MUKILTEO WATERSHED-BASED STORMWATER STRATEGIES PLAN

Prepared for **May 2013**

City of Mukilteo

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SUMMARY

The City of Mukilteo, like most Puget Sound area cities, has experienced for many years unnaturally high peak stream flows, low summer flows, and decreased water quality associated with increased levels of development, land clearing, infrastructure, and impervious surfaces. Alterations in the natural hydrologic regime and introduction of pollutants have led to higher rates of erosion and degraded habitat. To address these issues, the City and its project partners, City of Everett, Snohomish Conservation District, Snohomish County Airport (Paine Field), the Mukilteo School District and Washington State Department of Ecology, have developed a Stormwater Strategy Plan to prioritize and implement regional, watershed-based stormwater strategies.

Ecology's Puget Sound Characterization (Stanley et al. 2011), which established a framework to evaluate watershed processes, was used as the basis for determining stormwater strategies and prioritizing management areas. As part of the characterization work, Ecology developed equations to characterize the relative importance of key components of water flow processes, water quality, and habitat.

In this project, we used the results of the regional characterization, normalized to our study area, in combination with finer resolution data such as land cover, streams and wetlands data, and stormwater infrastructure to evaluate watershed processes at a local scale. The study area was divided into 36 sub-basins called project analysis units (PAUs). For each PAU, we assigned an intactness score between 0 and 1 for each water process: delivery, surface water storage, and discharge, with each process receiving equal weight and total intactness scores ranging from 0 to 3.

This analysis resulted in importance scores from the Ecology work that ranged from 0.9 to 2.3 and intactness scores, developed specifically for this project that ranged from 0.0 to 2.0. Scores varied by location within the study area; PAUs with ravines and coastal bluffs were generally more intact, but less important than PAUs located on the plateau. The plateau areas had greater importance, but are less intact as that is where most of the development is concentrated.

The combination of importance and intactness scores were used to identify general management categories. PAUs with high importance and intactness scores were designated "Preserve", PAUs with high importance scores, but low intactness scores were designated "Repair", the remainder of PAUs, with lower importance scores and a range of intactness scores were designated "Targeted Management" category. The importance and intactness scores for each process were used to identify appropriate stormwater management strategies for each PAU. For example, in PAUs with high importance scores for surface water storage, but low intactness scores, stormwater management strategy that focus on storage were recommended. Final recommendations specific for each PAU, were developed based on known limitations (i.e. steep slopes), known problems, opportunities identified by other studies, landscape position, and overall feasibility.

Finally, each PAU was prioritized based on the results of this analysis. PAUs in the "Preserve" and Repair" categories were given the highest prioritization for implementation; PAUs in the "Targeted

Management" category were prioritized based on a secondary score which represented water quality, habitat (freshwater fish) and connectivity.

This effort is intended to support the Comprehensive Surface Water Management Plan (SWMP) Update, which is a component of the Stormwater Management Program. The updated SWMP will address the new NPDES permit requirements for Phase II communities that go into effect in August 2013. Additionally, this effort is intended to strengthen regional collaboration efforts between the City and its project partners in developing stormwater management tools and strategies for protection and restoration of hydrologic and ecological functions.

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1.0 INTRODUCTION

The City of Mukilteo, like most Puget Sound area cities, has experienced for many years unnaturally high peak stream flows, low summer flows, and decreased water quality associated with increased levels of development, land clearing, infrastructure, and impervious surfaces. Alterations in the natural hydrologic regime and introduction of pollutants lead to higher rates of erosion and degraded habitat. To address these issues, the City and its project partners have developed this Stormwater Strategy Plan (Plan) to help guide the implementation of regional, watershed-based stormwater solutions. This work will identify key watershed processes such as groundwater recharge, surface storage, and discharge; and develop stormwater strategies that target restoration of important processes to improve the overall hydrologic and ecologic condition of the watershed. This work is funded by a Puget Sound Watershed Protection and Restoration grant that was awarded by the Washington State Department of Ecology (Ecology) to the City of Mukilteo in the spring of 2012.

This Plan identifies appropriate management strategies to protect and/or restore key watershed processes throughout the study area as well as opportunities to advance off-site stream and wetland mitigation efforts to more effectively compensate for development impacts on water quality, water quantity and habitat. The Plan outlines opportunities for low impact development (LID) techniques in heavily urbanized areas, and identifies priority areas for stormwater retrofits. The Plan references some of the BMPs and principles outlined the 2012 Stormwater Management Manual for Western Washington (SWMMWW).

1.1 Purpose/Goals

The Plan is intended to assist the project partners, cities of Mukilteo and Everett, Snohomish Conservation District, Snohomish County Airport (Paine Field), the Mukilteo School District and Washington State Department of Ecology (Ecology) in developing stormwater management tools and strategies that will be effective, cost-efficient, and provide a high degree of support for restoring important hydrologic and ecologic functions. Specific project objectives include:

- Develop low impact and stormwater management strategies that are consistent with watershed processes;
- Prioritize capital improvements and stormwater retrofit projects;
- Identify areas for protection;
- Collaborate with project partners, stakeholders, and the public throughout the life of the project;
- Provide information in a format that is accessible to the public through a website that will be available well beyond the life of the project; and

- Support future grant funding efforts for stormwater management and natural system enhancement.

1.2 Project Background and History

This project is the direct result of several recent actions directed at protecting water resources in the Puget Sound Area. The Puget Sound Partnership 2008 Action Agenda identifies six objectives to reduce the sources of water pollution in Puget Sound. The second of these objectives focuses on urban stormwater management. The Action Agenda was updated in 2012 and identified five elements for stormwater management to prevent pollution of water resources from urban stormwater.

- take a watershed approach to management;
- prevent new problems;
- fix existing problems;
- control sources of pollution; and
- education.

Elements of these goals are reflected in the NPDES MS4 permits that will take effect in August 2013.

To promote the concept of watershed scale planning, Ecology (using an EPA grant) funded The Puget Sound Watershed Characterization (Stanley et al, 2011). This study is based on a systematic analytic framework that utilizes landscape data to provide information needed to support regional, county, and watershed-based planning. The results of this work provide guidance for making land use decisions and prioritizing specific geographic areas for protection, restoration, and conservation at the local scale.

