles 0.0 and 0.5, was among the lowest scoring stream reaches in the entire county; that reach scored 52 percent. In comparison, the lowest score in the county was 46 percent for Clear Creek between river miles 0.0 and 1.0.

Table 3-2. Salmonid Conservation Value for Portions of Gorst Creek Watershed (May and Peterson 2003)

Portion of Sub-watershed	Score (maximum = 9)	Percent Maximum Score
Jarstad Creek	6.58	73
Gorst Creek RM 1.0 to headwaters	6.44	72
Heins Creek	6.26	70
RM 0.75 to 1.0	6.10	68
RM 0.50 to 0.75	4.93	55
RM 0.00 to 0.25; RM 0.25 to 0.50	4.69	52
Parish Creek	4.69	52

Note: RM = river mile

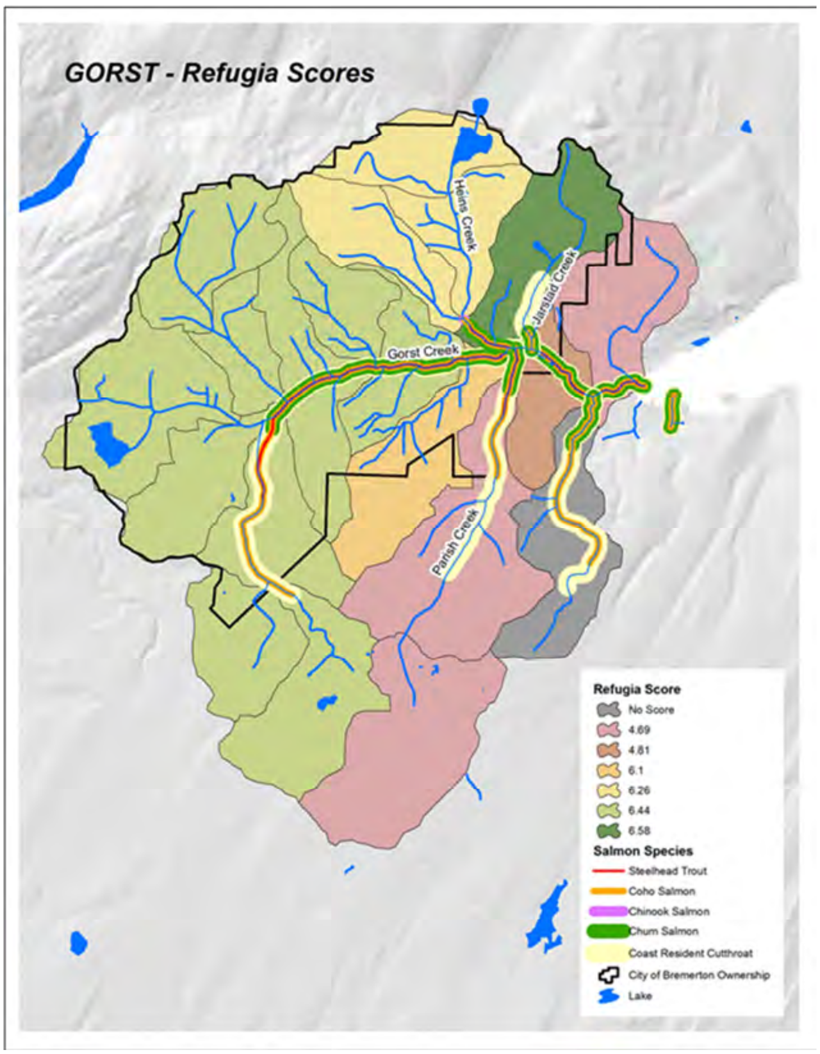


Figure 3-11. Salmonid Conservation Value for Sub-watersheds within Gorst Creek Watershed

Source: May and Peterson (2003)

Sub-watersheds are those used for the water flow assessment and do not correspond exactly to those of May and Peterson (2003).

3.2.4 Fish and Wildlife Habitat Assessment Results

According to the WDFW assessment, the most important fish and wildlife habitats in the Gorst Creek Watershed are:

- The streams that support trout and anadromous salmonids;
- The estuary that supports waterfowl, shorebirds, great blue herons, bald eagles, juvenile salmon, and other species; and
- The large contiguous area of managed forest on the north side of the Gorst Creek Watershed that is owned and managed by the City of Bremerton.

The forest on the north side of the Gorst Creek Watershed is especially valuable for three reasons. First, it is protected in public ownership and lies in a large contiguous area of open-space that contains two other large tracts of publicly owned forest: Green Mountain and Tahuya State Forests. Relative to other open-space blocks in the Puget Trough Ecoregion, the size of this entire open-space block (106,400 acres) is exceptional—it is the largest open-space block in the Puget Trough Ecoregion of the Puget Sound Basin. For the conservation of wildlife, size matters. In fact, the area of contiguous habitat may be the single most important variable determining the long-term viability of wildlife populations (Diamond 1975; Soule and Simberloff 1986). Second, the large forested area on the north side covers roughly half of the Gorst Creek Watershed; therefore, this area has a significant beneficial effect on the freshwater habitats of trout and anadromous salmonids. And third, the beneficial effects of this forest sustain water flow and water quality processes within the watershed and contribute to the overall quality of habitats in the Gorst Creek estuary.

The 2003 Kitsap Salmonid Refugia Report stated that without the hatchery influence, portions of the Gorst Creek Watershed would likely qualify as class B refugia. Although this class B refugia has been altered from natural conditions, at least some salmonid populations appear to be self-sustaining and resilient. Hence, the Kitsap Salmonid Refugia Report suggests that the Gorst Creek Watershed has the potential to contribute to the recovery of federally threatened Chinook and steelhead salmon. Gorst Creek may be too small for self-sustaining wild runs of Chinook or steelhead, but it could potentially support these species irregularly as a refuge. The Gorst Creek drainage was classified as a Tier 1 (high priority) watershed by the East Kitsap Peninsula Lead Entity (2004). Tier 1 is the highest priority for funding for salmon conservation and restoration through the Salmon Recovery Funding Board program. Future development in the watershed should not interfere with future efforts to restore in-channel and riparian habitats and build self-sustaining salmonid populations.

The current degraded condition of the estuary’s shorelines belies the estuary’s value for wildlife. Compared to other shorelines in the Central Puget Sound sub-basin, the 2 miles of marine shoreline along the Gorst Creek estuary have an average index score at the 65th percentile and portions of that shoreline scored even higher—at the 83rd percentile. PSNERP gave their lowest recommendation for the drift cells in the estuary—“enhance low.” Shorelines given this recommendation have the lowest priority for restoration relative to other shorelines in Puget Sound. However, “enhance low” sites are places where strategic actions may enhance significant existing functions such as habitat for salmon, shellfish, and waterfowl. Although the Gorst Creek estuary does provide some wildlife habitat, the function and extent of that habitat is likely a shadow of its historical extent (see Collins and Sheikh 2005).

Restoration actions in the estuary could restore some wildlife habitat. Priority actions of greatest benefit to fish and wildlife should be assessed at a finer scale, looking at existing ecological processes that affect the estuary, and attempting to restore ecological structure and function at site-specific locations, given the degraded condition of the estuarine shoreline and nearshore processes overall. Such an analysis is outside the scope of this assessment, but interested readers can consult Sinclair Inlet Enhancement Opportunities, which lists specific projects within the Inlet, which, if undertaken, would contribute to protecting and restoring ecosystem processes, structures, and functions of Sinclair Inlet, as well as reducing watershed pollution, and protecting and restoring sustainable fish and wildlife populations (Aquascape II) (NAVFAC Northwest 2010).

3.3 INTEGRATED ANALYSIS TO THE GORST CREEK WATERSHED

The following section overlays watershed characterization results with fish and wildlife habitat assessment results, and provides a summary table with recommendations based on the relative ranking of the Assessment Units within the watershed.

In general, the central and the northern portion of the watershed, currently managed for the City of Bremerton's water supply, are identified as key areas, which should continue to be protected and conserved to support ecological processes and habitat within the watershed. The southern half of the watershed, underlain by glacial till, is less susceptible to development impacts, and could accept more growth and development, provided that existing wetlands and stream corridors are protected by adequate buffers, and that development implements stormwater BMPs. The detailed results, broken out by Assessment Unit, are presented below.

Figure 3-12 graphically shows the integration of results of the fish and wildlife assessment, specifically focused on the Local Habitat Area (LHA) assessment, with the overall results of the water flow assessment. This map is to be used in conjunction with Table 3-3, which is color coded to match the combined results of Figure 3-12. For the LHA the darker green AUs represent areas of high habitat value and the light green AUs are areas of moderate high value. The dark blue AUs represent areas of low habitat values and light blue are areas of moderate low habitat importance. For the water flow assessment, P1, P2, = Protection 1 and 2 categories; C1, C2 = Conservation 1 and 2 categories; R1 and R2 = Restoration 1 and 2 categories; RD = Restoration/Development category and DR = Development/Restoration category. The numerals from 1 to 20 identify the AU number.