This Plan is based on the Puget Sound Watershed Characterization Project completed by Ecology (Stanley et al. 2011) and builds on Mukilteo's recent efforts to: 1) identify priority wetland and stream mitigation sites using a watershed-based approach, and 2) develop a comprehensive stormwater inventory (geodatabase) and geometric network. The City developed a watershed-based mitigation program, which was described in the Draft Critical Areas Mitigation Program (CAMP) report dated March 2011 (ESA 2011). In addition, the City also created a stormwater geodatabase, which is a comprehensive geospatial inventory of existing flow directions and stormwater features (catch basins, outfalls, detention ponds, bioswales, etc.) throughout the city (completed June 2011 and subsequently updated in October 2012). This Stormwater Strategies Plan and the CAMP would contribute directly to meeting recovery targets established in the Puget Sound Partnership 2020 Action Agenda related to reducing development pressure, maintaining natural land cover, improving water quality, and protecting summer stream flows.

The Plan is intended to support Mukilteo's Stormwater Master Plan (SWMP) Update, which is a component of the Stormwater Management Program. The updated SWMP will address the new NPDES permit requirements for Phase II communities that go into effect in August 2013. The SWMP is required to outline a suite of actions required by the permit that, when implemented, are presumed to reduce

pollutant discharge to surface waters to the maximum extent practicable and demonstrate that all known and reasonable methods of prevention, control and treatment have been considered. The Plan will rely on a comprehensive evaluation of sub-basins called project analysis units (PAUs) within the project area and will consider strategies that fall outside the limits of traditional stormwater management practices. This comprehensive approach will ensure that the stormwater management techniques required by the SMWP are protective of water resources, appropriate to watershed position and resource, and work in concert with other management strategies to provide the maximum level of protection.

In addition, the 2012 MS4 (Phase II) permit requires the evaluation and implementation of low impact development (LID) and watershed planning as part of the SWMP. The proposed MS4 permit special condition S.5.C.4.f would require local governments to review local codes, rules, and standards and where needed, to amend them to incorporate Low Impact Development (LID) principles and LID Best Management Practices (BMPs). The proposed MS4 permit also states that Phase II permittees develop plans that comprehensively address the impacts of urbanization and prepared SWMPs set in a watershed context. While this Plan is only one element of Mukilteo's Stormwater Management Plan, it does recommended a specific suite of actions for each PAU based on a watershed analysis and is appropriate at a watershed/sub-watershed scale

1.3 Problem Statement

Numerous studies have linked development with impaired stream processes, degraded instream habitat, and degraded water quality (Booth 1991; Booth et al. 2002; Alberti et al. 2006). Since the early 1990s stormwater management manuals have been developed to mitigate the impacts of development on stream hydrology and water quality; these manuals focused largely on reducing peak flow events using structural, end-of-pipe techniques (Booth et al. 2002). Recent studies have concluded that there is little evidence that traditional stormwater management practices are protective of physical, chemical, or biological processes (Maxted and Shaver, 1997; Horner et al., 1999, 2002; Maxted, 1999). It is likely that traditional stormwater management approaches are unsuccessful because they fail to account for stream processes that occur at multiple spatial scales and are controlled by regional landscapes (NRC 1992). Recommendations provided in this report are meant to address impacts from development on streams at multiple scales by targeting stormwater management strategies.

1.4 Landscape Overview

The study area covers approximately 25.5 square miles and includes portions of the cities of Mukilteo and Everett, Snohomish County, and Paine Field (Map 1). The northern portion of the study area is located in Water Resource Inventory Area (WRIA) 7: Snohomish Basin and the southern portion is located in WRIA 8: Cedar-Sammamish Basin. Although the study area is located within large WRIAs, it consists of isolated, small watersheds that drain directly to Puget Sound and are not part of larger river systems. To better understand variability in the scores due to natural differences in the way water

interacts with the landscape, the study area was further divided into three primary landscape positions based on landform: plateau, ravine, and bluff (Map 2).

Climate is the largest scale driver of stream processes and controls the timing, type (rain or snow) and amount of precipitation delivered to a watershed; however, at the scale of this project, climate parameters currently show little to no variation under natural conditions. In this region geology, soils, physiography, and land cover control the diversity in watershed processes such as the movement of water, sediment, nutrients and chemicals. The natural interaction of these drivers and controls at multiple scales results in the form and function of aquatic ecosystems at the reach level (Beechie and Bolton 1999, Dale et al. 2000, Gove et al. 2001, Hidding and Teunissen 2002, Beechie et al. 2010). Human disturbance such as roads, impervious surfaces, and pollutants, may degrade these processes at the regional and reach scale.

1.4.1 Climate

Climatic conditions in the study area are typically consistent with the broad patterns found throughout Puget Sound. This region can generally be characterized as having a wet mild season and a warmer drier season. The prevailing wind direction is out of the south or southwest during the wet season and northwest in summer. The average annual rainfall is approximately 35 inches and is influenced by both the convergence zone and the Olympic rain shadow (Ecology 1992). Rainfall occurs throughout the year, but typically more than half falls between November and March. Winter months have typical low temperatures in the high 20s to low 30s (deg F) and highs in the 40s. Summer high temperatures can reach over 90 but are typically in the 70s. The Puget Sound region climate is also characterized by cyclical climate patterns, with warmer, drier periods and colder, wetter periods occurring at decadal intervals (Gustafson et al. 2000).

1.4.2 Geology/Soils and Topography

The Puget Sound area has been significantly influenced by Pleistocene glaciers, as much as 3,600 feet thick that moved southward from the Coast Mountains of British Columbia and carved out the Strait of Juan de Fuca and Puget Sound (Gustafson et al. 2000). Most of the project area is located on a low plateau ranging in elevation from 400 to 600 feet. A narrow strip of land along the western portion of the study area, along Puget Sound, contains steep shoreline bluffs extending from sea level to the plateau. Several steep ravines cut through the landscape from east to west.