Combined Median Weighted Value from Fish & Wildlife with Overall Water Flow Restoration & Protection Results

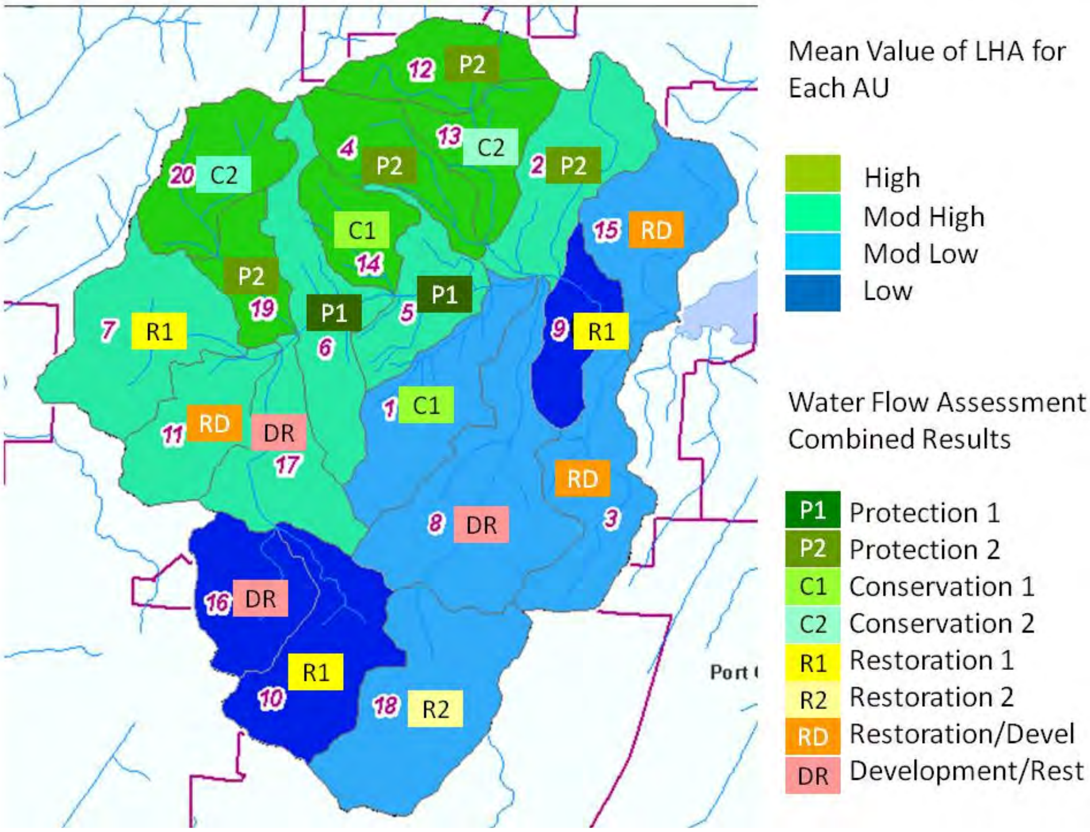


Figure 3-12. Integration of Fish and Wildlife Local Habitat Assessment (LHA) and Overall Water Flow Assessment Results. The individual numbers, 1 though 20, represent the specific AU listed in Table 3-3.

Table 3-3. Integrated Water Flow and Fish and Wildlife Assessment Results and Recommended Management Actions

AU No.	Overall Water Flow Assessment Results Synthesized Results: Importance and Degradation Matrix	Sediment Assessment: Export Potential	Local Habitat Assessment Results – Relative Level of Habitat Value	2003 Kitsap Salmon Refugia Report Score (0 to 6.58) (May and Peterson 2003)	Integrated Results	Notes and Suggested Management Measures
1	Conservation 1	Moderate High	Moderate	Moderate Low (6.1)	Protection	Important area for groundwater discharge for Gorst Creek; moderate value for habitat due to rural development and roads. Despite lower habitat assessment rating, development should be minimized in this area due to its immediate impact upon groundwater discharge processes (roads, ditches, and impervious surfaces alter discharge patterns) and Gorst Creek flows.
2	Protection 2	Moderate High	Moderate High	High (6.58)	Protection	Jarstad Creek has the highest salmon refugia score in watershed, so extra measures are needed to protect water flow processes in this AU. Due to high sediment export potential, logging activities should be limited in this AU. Maintain appropriate zoning for protection.
3	Restoration-Development	High	Moderate Low	No Score	Development and Restoration	Relatively high level of degradation. Not rated by salmon refugia study. More appropriate area for moderate density development provided measures are implemented to reduce erosion and sediment export (adequate stream buffers, setbacks, reduced overland flow through infiltration and vegetation cover).
4	Protection 2	High	High	Moderate (6.26)	Protection	For headwaters AU, the processes are essentially intact, with high habitat value; given these values and high sediment export potential it is important to maintain forest cover, limit logging activities and maintain appropriate zoning for protection.
5	Protection 1	Moderate	Moderate High	Moderate High (6.44)	Protection	Area has some degradation due to roads, but has extensive slope wetlands and groundwater discharge critical to Gorst Creek. High habitat and salmon refuge value indicates that this area should be protected from further degradation. Maintain appropriate zoning for protection.
6	Protection 1	Moderate	Moderate High	Moderate High (6.44)	Protection and Restoration	Southern portion of AU has more clearing of forest and should be restored. Maintain appropriate zoning to protect this area.
7	Restoration 1	Moderate	Moderate High	Moderate High (6.44)	Restoration 2A	High habitat and salmon refugia scores identify this as a higher priority area to undertake restoration actions. The golf course has degraded many of the wetlands and water courses (also on AU11); a comprehensive restoration program should be developed to restore these areas. Maintain zoning to protect open space, rural nature, and increase forest cover.
8	Development-Restoration	High	Moderate	Low (4.69)	Development 3A	Area of low importance for water flow processes and moderate for habitat; more appropriate area for moderate to higher density development compared to other AUs within the Gorst Creek

AU No.	Overall Water Flow Assessment Results Synthesized Results: Importance and Degradation Matrix	Sediment Assessment: Export Potential	Local Habitat Assessment Results – Relative Level of Habitat Value	2003 Kitsap Salmon Refugia Report Score (0 to 6.58) (May and Peterson 2003)	Integrated Results	Notes and Suggested Management Measures
						Watershed. High sediment export potential requires development measures that reduce erosions through adequate buffers and setbacks (from steep slopes) and reduction of overland flow through infiltration and plantings (LID measures). Clustering may be appropriate in this area in order to minimize potential sediment export impacts.
9	Restoration 1	Low	Low	Low (4.81)	Restoration 2C	Though this area has a low score for habitat and salmon refugia, it is a higher priority for restoration due to generally intact upstream processes (northern half of watershed). Channelization, culverts, and reduced riparian cover have degraded stream corridor and discharge processes. A comprehensive program to restore creek corridor should be developed. Effective Impervious surface should be reduced through a stormwater retrofit program.

AU No.	Overall Water Flow Assessment Results Synthesized Results: Importance and Degradation Matrix	Sediment Assessment: Export Potential	Local Habitat Assessment Results – Relative Level of Habitat Value	2003 Kitsap Salmon Refugia Report Score (0 to 6.58) (May and Peterson 2003)	Integrated Results	Notes and Suggested Management Measures
10	Restoration 1	Low	Low	Moderate High (6.44)	Restoration Area 2B	Low habitat value due to impacts from adjoining residential area but high salmon refugia score. Large area of wetlands that play an important role in regulating downstream flow. Wetlands and streams should be protected and restored, with appropriate buffers provided. This is an appropriate area for moderate density development provided clustering approach is used.
11	Restoration-Development	Low	Moderate High	Moderate High (6.44)	Restoration Area 2A	High habitat and salmon refugia scores identify this as a priority area to undertake restoration actions. The golf course has degraded many of the wetlands and water courses; a comprehensive restoration program should be developed to restore these areas. Recharge is the key process to restore. Also restore discharge and storage processes.
12	Protection 2	Mod High	High	Moderate (6.26)	Protection	Same as No. 4 Headwaters AU: processes essentially intact, high habitat value. Maintain forest cover and protective zoning.
13	Conservation 2	High	High	Moderate (6.26)	Protection	Same as No. 4 Headwaters AU: processes essentially intact, high habitat value. Maintain forest cover and protective zoning.
14	Conservation 1	High	High	Moderate High (6.44)	Protection	Same as No. 4 Headwaters AU: processes essentially intact, high habitat value. Maintain forest cover and protective zoning.
15	Restoration Development	Moderate High	Moderate	Low (4.69)	Development	Relatively high level of degradation and low habitat score; more appropriate area for higher density development provided measures are applied to reduce potential sediment export.
16	Development - Restoration	Low	Low	Moderate High (6.44)	Development	The western edge of this AU is degraded by airport development. It has a moderately high score for salmon refugia, so the AU stream should be adequately protected (appropriate width buffers). More appropriate area for higher density development within the Gorst Creek Watershed, provided that streams and wetlands have adequate buffer protection.
17	Development-Restoration	Moderate	Moderate High	Moderate High (6.44)	Development Area 3B	Although the overall assessment for water flow indicated "development," this area should receive a higher degree of protection based on moderate high habitat value. May be an appropriate area for low-to-moderate density development, provided habitat resources (forest, streams, and wetlands) are protected through use of clustering. Landfill in downstream, northern portion of AU has collapsed the culvert-carrying stream, which gives it priority for restoration.
18	Restoration 2	Low	Moderate	Low (4.69)	Restoration Area 2B	Overall, this AU has a low-to-moderate value for water flow processes and habitat. Appropriate area for moderate density development, provided that existing streams and wetlands receive