The surficial geology along the western portion of the study area is more complex as ravines cut through the landscape and expose glacial outwash and isolated patches of sedimentary deposits (Map 3). Most of the study area is underlain with glacial till, primarily Alderwood soils, which generally have low infiltration rates. However, there are small pockets of Everett soils (Hydrologic Group B) located on the plateau and some alluvium associated with stream channels (Map 4).

1.4.3 Land Cover

Historically, land cover within the study area consisted primarily of coniferous forest, which was logged during the late 1800s and early 1900s. Since that time, land cover within the study area has been highly altered and consists primarily of residential, commercial, and industrial land uses. Impervious surface cover within the study area ranges from 8 to 63 percent with most of the undeveloped areas located in the steep ravines, along stream corridors and along the steep shoreline bluffs; and most of the development associated with Paine field and a commercial district located at the headwaters of several watersheds (Map 5).

1.4.4 Hydrology

The study area includes 15 watersheds, and the headwaters of Swamp Creek. All of these watersheds drain west to Puget Sound except Swamp Creek. Only the upper portion of the Swamp Creek watershed is located within the study area and this stream drains south to Lake Washington. The watersheds were further sub-divided into 38 sub-basins called PAUs ranging from approximately 112 to 1,399 acres in size.

All of the streams located within the study area are relatively small, (1st or 2nd order using the Strahler system), with Swamp Creek, Big Gulch, Japanese Creek and Lunds Gulch being the largest streams. Stream hydrology is rain dominated. Due to relatively short stream length, the watersheds respond to storm events rapidly, though there is no flow data for these streams to confirm response times. Channel gradients vary throughout the study area, but in general tend to be low gradient in the upper reaches and steeper in the ravines.

1.5 Political geography

Project partners include the cities of Mukilteo and Everett; Snohomish Conservation District, Snohomish County Airport (Paine Field), the Mukilteo School District and Ecology. The study area includes portions of the cities of Mukilteo and Everett; Snohomish County and Paine Field (Table 1).

Table 1. Summary of Project Area Jurisdictional Boundaries

Jurisdiction	Total Area with the Study Area (acres)	Percent of Total Area
City of Mukilteo	3,993	25%
City of Everett	2,250	14%
Snohomish County[1]	7,362	45%
Paine Field	1,294	8%
Lynnwood	1,061	7%
Edmonds	332	2%
Total	16,292	--

[1]Includes all of the Mukilteo UGA and portions of the UGAs of Everett, Lynnwood, Mill Creek, and Bothell

2.0 DATA SOURCES AND METHODS

The analysis of the PAUs performed for this study builds on Ecology's Puget Sound Watershed Characterization framework to evaluate the importance of watershed processes and the level to which these watershed processes are intact within the study area. Ecology's Puget Sound Watershed Characterization (Stanley et al. 2011), which established a framework to evaluate watershed processes at large spatial scales, was used as the basis for determining stormwater strategies and prioritizing management areas (Figure 1).

Ecology characterized the relative importance of key components of water flow processes, water quality, and habitat regionally. In this project, we used the results of the regional characterization, normalized to our study area, in combination with finer resolution data such as land cover, streams and wetlands data, and stormwater infrastructure to evaluate watershed processes at a local scale. To develop an integrated secondary score, three additional parameters were used: results of the Ecology characterization of sediment export potential and fish habitat, and a third parameter developed as part of this study to quantify hydrologic connectivity. This project makes recommendations for a menu of strategies that are appropriate site scale given the results of the watershed analysis, but does not provide the detailed site specific information necessary to support design and implementation of these strategies at the site scale.

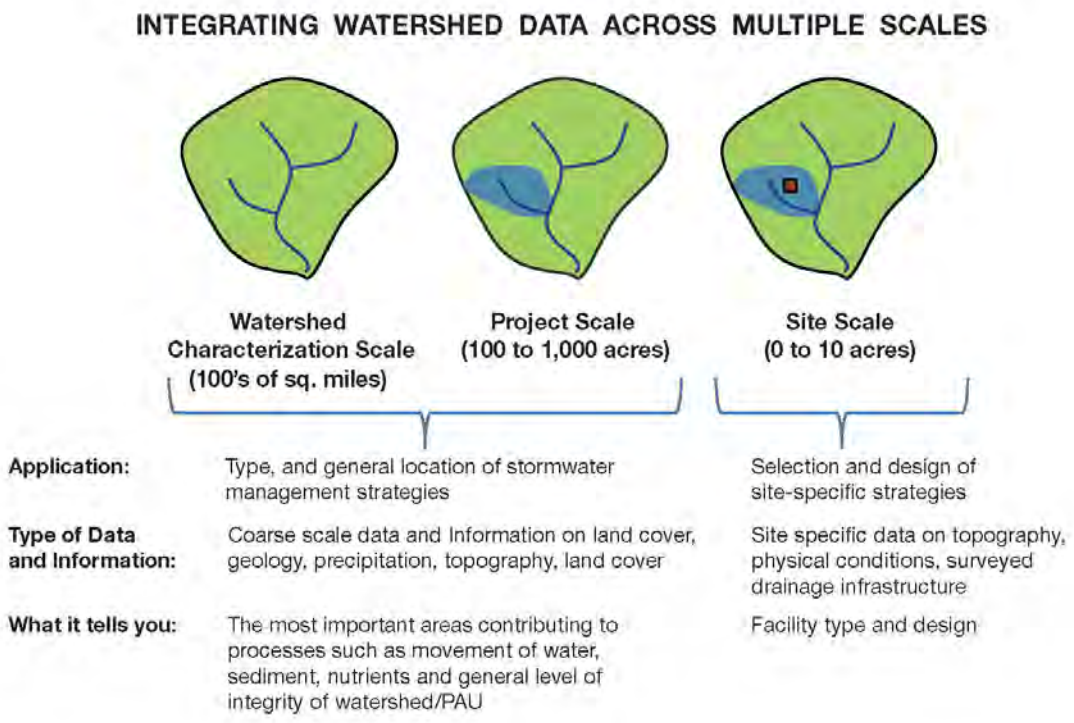
2.1 Data Sources – Spatial

A number of key spatial datasets were used for this analysis. Several jurisdictions and agencies provided data, which was used to create the following primary datasets:

- Water Flow Results (assessment unit level) (Ecology)
- Water Quality Results (assessment unit level) (Ecology)
- Fish & Wildlife Freshwater Habitat Assessment Results (assessment unit level) (WDFW)
- Land Use (Snohomish County)
- Transportation (Snohomish County)
- Hydrology (City of Mukilteo, Snohomish County)
- Stormwater Drainage Inventory (City of Mukilteo, City of Everett, Paine Field, Snohomish County)

A complete list of GIS data used for this analysis is provided in Appendix A.

Figure 1. Integrating Watershed Data across Multiple Scales



2.2 Drainage Basins Delineation

Ecology mapped the boundaries of 13 Assessment Units (AUs) throughout the study area. These AUs were delineated using WDFW Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) in partnership with the Northwest Indian Fisheries Commission data and are intended to be used for basin sizes ranging from 1 to 10 square mile scale. To better represent variability at the study area scale, the 13 AUs were further subdivided into 38 Project Analysis Units (PAUs) using a combination of high resolution LiDAR digital elevation model (DEM), hydrology and stormwater infrastructure maps that included data on invert elevations and flow direction. In some cases, the boundary of the AU was adjusted to match the more detailed topographic and drainage information (Map 6). The PAUs range from 112 to 1,399 acres and generally correspond to 1st order streams (Table 2).

Table 2. PAU Summary

Watershed/PAU	Area (acres)	%Total Impervious Area (TIA)
Big Gulch		
Big Gulch North	*303*	*23%*
Big Gulch South	*419*	*41%*
Big Gulch West	*365*	*26%*
Big Gulch Southeast	*463*	*50%*
Brewery Creek		
Brewery Creek East	*133*	*42%*
Brewery Creek West	*171*	*35%*
Chennault Beach		
Chennault Beach Creek/Upper Chennault Beach Creek West	184	33%
Upper Chennault Beach Creek	278	43%
Lower Chennault Beach Creek North	*122*	*31%*
Lower Chennault Beach Creek South	*215*	*30%*
Edgewater		
Edgewater East	165	35%
Edgewater West	175	21%
Goat Trail Ravine	382	35%
Hulk Creek		
Hulk Creek East	248	23%
Hulk Creek North/South	127	11%
Japanese Creek		
Japanese Creek Mid	*277*	*25%*
Japanese Creek North	*213*	*13%*
Japanese Creek South	*659*	*63%*

Watershed/PAU	Area (acres)	%Total Impervious Area (TIA)
Lunds Gulch Creek		
Lunds Gulch East	*1,044*	*38%*
Lunds Gulch SE	*344*	*54%*
Lunds Gulch West	*359*	*8%*
Lunds Gulch North/Lunds Gulch South	470	20%
Lunds Gulch SW	132	18%
Naketa Beach	160	41%
Norma Creek		
Norma Creek East	*666*	*30%*
Norma Creek West	*168*	*15%*
Olympic View	173	32%
Picnic Point Creek		
Picnic Point Ravine	*441*	*16%*
Picnic Point Ravine East	*747*	*40%*
Picnic Point Ravine West	*229*	*15%*
Smugglers Gulch Creek		
Smugglers Gulch North/Olympic View North	112	23%
Smugglers Gulch South	220	26%
Swamp Creek		
Swamp Creek A	*958*	*39%*
Swamp Creek C	*933*	*53%*
Swamp Creek D	*977*	*42%*
Swamp Creek E	*1,077*	*43%*
Swamp Creek F	*1,399*	*35%*
Swamp Creek G	*798*	*43%*

2.3 Landscape Position

Landscape position is a descriptive term intended to coarsely group areas with similar geologic characteristics, topographic characteristics, and hydrologic processes. Three distinct landscape positions were identified within the study area: plateau, ravine, and bluff (see Map 2). The importance of key watershed processes does vary by landscape position; therefore, the landscape position of each PAU was used as an indication of which management strategies may be most appropriate (Figures 2 and 3).