AU No.	Overall Water Flow Assessment Results Synthesized Results: Importance and Degradation Matrix	Sediment Assessment: Export Potential	Local Habitat Assessment Results – Relative Level of Habitat Value	2003 Kitsap Salmon Refugia Report Score (0 to 6.58) (May and Peterson 2003)	Integrated Results	Notes and Suggested Management Measures
						adequate protection and restoration of wetland storage functions where they have been degraded; wetlands will help control downstream erosion in AU8.
19	Protection 2	Moderate High	High	Moderate High (6.44)	Protection	Same as No. 4 Headwaters AU: processes essentially intact, high habitat value. Limit forestry activities given high sediment export potential. Maintain forest cover and protective zoning.
20	Conservation 2	High	High	Moderate High (6.44)	Protection	Same as No. 4 Headwaters AU: processes essentially intact, high habitat value. Limit forestry activities given high sediment export potential. Maintain forest cover and protective zoning.

3.4 RECOMMENDATIONS

Generally, the integrated results of the watershed characterization, when combined with the local habitat area relative values, consistently support the following actions:

1. **Central and Northern Portions of the Gorst Creek Watershed**: Protect and conserve these areas that are owned by the City of Bremerton and managed to protect the City's water supply. This includes AUs 1,2,3,4,5,6,12,12,14,19 and 20 as shown in Figure 3-11 and Table 3-3. The exception to this is AU No. 9, which is identified as a restoration area (see area 2C below) because, while having a low relative habitat value score and a low (4.81) salmon refugia score, is significant because of its landscape position and immediate potential to affect groundwater discharge processes and Gorst Creek flows.
2. **Restoration Area 2A**: The AUs contained within this area are largely City-owned, and include the City's golf course (AUs 7 and 11). This area is ranked as Restoration 1 and Restoration/Development by the watershed characterization, has a moderate relative habitat value, and a moderate high salmonid refugia score (6.44). The delivery, recharge and discharge processes are degraded. Restoration actions to improve recharge should include infiltration swales or galleries adjacent to the lower permeability fairways and greens. For the discharge process, restoration measures could include re-establishment of the natural hydrology of depressional and slope wetlands.
3. **Restoration Area 2B**: Although this area ranks relatively low for habitat value, the depressional wetlands that occur within the AU (10 and 18) are important for regulating downstream flows; the upper reaches of Gorst Creek in AU 10 scored moderate high (6.44) in the 2003 Kitsap Salmon Refugia Report for AU. The wetlands in AU 10 should be protected and restored to help support baseflows and reduce downstream erosion. Given the significance of the stream with respect to its salmonid refugia score, such actions would benefit downstream flows and fish populations within the tributary as well as the mainstem of Gorst Creek.
4. **Restoration Area 2C**: While this area (encompassing AU 9) received a low relative habitat value rating, and also scored low (4.81) on the salmonid refugia score, its landscape position and relatively intact upstream processes in the northern and central portion of the waterhed, create opportunities for restoration within the AU. Restoration actions could include reducing stream channelization and ditching, as well as restoring degraded riparian cover within the corridor. This area could also be the focus of stormwater retrofit actions, such as reduction of effective impervious area. A focused restoration plan should be developed in this AU to identify specific restoration opportunities.
5. **Areas More Appropriate for Higher Density Development**: AUs 3,8,15,16 and 17 and more appropriate for moderate to higher density urban development provided the recommendations in Table 3-3 are implemented. Generally, this represents the southeastern half of the watershed. Development in these areas should include clustering of development and green infrastructure and stormwater retrofits to support the contiguous network of protection, conservation, and restoration throughout the remainder of the watershed. In addition, a portion of Gorst Creek in AU 17 should be restored to support salmonid habitat downstream; the stream runs through a culvert buried in an old landfill that is a source of known contaminants downstream. However, given that most of this area is underlain by glacial till, with relatively low habitat value and low salmonid refugia scores, and of less importance to sustaining recharge and discharge water flow processes in the watershed, development in these areas would have less adverse effects on water flow and habitat conditions relative to development in other areas within the watershed.

4. REFERENCES

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Island Press, Washington, DC. 493 pp.

Anchor QEA. 2009. Geospatial methodology used in the PSNERP comprehensive change analysis of Puget Sound: Puget Sound Nearshore Ecosystem Restoration Project. U.S. Army Corps of Engineers, Seattle District, and Washington State Department of Fish and Wildlife, Olympia, WA.

Bedford, B.L. 1999. Cumulative effect on wetland landscapes: Links to wetland restoration in the United States and Southern Canada. Wetlands 19(4):775–788.

Bedford, B.L., and E.M. Preston. 1988. Developing the scientific basis for assessing cumulative effects of wetland loss and degradation on landscape functions: Status, perspectives and prospects. Environmental Management 12(5): 751–771.

Beechie, T., and S. Bolton. 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds. Fisheries Habitat 24:6–15.

Berry, H.D., J.R. Harper, T.F. Mumford, B.E. Bookheim, A.T. Sewell, and L.J. Tamayo. 2001. The Washington State shorezone inventory user's manual. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA.

Borde, A.B., C. Judd, N.K. Sather, and R.M. Thom. 2009. East Kitsap County nearshore habitat assessment and restoration prioritization framework. PNWD-4053. Battelle Marine Sciences Laboratory, Sequim, WA.

Cassidy, K.M. 1997. Land cover of Washington State: Description and Management. *In*: K.M. Cassidy, C.E. Grue, M.R. Smith, and K.M. Dvornich (eds.). Volume 1: Washington State Gap Analysis—Final Report. Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle, WA.

Cereghino, P., J. Toft, S. Simensted, E. Iverson, S. Campbell, C. Behrens, J. Burke, and B. Craig. In preparation. Puget Sound nearshore conservation strategies. Puget Sound Nearshore Restoration Project. U.S. Army Corps of Engineers, Seattle District, and Washington State Department of Fish and Wildlife, Olympia, WA.

City of Bremerton, Gorst Creek Watershed Comprehensive Plan, Draft Existing Conditions Technical Memorandum, Prepared for the City of Bremerton, Kitsap County and the Environmental Protection Agency by Parametrix, May 2011.

Collins, B.D., and A.J. Sheikh. 2005. Historical reconstruction, classification, and change analysis of Puget Sound tidal marshes. Project Completion Report prepared for Washington Department of Natural Resources, Aquatic Resource Division, Olympia, WA. University of Washington, Puget Sound River History Project, Department of Earth and Space Sciences, Seattle, WA. June 30, 2005.

Dale, V.H., S. Brown, R.A. Haeuber, N.T. Hobbs, N. Huntly, R.J. Naiman, W.E. Riebsame, M.G. Turner, and T.J. Valone. 2000. Ecological principles and guidelines for managing the use of land. Ecological Applications 10(3): 639–670.

Dethier, M.N. 1990. A marine and estuarine habitat classification system for Washington State. Washington Natural Heritage Program, Department of Natural Resources, Olympia, WA.

Diamond, J.M. 1975. The island dilemma: Lessons of modern biogeographic studies for the design of natural reserves. Biological Conservation 7:129–146.

Diefenderfer, H.L, K.L. Sobocinski, R.M. Thom, C.W. May, A.B. Borde, S.L. Southard, J. Vavrine, and N.K. Sather. 2009. Multiscale analysis of restoration priorities for marine shoreline planning. Environmental Management 44:712–731.

DNR (Department of Natural Resources). 2001. Washington shorezone inventory data dictionary. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA.

East Kitsap Peninsula Lead Entity. 2004. Salmon recovery strategy. Final Draft. Kitsap County Department of Community Development, Port Orchard, WA.