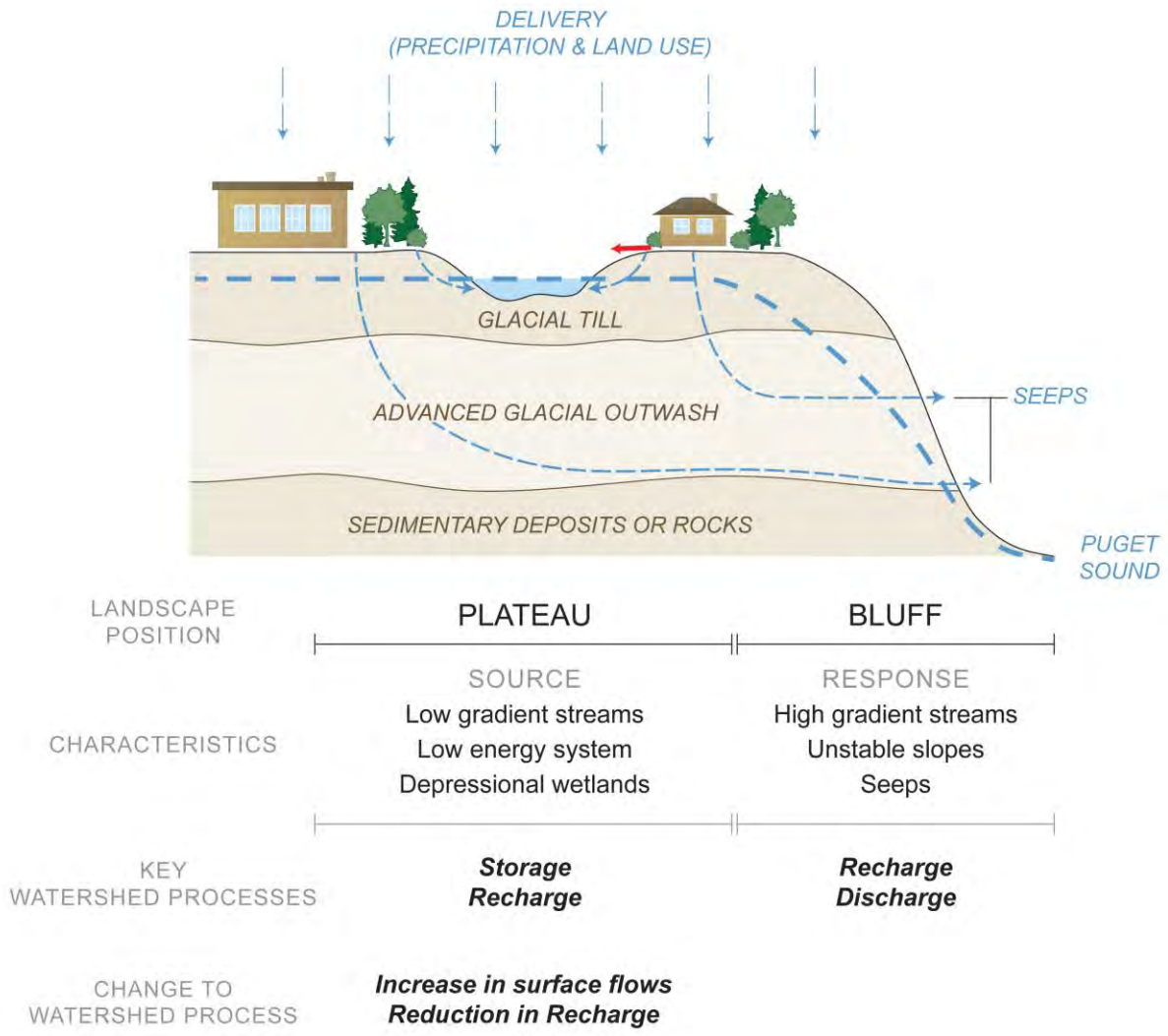
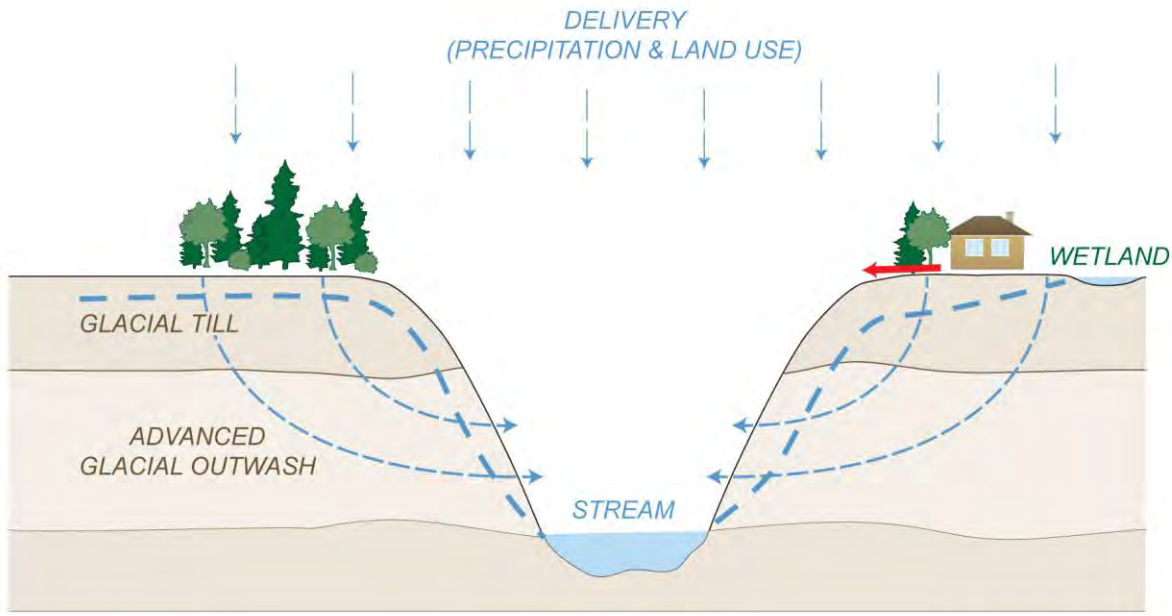


Figure 2. Watershed Processes Bluff and Plateau Landscape Position



LANDSCAPE POSITION	RAVINE	PLATEAU
	RESPONSE	SOURCE
CHARACTERISTICS	High gradient streams Unstable slopes Seeps	Low gradient streams Low energy system Depressional wetlands
KEY WATERSHED PROCESSES	***Recharge*** ***Discharge***	***Storage*** ***Recharge***
CHANGE TO WATERSHED PROCESS	***Higher stream flows***	***Increase in surface flows*** ***Reduction in Recharge***

Figure 3. Watershed Processes Ravine and Plateau Landscape Position

2.4 Models and Analysis

Ecology developed models to evaluate the importance and level of degradation of watershed processes based on GIS data of key landscape elements that influence the movement of water through the watershed. The main processes Ecology evaluated were water flow, water quality; while WDFW provided an assessment of the fish & wildlife habitats. This project focused on the importance scores from the water flow model, which includes delivery, surface storage, recharge, and discharge, as these processes are more likely to be restored through the use of stormwater management strategies (Table 3).

Table 3. Flow Variables

Process	Importance Score Pre-developed Condition (Ecology GIS data)	Intactness Score Existing Condition (Study GIS Data)
Delivery	Precipitation Rain on snow areas	Impervious Surface
Surface Storage	Low gradient floodplain	City and County Wetland Inventories
Recharge	High Permeability Deposits Low Permeability Deposits	High Permeability Deposits Low Permeability Deposits
Discharge	Geology, soils, topography	Stormwater infrastructure

The results for the water flow degradation model were not used in this analysis. The results from the water quality and habitat models were used to develop a secondary score as described in Section 2.5.

For this effort, an intactness score for water flow was developed for key watershed processes of delivery, surface storage, recharge, and discharge using higher resolution data related to land use, stormwater infrastructure, and streams and wetlands. Results were used to characterize the level of intactness of each key watershed process for each PAU relative to other PAUs within the study area.

The Ecology water quality and habitat models were used evaluate key secondary processes within the study area. Specifically, this study used the sediment potential sub-model (which is part of the water quality model) and the WDFW freshwater habitat assessment model. This score was used to prioritize implementation of stormwater management strategies through the study area (Figure 4).