Fresh, K.L., D.J. Small, H. Kim, C. Waldbillig, M. Mizell, M.I. Carr, and L. Stamatiou. 2006. Juvenile salmon use of Sinclair Inlet, Washington, in 2001 and 2002. Technical Report No. FPT 05-08. Washington Department of Fish and Wildlife, Olympia, WA.

Gersib, R. 2001. The need for process-driven, watershed-based wetland restoration in Washington State. Proceedings of the Puget Sound Research Conference 2001.

Gove, N.E., R.T. Edwards, and L.L. Conquest. 2001. Effects of scale on land use and water quality relationships: A longitudinal basin-wide perspective. Journal of the American Water Resources Association 37(6):1721–1734.

Hidding, M.C., and A.T.J. Teunissen. 2002. Beyond fragmentation: New concepts for urban-rural development. Landscape and Urban Planning 58(2/4):297–308.

Johnson, D.H., and T.A. O’Neil. 2001. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, Oregon.

Leu, M., S.E. Hanser, and S.T. Knick. 2008. The human footprint in the west: A large-scale analysis of anthropogenic impacts. Ecological Applications 18:1119–1139.

May, C.W., and G. Peterson. 2003. 2003 Kitsap salmonid refugia report: Landscape assessment and conservation prioritization of freshwater and nearshore salmonid habitat in Kitsap County. Prepared for Kitsap County, Port Orchard, WA. October 31, 2003.

National Research Council. 2001. Committee on mitigating wetland losses: Compensating for wetland losses under the Clean Water Act. National Academy Press, Washington, DC. 348 pp.

NAVFAC Northwest (Naval Facilities Engineering Command Northwest). 2010. Sinclair Inlet enhancement opportunities (Aquascape II). Bremerton, WA. August 2010.

OFM, 2007. Washington State Office of Financial Management. Washington State Growth Management Population Projections by County. 2007 Projections by five year intervals. High projections. Data accessed via: http://www.ofm.wa.gov/pop/gma/projections07.asp

Poiani, K.A., B.D. Richter, M.G. Anderson, and H.E. Richter. 1996. Biodiversity conservation at multiple scales: Functional sites, landscapes, and networks. Bioscience 50(2):133–146.

Quigley, T.M., R.W. Haynes, and W.J. Hann. 2001. Estimating ecological integrity in the interior Columbia River basin. Forest Ecology and Management 153:161–178.

Roni, P., T.J. Beechie, R.E. Bilby, F.E. Leonetti, M.M. Pollock, and G.R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management 22:1–20.

RTI (Rural Technology Initiative). 2010. Washington State parcel database. Rural Technology Initiative, University of Washington, Seattle, WA.

Sceva, J.E. 1957. Geology and ground-water resources of Kitsap County, Washington. U.S. Geological Survey Water-Supply Paper 1413. 178 pp., 3 plates.

Shipman, H. 2008. A geomorphic classification of Puget Sound nearshore landforms. Puget Sound Nearshore Partnership Report No. 2008-01. Published by Seattle District, U.S. Army Corps of Engineers, Seattle, WA.

Simenstad, C., M. Logsdon, K. Fresh, H. Shipman, M. Dethier, and J.Newton. 2006. Conceptual model for assessing restoration of Puget Sound nearshore ecosystems. Puget Sound Nearshore Partnership Report No. 2006-03. Published by Washington Sea Grant Program, University of Washington, Seattle, WA.

Soule, M.E., and D. Simberloff. 1986. What do genetics and ecology tell us about the design of nature reserves? Biological Conservation 35:19–40.

Stanley, S., J. Brown, and S. Grigsby. 2005. Protecting aquatic resources, Volume 1. A guide for Puget Sound planners to understand watershed processes. Washington State Department of Ecology Publication 05-06-027. Olympia, WA.

Stanley, S., S. Grigsby, T. Hruby, and P. Olson. 2009. Version 2, Puget Sound Watershed Characterization Project: Description of Methods, Models, and Analysis. Washington State Department of Ecology Publication #10-06-005 (in review). March 2010. Olympia, WA.

Stanley, S. S. Grigsby, D. Booth, G. Wilhere, D. Hartely, J. Thomas, P. Bissonnette, and J. Lee. In preparation, 2011. The Puget Sound Basin Characterization, Volume 1 – Water Resource Assessments. Washington State Department of Ecology.

Theobald, D.M. 2010. Estimating natural landscape changes from 1992 to 2030 in the conterminous US. Landscape Ecology 25:999–1011.

Treaty Indian Tribes in Western Washington. 2008. Tribal natural resource management 2008: An annual report from the Treaty Indian Tribes in Western Washington.

Weber, T.C., and W.L. Allen. 2010. Beyond on-site mitigation: An integrated multi-scale approach to environmental mitigation and stewardship for transportation projects. Landscape and Urban Planning 96(4), 240–256. Elsevier B.V.

Whatcom County Shoreline Master Program Update. 2006. Shoreline Inventory and Characterization.

Wilhere, G.F., M. Goering, and H. Wang. 2008. Average optimacity: An index to guide site prioritization for biodiversity conservation. Biological Conservation 141:770–781.

Wilhere, G.F., T. Quinn, J. Jacobson, D. Gombert, and D. Miller. In preparation. A fish and wildlife habitats assessment for the Puget Sound watershed characterization project: Terrestrial, freshwater, and marine nearshore environments. Washington Department of Fish and Wildlife, Habitat Program, Olympia, WA.

Winter, T.C. 2001. The concept of hydrologic landscapes. Journal of the American Water Resources Association 37(2):335–348.

APPENDIX A

Methods for Characterization

Appendix A. Characterization Methods

Methods

The approach used for this project is described in Ecology publication #10-06-05, "Puget Sound Watershed Characterization Project: Description of Methods, Models and Analysis"
 The document provides guidance on how to conduct a coarse-scale characterization for multiple watershed processes. Appendix B of this publication also present the models used to score hydrologic processes. T his document can be accessed at the following link:
http://www.ecy.wa.gov/mitigation/landscapeplan/peerreview.html

The appendices provide tables describing the individual components of the water flow process, as well as human activities that are impairments to the process. The numeric models allow a user to identify the areas in a watershed that are more important to maintaining that process, and areas where that process is most impaired. The equations in these models use the environmental characteristics described in the tables as variables that establish the relative level of importance and impairment. All of the indicators of importance or impairment are based on peer-reviewed research

Variables receive maximum values of 1, 2, or 3, representing low, medium, or high importance of a characteristic or impairment of a characteristic. The models reflect that a higher total score represents a sub-unit of greater importance for supporting a process in a watershed, or one with a higher degree of impairment to that process.

In general, scoring is normalized to conditions within in a watershed or basin. However, Thus, the models provide a *comparison* of the *relative level of importance and impairment* of process components (see Steps 3 and 4 of Ecology publication #05-06-027). The scores do not represent a specific rate (e.g., rate of removal of sediment or nitrogen) or specific level of impairment of a process, and cannot be compared to scores outside of the analysis area. We do not have enough information at this time to calibrate models to conditions throughout the state and establish relative importance of processes and impairments among different watersheds.

APPENDIX B

Framework for Planning

Appendix B. Land Use Planning Framework

Land Use Planning Framework

Successful watershed planning uses larger scale information (i.e. the characterization) to help identify planning solutions at smaller scales. To accomplish this, a watershed based planning framework, as presented below, should be applied. A more detailed discussion of this planning framework is presented in "Guidance for Protecting and Managing Wetlands in Western Washington", Volume 2, Chapters 4 and 5 (Granger et al. 2005).

The methods described in this document for mapping important areas and relative impairments to watershed processes address the first box of the diagram above, "Characterize Watershed Processes." Planners can then use this information to develop preliminary solutions (box 2, "Prescribe Solutions") including alternative scenarios for development/ management. Examples include:

- Selecting the appropriate types and intensity of development for different locations
- Changing zoning to better protect the ecological services provided by the environment
- Identifying the best locations for mitigation
- Identifying the types of mitigation needed in different areas
- Locating the best areas for cost-effective restoration.

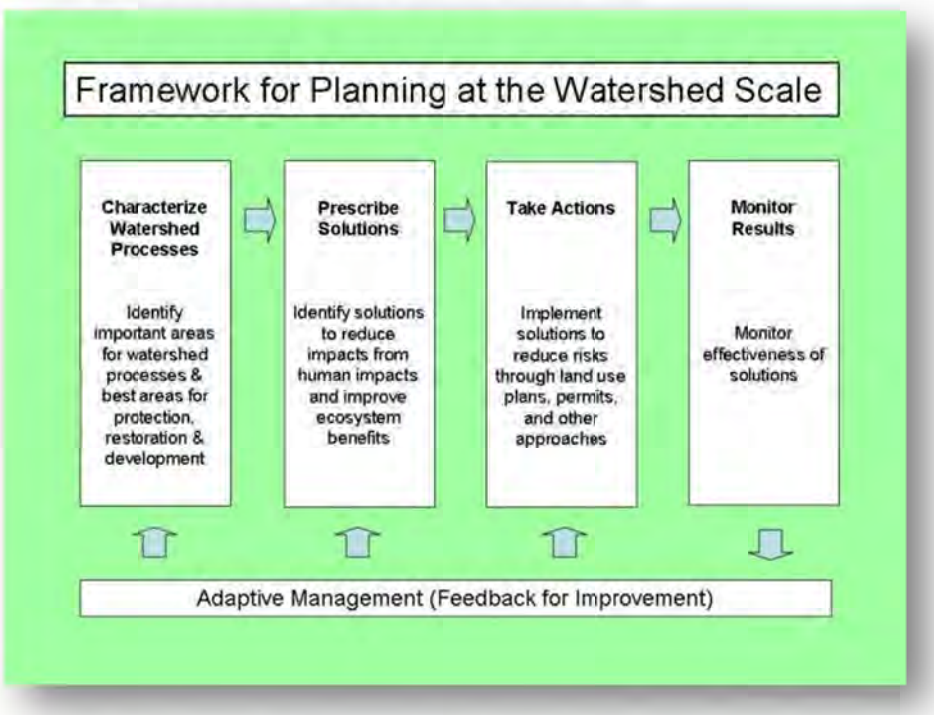


Figure B-1 – Framework for Planning at the Watershed Scale. The four main steps for developing a watershed based plan.

When scenarios for future development and management are analyzed, locally reviewed, and accepted, the solutions can be incorporated in Shoreline Master Program and/or

Comprehensive Plan updates and implemented through the regulatory process . The final, and most important step in the framework, is monitoring the results of the adopted plan. This determines if the provisions of the plan are effectively protecting and/or restoring aquatic ecosystems. Feedback from this monitoring effort can be used to modify or "adapt" the plan to correct those aspects that are not meeting the objectives of protection and restoration.

Examples of Use of a Planning Framework by Other Jurisdictions

Whatcom, King, and Jefferson counties are presently using a framework for planning at the watershed scale as part of their Shoreline Master Programs (SMP) updates. These jurisdictions are using variations of earlier versions of the characterization models outlined in Ecology Publication 05-06-027. The Whatcom County Council adopted their draft SMP on February 27, 2007. The draft SMP characterization and restoration reports (Appendix C, Volumes I and II) are available at the following site:

http://www.co.whatcom.wa.us/pds/shorelines_critical_areas/workproducts.jsp

Whatcom County's characterization work provided information necessary to: 1) select appropriate environment designations and development standards for shoreline areas and 2) develop watershed-based restoration and protection recommendations for shoreline resources. Figure B-2 displays the important areas identified for the hydrology process in Whatcom County at the watershed scale. Using this information, as well as a characterization of the level of impairment, the county developed tables providing recommendations at a reach scale for protection and restoration measures and environment designations (Figure B-3).

A draft watershed management plan was developed by Whatcom County in 2007 for the Birch Bay watershed. Using a watershed based characterization of both hydrologic processes and wildlife, the plan identified protection, restoration and development management zones (Figure B-4).

Additionally, specific measures for restoration of processes were proposed for each sub-unit within the study area. The County is in the process of preparing regulatory and non-regulatory measures to implement the management plan. The draft management plan is available at the following site:

http://www.co.whatcom.wa.us/pds/shorelines_critical_areas/pdf/CompleteBBCharacter_PublicDraft.pdf

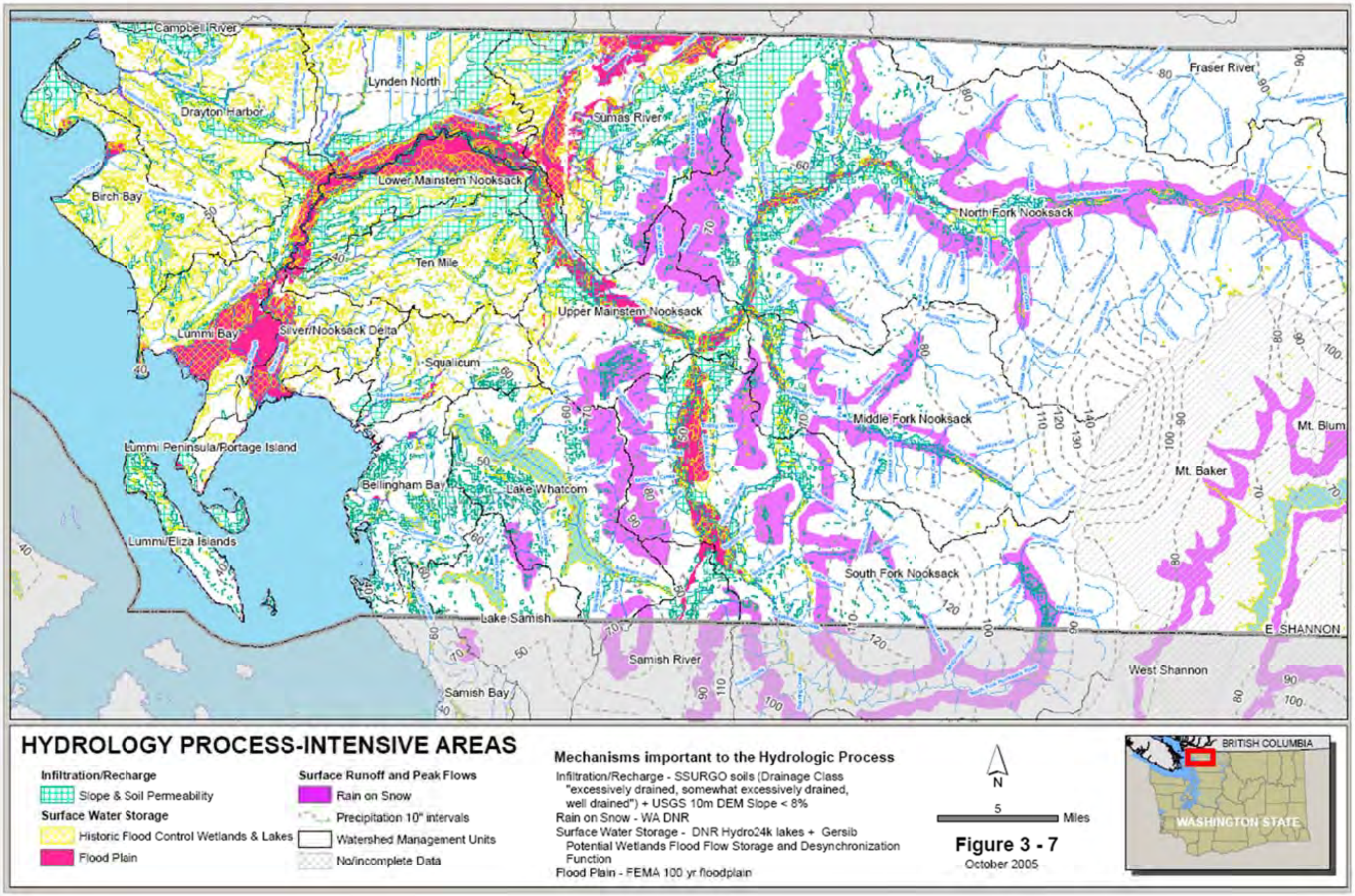


Figure B-2. Example of characterization map for water process. (Whatcom County). This map was developed using methods described in the Department of Ecology publication # 05-06-027 (Protecting Aquatic Ecosystems). This map, along with maps for four other watershed processes, was used to develop SMP protection and restoration measures (Figure B-3).

ɔle 7-1. Summary of Process Intensity and Alterations by Drainage Area, Upper Mainstem Nooksack WMU

Process		Process Intensity*																						
Process		Hydrology								Sediment						Water Quality				LWD		Heat/Light		
Mechanism		Infiltration & Recharge		Surface Water Storage		Snowmelt and Runoff		Ground-water		Mass Wasting		Surface Erosion		Storage		Inputs		Storage		LWDRP		Canopy Cover		
Intensity		Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Potential for Restoration and Protection
1	Lower Nooksack Floodplain	↑	↓	↑	↓	↓	↓	↑	↔	↓	↓	↓	↔	↑	↓	↓	↔	↑	↓	↔	↑	↓	↑	This portion of the Nooksack Mainstem has significant, intact riparian wetlands, but armoring and levees likely limit surface, hyporheic, and groundwater interactions between the river and its floodplain. Strategic levee setbacks accompanied by riparian restoration may help restore natural stream morphology and improve habitat.
2	Smith Creek	↓	↓	↓	↓	↑	↓	↓	↓	↓	↔	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓	↑	↓	Upper Smith Creek is relatively unimpaired by forest practices. Lower Smith Creek lies on the Nooksack floodplain, and has a hydrologic connection to the larger river system. Restoring /preserving connectivity in the lower drainage may improve functions in both the Nooksack and the creek.
3	Lower Anderson Creek	↔	↓	↔	↑	↓	↓	↔	↔	↓	↓	↓	↓	↔	↑	↓	↔	↔	↑	↑	↔	↑	↔	Restoring lost wetlands and riparian areas in lower Anderson Creek has the potential to improve water quality, water quantity, and habitat complexity.
4	Upper Anderson Creek	↓	↓	↓	↓	↑	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓	↑	↔	The upper Anderson Creek is relatively unimpaired by forest practices. Protection of rain-on-snow zones and landslide hazard areas is recommended to prevent increased disturbance regime.
5	Upper Nooksack Floodplain	↑	↔	↑	↔	↓	↓	↑	↔	↓	↓	↓	↔	↑	↔	↓	↔	↑	↔	↔	↑	↓	↑	Riparian restoration is the key component for re-establishing natural geomorphology. Such restoration will likely succeed only in the context of reduced sediment supply from upstream sources. The area in the vicinity of Smith Creek is highly altered and may provide significant opportunities for restoration projects.
6	Other Tributaries	↓	↓	↓	↓	↔	↔	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓	↑	↔	These are typically short, steep tributaries upstream of the major tributaries. Opportunities for restoration may be more limited.