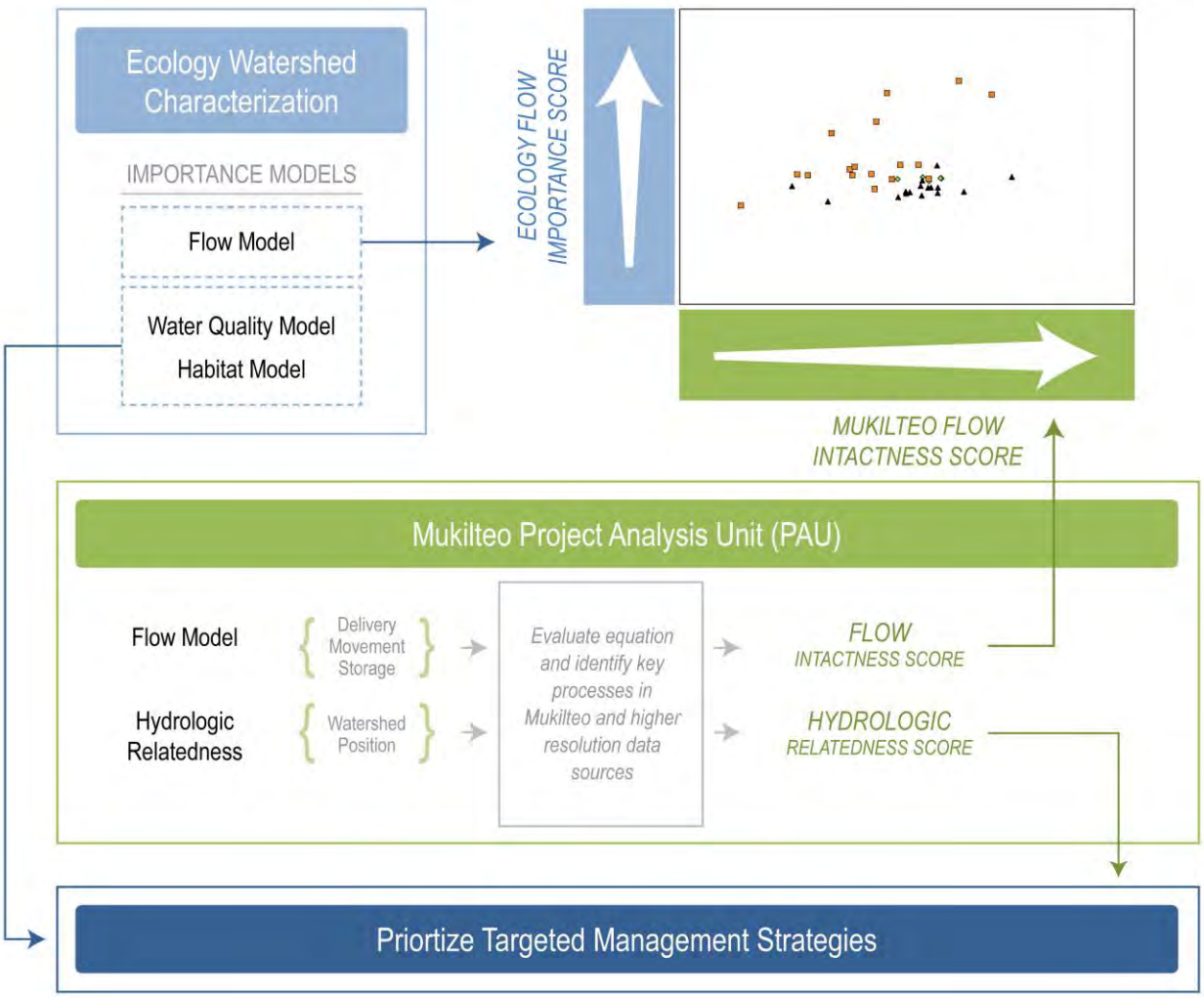


Figure 4. Watershed Analysis Methods Flow Chart

2.4.1 Ecology Flow Importance Model

Ecology calculated importance scores for water flow processes for all Puget Sound watersheds as part of the Watershed Characterization work; details of the watershed characterization project, including Volume I (Water Resource Assessments) and Volume II (Habitat Assessments) can be accessed from the following URL: http://www.ecy.wa.gov/services/gis/data/pugetsound/characterization.htm (Stanley et al. 2011). The scores represent the relative importance of each process relative to a given WRIA. To support this effort, Ecology staff used the raw importance score for each process in Ecology's flow importance model and normalized them to the study area. These normalized scores represent the importance of delivery, storage, recharge, and discharge within the study area. Sediment delivery potential scores and freshwater habitat from the Watershed Characterization (Stanley et al. 2011) work were also used for this analysis as a secondary processes as discussed in Section 2.5.

2.4.2 Study Area Intactness Score for Flow

An intactness score for flow processes was developed for each PAU using methods and equations similar to those used by Ecology in their flow degradation model (Stanley et al. 2011; Table 4). The equations developed as part of this study characterize how intact delivery, storage, recharge, and discharge processes are under existing conditions (Figure 5).

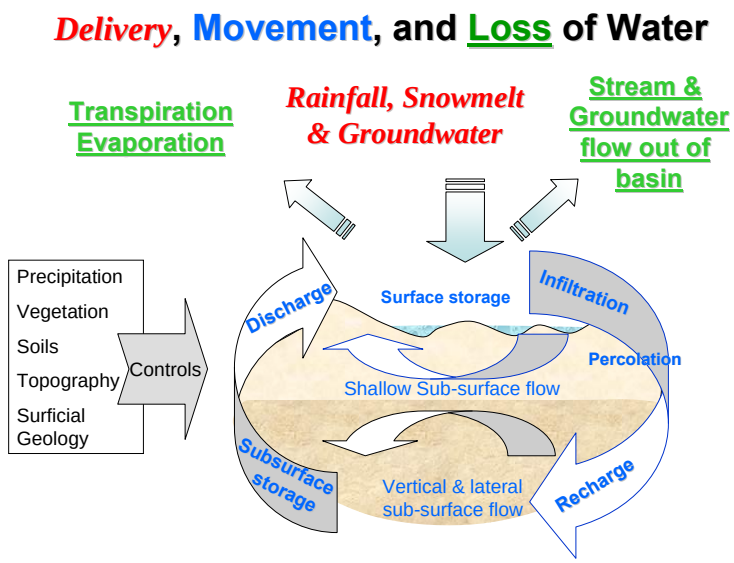


Figure 5. Illustration of Watershed Processes in the Puget Sound Region (Stanley et. al. 2011).