Red: High restoration potential: Moderate to high process intensity with high degree of alteration
Blue: Moderate restoration potential: -- Moderate to high process intensity with moderate degree of alteration; OR low process intensity with high degree of alteration
White: Low restoration potential: Low process intensity with low to moderate degree of alteration
Gold: High protection potential: Moderate to high process intensity with low degree of alteration

* Function responses to alteration of these processes tend to be less dependent on the level of process-intensity, which is historically low in Whatcom County. Therefore, the assessment of restoration potential is based primarily on the degree of alteration.

Reach	Existing SEDs	Recommended SEDs		Comment
		Left Bank	Right Bank	
Reach 16	Conservancy	Resource/ Conservancy	Conservancy	Rural near downstream end of Reach 16 near Everson, otherwise Conservancy designation will protect existing process-intensive areas
Reaches 17-19	Conservancy/ Tribal	Conservancy/ Tribal	Conservancy/Tribal	

:k

Figure B-3. Protection and Restoration Measures. The upper table was used by Whatcom County to summarize watershed characterization results for the upper mainstem Nooksack Water Management Unit. Components for each process are evaluated based on intensity/importance of the processes, the degree of impairment, and the potential for protection and restoration. This table was then used to help determine appropriate land-use designation (lower table) for shoreline reaches and specific restoration measures in a separate restoration plan.

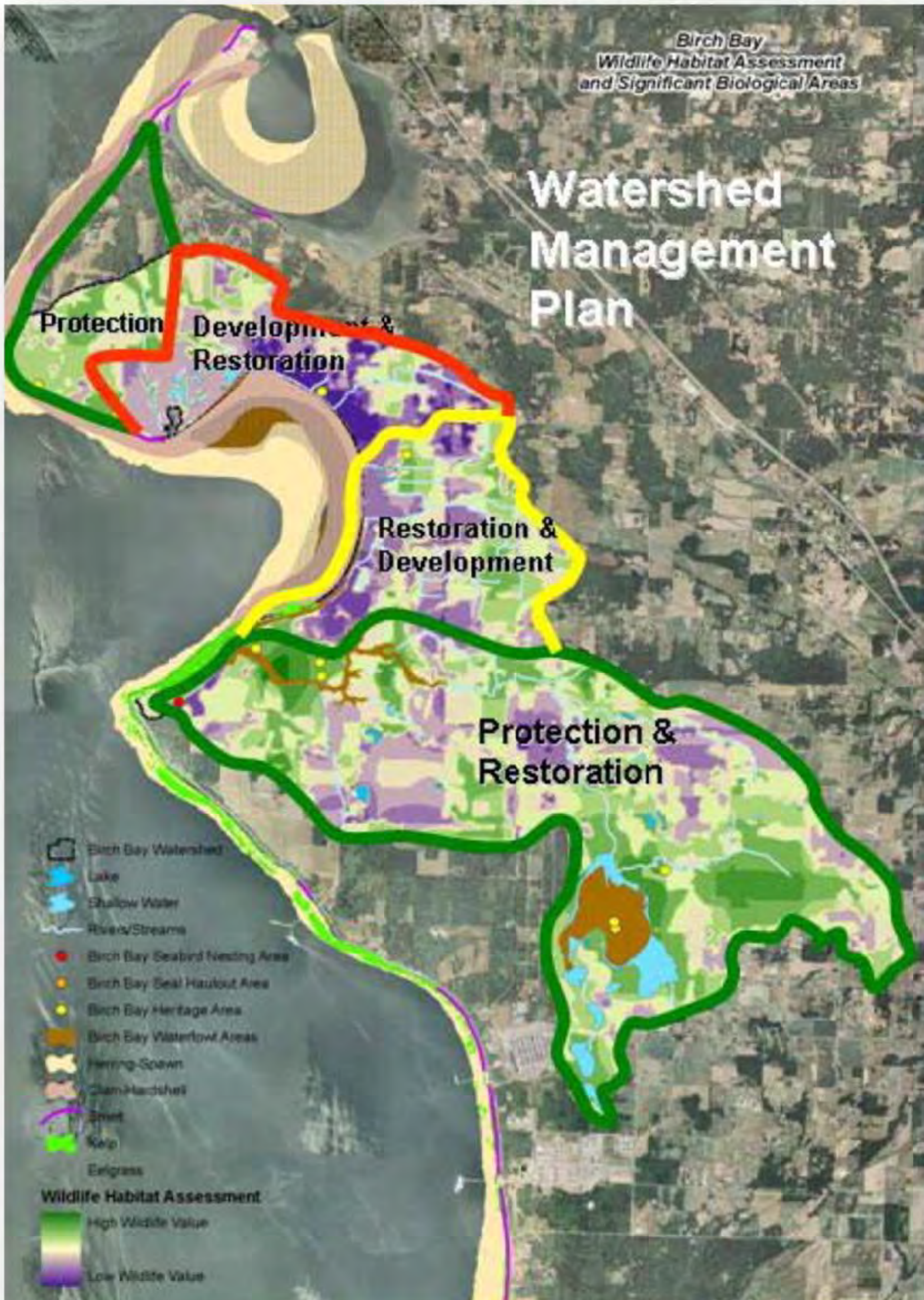


Figure B-4. Draft Management Plan for Birch Bay, Whatcom County.

APPENDIX C

Methods for Terrestrial Habitat Assessments

Appendix C. Terrestrial Habitat Assessment Methods

The first major step in the regional assessment for the entire Puget Sound Basin was to delineate open-space blocks. An open-space block is a contiguous area containing land uses – such as commercial forest, agriculture, parks, and designated open-space – that maintain natural or quasi-natural habitats or serve as habitats for native wildlife.

Two GIS data layers were used to identify open-space blocks: Landcover/landuse data developed by the Coastal Change Analysis Program (C-CAP 2005) and parcel data developed by the Rural Technology Initiative (RTI 2010) at the University of Washington.

The C-CAP data were used to identify areas of open-space and all C-CAP classes except for water and the four developed classes (low, medium, and high intensity developed, and Open Space Developed) qualified as open-space. The bare land class was included as open-space only where it existed above 1000 ft elevation, as this class contained gravel pits and other cleared land within the more urban lowland areas.

The parcel data were assembled from county tax assessor data from all counties in the Puget Sound Basin except Island County. These were used to identify those parcels that had a significant human presence. The data attribute "SumMarketTotalValue" is the parcel's total market value normalized to the parcel's acreage. Parcels with greater than $30,000 for this attribute were identified as having a significant human presence, and these areas were considered non-open space.

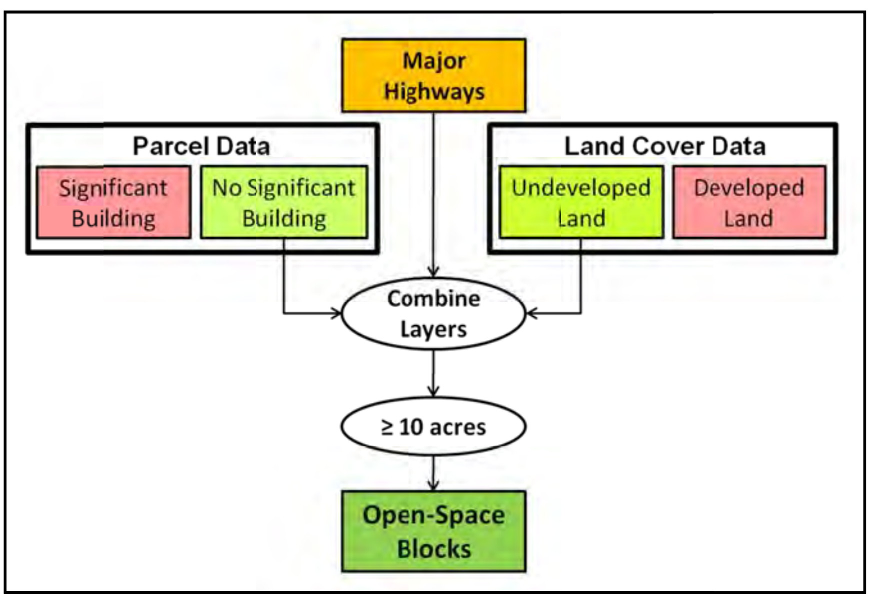


Figure A1. GIS process used to construct open-space blocks. Land cover data were C-CAP and parcel data were from the Rural Technology Initiative (RTI) at the University of Washington.