Variables used in this analysis were selected because they (1) represent key processes within the study area and (2) provide a link to stormwater and land use strategies. Higher scores indicate a higher level of intactness.

Table 4. Flow Intactness Variables

Key Watershed Process	Max Score
Delivery = I_TIA = Score for Intactness of Timing*	1
Surface Storage = I_SS = Score for Intactness of Surface Storage	1
Recharge = I_R = Score for Recharge Intactness	1
Discharge = I_Dc = Score for Intactness of Discharge Processes Accounting for Stormwater Conveyance	1
Maximum Overall Intactness Score	4

*TIA = Total Impervious Area

Delivery

Delivery refers to the amount of flow generated in the watershed by precipitation. Impervious surfaces generally increase the total volume of runoff in a basin by reducing the amount of precipitation returned

to the atmosphere through evapotranspiration and reducing infiltration to deep groundwater (Figure 6). The result, particularly in small stream systems, is an increase in the magnitude and frequency of peak flow events (Booth 1991; Burgess 1998).

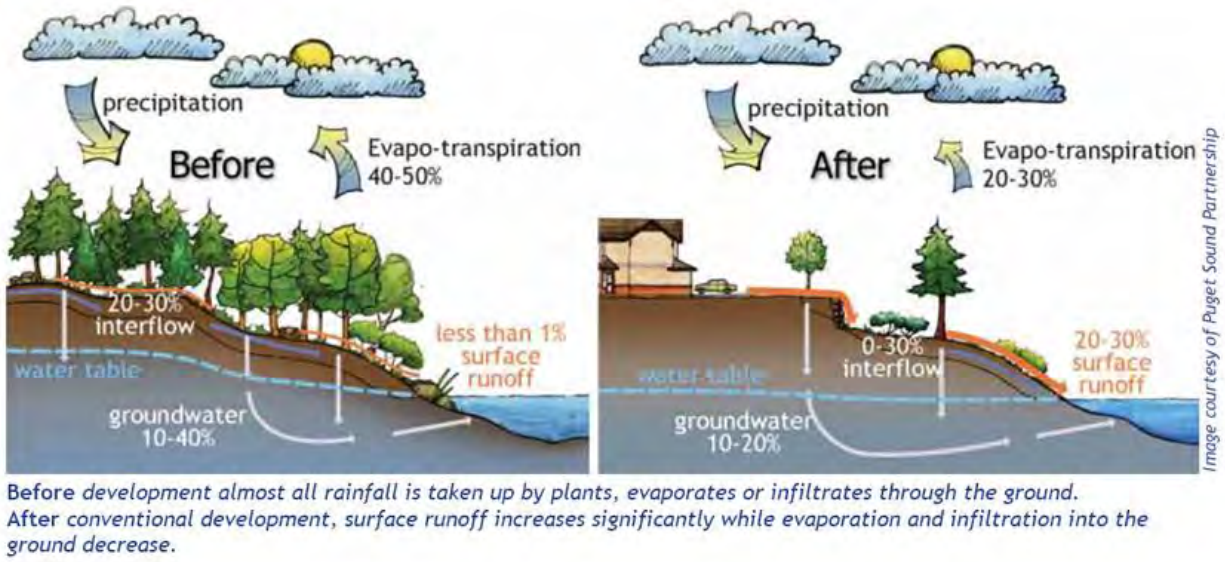


Figure 6. Puget Sound Hydrologic Cycle Graphic (Puget Sound Partnership 2012)

An intactness score for the volume and thus delivery of flow to the stream within each PAU was developed using the percent of total watershed impervious surface cover using the following thresholds based on work performed on Puget Sound streams (Booth 1991; Booth et al. 1996; May et al. 1997).

I_TIA = Score for Intactness of Timing

= 1 if TIA is less than 10 percent
= 0.5 if TIA between 10 and 35 percent
= 0 if TIA is greater than 35 percent

A high score represents low amounts of impervious surfaces and a higher level of intact hydrologic regime.

Surface Storage

Storage refers to the amount of runoff stored within the watershed as surface water. In natural systems, both wetlands and floodplains can provide surface water storage, which attenuates peak flows. The study area has numerous wetlands but the streams are relatively small and confined; therefore, floodplains do not provide a significant amount of storage within the study area. As a result, floodplains were not evaluated and only the density of wetlands was used to characterize surface water storage.

Wetland area within each PAU was calculated using a combination of City and County wetland inventory data. This analysis targeted wetlands located on slopes less than 1 percent , to capture the wetlands likely to provide storage and does not include slope wetlands. The 1 percent threshold was developed

using an iterative process based on a review of the wetland maps and site specific knowledge of wetlands throughout the study area. An intactness score for the density of low gradient wetland within each PAU was developed using the following equation and normalized for the study area:

I_SS = Score for Intactness of Surface Storage

Density = Area of Depressional Wetland/Area PAU
Normalized = Density PAU/Max Density Study Area

Although a target density of depressional wetlands that would represent intact conditions is unknown for the study area, higher scores represent PAUs with a greater density of depressional wetlands and therefore, were assumed to be more intact for surface water storage processes.

Recharge

Recharge is an important process because it affects the volume of precipitation reaching the stream as overland flow through infiltration to shallow and deep groundwater. Infiltrating runoff attenuates peak flows that can cause excessive erosion and/or flooding. An intactness score for the potential amount of recharge within each PAU was developed based on the equations presented in the Ecology degradation model (Stanley et al. 2011).

I_R = Score for Recharge Intactness

I_R = Recharge Coefficient x Total Recharge
Where:
Recharge Coefficient = Area of Land Use Cover Type x Intactness Coefficient/PAU Area

The intactness coefficient is based on equations in the Ecology degradation model (Stanley et al. 2011), which reduces total recharge based on geology and soils by a factor that represents the intensity of land use within each PAU (Table 5).