The non-open space parcels were spatially removed from the C-CAP derived open-space areas, and major highways (state routes, federal highways, and interstates) were also removed from open-space blocks. Some blocks were connected to other blocks by thin lines of open-space. Most were too narrow to serve as functional habitat corridors, so a GIS process was applied to the data that eliminated these connections. Only those open-space blocks that were 10 acres or greater were retained as the final set of open-space blocks .

Importance of Open-Space Blocks for Wildlife Habitats

The habitat value of each open-space block was a function of land use impacts, open-space fragmentation, vegetation zone, and priority habitats and species (PHS) (Figure A2). The land uses around each open-space blocks was assessed for their potential impact on habitats within the block. The parcel data gives the main land use of every parcel. Each parcel's land use was assigned a potential impact value from 1 to 100 (low to high; Table A1). A mean impact value was calculated for parcels within a 3 mile buffer around each block. Impact of each parcel was weighted by parcel area. The mean value served as an indicator of impacts from the surrounding landscape. A mean land use impact was also calculated for land uses within each block

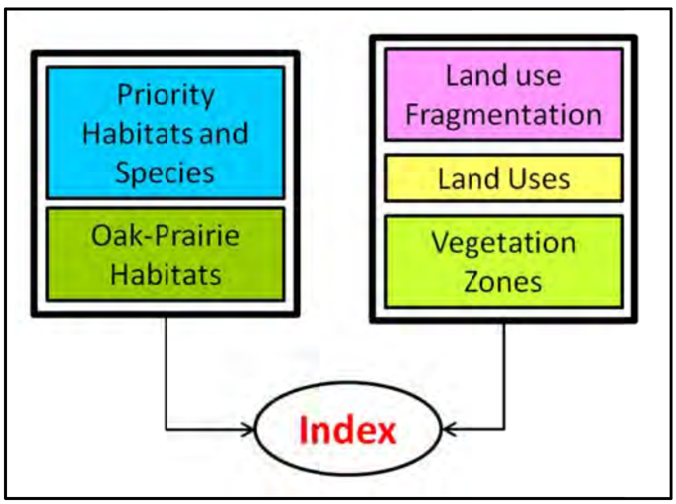


Figure A2. Major components of the terrestrial habitats assessment for the Puget Sound Basin. The index score is assigned to each open-space block. Land use fragmentation

Metrics of open-space fragmentation were calculated for each open-space block using the program FRAGSTATS (McGarigal and Marks 1995). The indices used in the terrestrial importance index were the shape index called "Circle" and the proximity index. The search radius for the proximity index was 3 mile (Figure A3).

Vegetation zone was also a factor used to influence the importance of open-space blocks. We used the GAP vegetation (Cassidy 1997) zones as a base data layer which we modified. We revised the Oak Woodland-Prairie Mosaic zone by using the 2005 oak woodland and grassland prairie data of the Washington Natural Heritage Program, historical prairie data from Robert Van Pelt at the University of Washington, and a mapping of dry prairie soils from the Natural

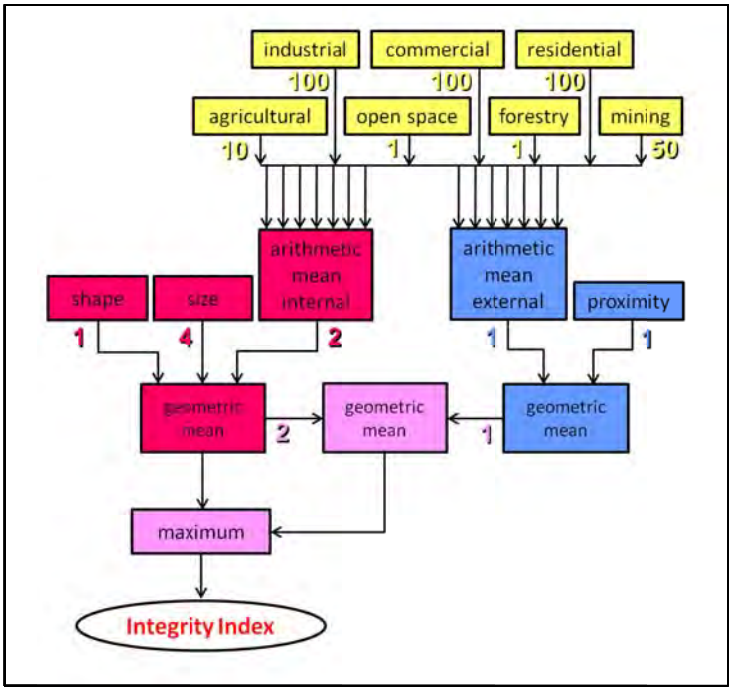


Figure A3. Factors used in land use and habitat fragmentation indices. Numbers are weights used in weighted geometric or arithmetic means. Proximity and shape indices were calculated with FRAGSTATS (McGarigal and Marks 1995).

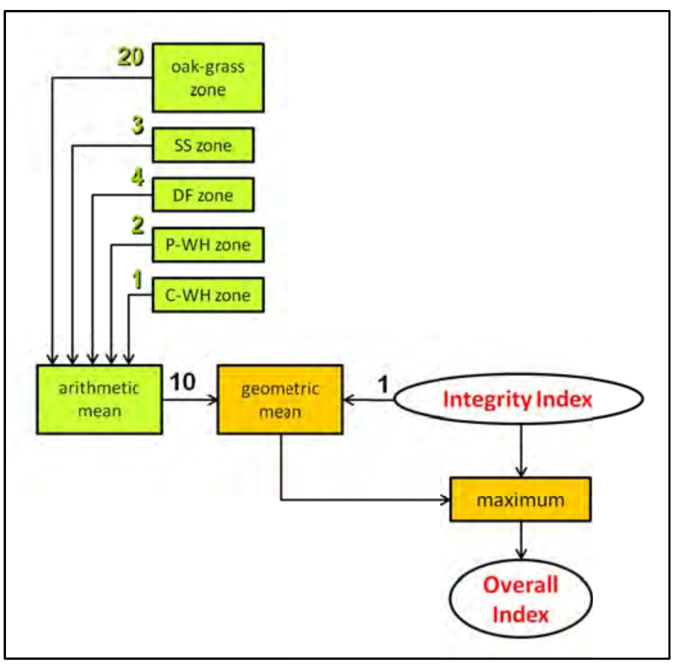


Figure A4. Combining vegetation zone index and integrity index (Figure A2). Numbers are weights used in weighted geometric or arithmetic means. The maximum function does the following: if the integrity index is high, then vegetation zone will not reduce it, but if integrity index is low, then vegetation zone can enhance it. In other words, integrity is more important than vegetation zone.

Table A1. Impact values assigned to each land use. Land uses listed in WAC 458-53-030, Stratification of assessment rolls — Real property. Values based on subjective professional judgment.

Type[#]	Code	Land Use Description	Impact Value
RCI	11	Household, single family units	100
RCI	12	Household, 2-4 units	100
RCI	13	Household, multiunits (5 or more)	100
RCI	14	Residential condominiums	100
RCI	15	Mobile home parks or courts	100
RCI	16	Hotels/motels	100
RCI	17	Institutional lodging	100
RCI	18	All other residential not elsewhere coded	100
RCI	19	Vacation and cabin	100
RCI	21	Food and kindred products	100
RCI	22	Textile mill products	100
RCI	23	Apparel and other finished products made from fabrics, leather, and similar	100
RCI	24	Lumber and wood products (except furniture)	100
RCI	25	Furniture and fixtures	100
RCI	26	Paper and allied products	100
RCI	27	Printing and publishing	100
RCI	28	Chemicals	100
RCI	29	Petroleum refining and related industries	100
RCI	30	Rubber and miscellaneous plastic products	100
RCI	31	Leather and leather products	100
RCI	32	Stone, clay and glass products	100
RCI	33	Primary metal industries	100
RCI	34	Fabricated metal products	100
RCI	35	Professional scientific, and controlling instruments; photographic and optical	100
RCI	39	Miscellaneous manufacturing	100
RCI	41	Railroad/transit transportation	100
RCI	42	Motor vehicle transportation	100
RCI	43	Aircraft transportation	100
RCI	44	Marine craft transportation	100
RCI	45	Highway and street right of way	100
RCI	46	Automobile parking	100
RCI	47	Communication	100
RCI	48	Utilities	100
RCI	49	Other transportation, communication, and utilities not classified elsewhere	100
RCI	50	Condominiums - other than residential condominiums	100
RCI	51	Wholesale trade	100
RCI	52	Retail trade - building materials, hardware, and farm equipment	100
RCI	53	Retail trade - general merchandise	100
RCI	54	Retail trade - food	100
RCI	55	Retail trade - automotive, marine craft, aircraft, and accessories	100
RCI	56	Retail trade - apparel and accessories	100
RCI	57	Retail trade - furniture, home furnishings and equipment	100
RCI	58	Retail trade - eating and drinking	100
RCI	59	Other retail trade	100
RCI	61	Finance, insurance, and real estate services	100
RCI	62	Personal services	100
RCI	63	Business services	100
RCI	64	Repair services	100
RCI	65	Professional services	100
RCI	66	Contract construction services	100
RCI	67	Governmental services	100
RCI	68	Educational services	100

	Code	Land Use Description	Impact Value
RCI	69	Miscellaneous services	100
RCI	71	Cultural activities and nature exhibitions	100
RCI	72	Public assembly	100
RCI	73	Amusements	100
ROS	74	Recreational activities	10
ROS	75	Resorts and group camps	10
ROS	76	Parks	10
ROS	79	Other cultural, entertainment and recreational	10
AG	81	Agriculture (not classified under current use law)	10
AG	82	Agriculture related activities	10
AG	83	Agriculture classified under current use chapter 84.34 RCW	10
ROS	84	Fishing activities and related services	10
M	85	Mining activities and related services	50
F	88	Designated forest land under chapter 84.33 RCW	1
OS	89	Other resource production	1
OS	91	Undeveloped land	1
F	92	Noncommercial forest	1
na	93	Water areas	0
OS	94	Open space land classified under chapter 84.34 RCW	1
F	95	Timberland classified under chapter 84.34 RCW	1
OS	99	Other undeveloped land	1

[#] Land use types: RCI= residential-commercial-industrial; ROS= recreational open space; OS=open space; AG = agriculture; M= mining; F= forestry; na = not applicable.

Resources Conservation Service. These data were reviewed to determine a reasonable current distribution of oak woodlands and prairies throughout the Puget Sound Basin. The Western Hemlock Zone was split using ecoregion boundaries to provide additional definition between low and higher elevation areas. Portions of the Western Hemlock Zone in the Puget Trough Ecoregion were renamed Puget Trough Western Hemlock. In the North Cascades and West Cascades Ecoregions, the Western Hemlock Zone were renamed Cascades Western Hemlock, and in the Northwest Coast Ecoregion the higher elevation Western Hemlock zone was renamed the Coastal Western Hemlock. For each open-space block, an average vegetation zone value was calculated based on the area of each vegetation zone intersecting the open-space block and the relative value assigned to each vegetation zone (Figure A4). The relative value of each vegetation zone was based on the percent of historical area lost and rarity of the zone.

Much of the PHS data are site-scale (e.g., nest and den sites, communal roosts), which does not match the scale of the assessment. We used only PHS data that were “regional-scale” occurrences, defined as occurrences greater than 100 acres in size. This filter limited the PHS data to 208 polygons that ranged in size from 110 to 321,000 acres. The mean and median size of PHS polygons used in the assessment were 4370 and 790, respectively.

Local Habitat Assessment

The local assessment assigned importance scores within open-space blocks at the resolution of 30 m x 30 m square grid cells. Scores were based on three factors: road density, land use, and parcel density. These factors are similar to factors used by Quigley et al. (2001), Leu et al. (2008), and Theobald (2010). Land use and land cover categories were assigned relative “impact values” using professional judgment (Table A2).

A focal mean with a circular window of radius 640 ft (6.5 pixels, 195 m; area = 29.5 acres or 12 ha) and a triangular weight function (Figure A5) was run on the impact layer to model the impacts of nearby surrounding land use/ land cover on each point in the landscape. The resulting mean impact values were compared to the original C-CAP data, and the maximum impact value was assigned to the pixel. Assigning the maximum impact models our assumptions about the affects of land use on adjacent habitats. For example, high intensity developed pixels (impact = 100) surrounded by forest pixels (impact = 1) would acquire lower mean impact values. However, it is unlikely that adjacent forest significantly improves the habitat quality of high intensity development. In contrast, adjacent high intensity development is likely to degrade the quality of forest habitats through edge effects. The focal mean function was run on the entire watershed and not just the open-space blocks. As a result, habitat quality within a block was affected by nearby conditions outside the block.

The county road layer was split into three separate layers: primary, secondary, and all other roads. A Euclidian distance function was run on each of these road layers. Next these layers were summed using relative weights of 3, 2, and 1 respectively, to represent different levels of traffic intensity for each road type. Road density and traffic intensity were assumed to be surrogates for the all impacts of roads on terrestrial wildlife. The resulting data layer was scaled from 1 to 100.

Table A2. Relative impact assigned to each land cover category. Landcover data and categories from the Coastal Change Analysis Program (C-CAP 2005). Values based on subjective professional judgment.

Land Cover Category	**Impact Value**
deciduous forest	1
evergreen forest	1
mixed forest	1
scrub/shrub	1
clear cut	1
water	1
palustrine forested wetland	1
palustrine scrub/shrub wetland	1
palustrine emergent wetland	1
estuarine emergent wetland	1
estuarine aquatic bed	1
unconsolidated shore	1
grassland[A]	10
pasture / hay	10
bare land	10
developed open space	10
low intensity developed	25
medium intensity developed	50
high intensity developed	100

[A] In Gorst Creek Watershed pixels classified as grassland are grassy vegetation associated with clear cuts, pastures, or the golf course.

Smaller parcels are assumed to have a bigger impact on wildlife habitats than larger parcels. In general, the smaller acreage parcels are currently developed, or will be developed in the near future, whereas larger parcels have not been developed, or even sub-divided for potential development. The parcel data were converted to a raster format with a 10 ft x10 ft resolution with the value of each pixel assigned the acreage of the parcel in which it was located (e.g., 0.1, 0.5, 1, 10 acres). The acreage values were normalized from 0 to 100 with parcels larger than 200 acres being assigned zero impact and parcels smaller than 0.2 acres assigned impact an impact of 100. A focal mean with a circular window of a 640 ft (6.5 pixels, 195 m; area = 29.5 acres or 12 ha) and a triangular weight function was run on this layer to provide parcel impact values for all pixels across the watershed.

The final impact index was the sum of the three layers: land use impact, road impact, and parcel density. The relative weights assigned to these layers were 1, 1, and 0.5, respectively. Impact values calculated for each pixel were normalized to the maximum and minimum values found within the open-space blocks.

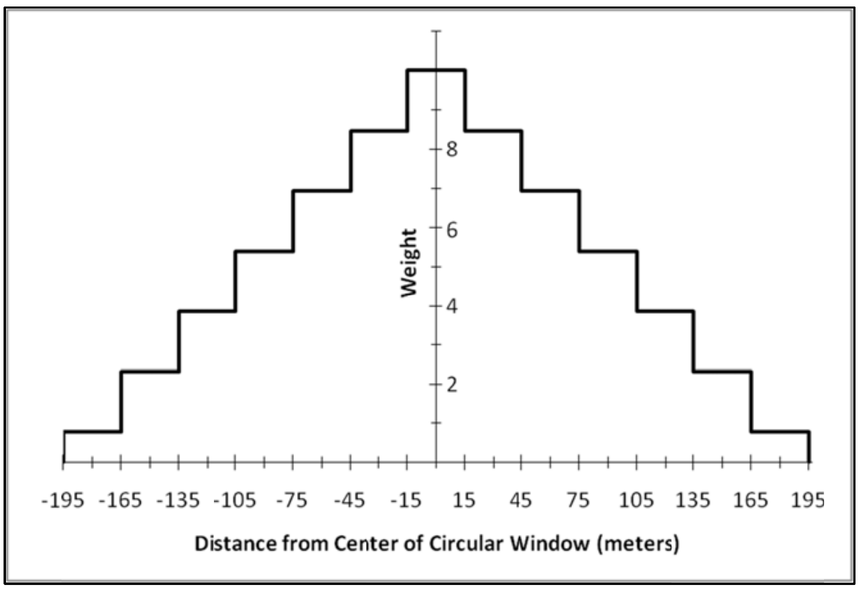


Figure A5. Triangular weight function used in focal mean. Maximum weight in focal mean occurs at center of circular analysis window and decreases linearly to zero at edge of window. Step values correspond to weights applied to pixels within the analysis window.