Table 5. Recharge intactness coefficient

Land Cover Type	Land Use Category	Reduction Coefficient (Rc)*	Intactness Coefficient (1-Rc)
High Intensity	80 to 100	0.9	0.1
Medium Intensity	51 to 79	0.75	0.25
Low Intensity	20 to 50	0.35	0.65

* Stanley et al. 2011

Total recharge was calculated for each PAU using the method provided by Ecology (Stanley et al. 2011).

Recharge (coarse grain deposits) = (0.838 x P x A)-9.77
Recharge (fine grain deposits) = (0.497 x P x A)-5.03
Total Recharge = [Recharge (coarse grained) + Recharge (fine grained)]/PAU Area

Where:

P = Precipitation

A = Area

Coarse grain deposits include alluvial, and recessional and advanced outwash. Data for underlying geology within the study was developed by WDNR (2000). Based on isopluvial maps developed for the Puget Sound area, mean annual precipitation within the study is relatively uniform: therefore, P= 35 inches (Ecology 1992).

Discharge

Under natural conditions, precipitation soaks into the ground and becomes shallow subsurface flow before concentrated in stream as surface flow. Pipes and ditches alter this process by intercepting shallow groundwater and concentrating it as surface flow decreasing the amount of time it takes runoff to reach the stream. This decrease in residence time can increase the magnitude of peak flow events and erosive power in the stream system leading to erosion and downcutting in ravines, which affects existing development and utility infrastructure. For this analysis, the ratio of manmade conveyance systems (e.g., pipes and ditches) to natural streams was used to represent the intactness of discharge processes, represented as concentrated channel flow. An intactness score for discharge processes was developed using the equations:

I_Dc = Score for Intactness of Discharge accounting for conveyance systems

Ratio = (miles of pipe + ditch)/miles stream)

Normalized = 1-(Ratio PAU/Max Ratio Study Area)

PAUs with very few stormwater conveyance systems would have a ratio less than 1; which would represent a highly intact system. The notable outlier is the Japanese Creek North PAU, which has a significant amount of impervious surface area due to the airport, but little stormwater infrastructure.

2.5 Integrated Secondary Score

In addition to evaluating the importance and intactness of flow processes, three other processes: (1) sediment delivery potential, (2) habitat, and (3) hydrologic connectivity were evaluated in this study because they are related to City goals and identified problems with erosion and sedimentation, water quality, and degraded fish habitat (Table 6). Results of the sediment potential (importance and degradation) models and the WDFW freshwater habitat model from Ecology (Stanley et al. 2011) were used to characterize these processes. A third variable, developed specifically for this project, was used to weight the position of the PAU within the watershed (headwater, middle, lower). PAUs located upstream of other PAUs received higher scores than PAUs draining directly to Puget Sound because improvements made in these PAUs would also benefit downstream PAUs (Freeman et al. 2007). The integrated secondary score was used as a method for prioritizing implementation of stormwater strategies in PAUs with similar levels of flow importance.

Table 6. Integrated Secondary Score Equations

Key Secondary Process	Max Score
Sediment Potential	1
Freshwater Habitat	1
Hydrologic Relatedness	1
Overall Score = Water Quality + Freshwater Habitat + Connectivity	***3***

2.5.1 Sediment Potential Score

Erosion in the ravines and sedimentation in the lower reaches of several streams is a problem throughout the study area. The Ecology Sediment Potential models analyzed natural sources and sinks of sediment by looking at three processes: surface erosion, mass wasting, and stream channel erosion based on attributes of the watershed (Stanly et. al. 2011). The results of the Ecology Sediment Potential model (importance) and the Sediment Degradation model were applied to each PAU within the study area. A combined score was generated for each PAU by averaging the importance and degradation scores. This represents both the potential to export sediment under natural conditions and the level of process impairment and considers the relative watershed size and position in the watershed. High sediment potential scores represent a naturally high potential for the PAU to delivery sediment and a high level of process impairment, indicating a high risk of erosion, landslides or slope failures. PAUs with a high score were given a higher priority for implementation of stormwater management strategies to reduce the risk associated with erosion and sedimentation.

2.5.2 WDFW Freshwater Habitat Score

The WDFW freshwater habitat score was derived from the quantity and quality of habitats for all salmonids present or potentially present in the larger Ecology assessment units. It is intended to provide relative conservation values for helping to prioritize watershed-based natural resource management actions. For more information on the WDFW Habitat Assessment, see volume 2 of the Puget Sound Watershed Characterization Project (A Coarse-scale Assessment of the Relative Value of Small Drainage Areas and Marine Shorelines for the Conservation of Fish and Wildlife Habitats in Puget Sound Basin) found at the following URL:
http://www.ecy.wa.gov/services/gis/data/pugetsound/characterization.htm.

2.5.3 Hydrologic Relatedness Score

A numeric score was assigned to each PAU to represent its relative position in a watershed that weights PAUs located upstream of other PAUs with more importance. This score was developed because flow processes in the headwaters also influence downstream reaches and implementing stormwater management strategies in PAUs located in upstream areas of a watershed would also benefit downstream PAUs. A score of 1 was assigned to PAUs located upstream of important resources. This was done to emphasize the importance of working in PAUs in the same watershed as valuable resources even. A score of 0.5 was given to PAUs located upstream of other PAUs located to account for the added benefit of affecting downstream PAUs. Lastly, because work performed in PAUs that discharge

directly to Puget Sound would not have any benefit outside that PAU, these PAUs were given a score of 0 for this category. Table 7 summarizes the scores developed to characterize hydrologic relatedness.

Table 7. Hydrologic Relatedness Scores

Hydrologic Relatedness	Score
High: located upstream of a PAU in the restoration/projection category	1
Medium: located upstream of a PAU in the targeted management strategy category	0.5
Low: discharges directly to Puget Sound	0

3.0 RESULTS

Importance and intactness scores of each individual watershed process, as well as integrated results have been developed for the study area. These results form the foundation for the stormwater management strategies specific to each PAU developed in Section 4.0 and provide a method for prioritizing action areas. (Specific numeric results are presented in Appendix C.)

3.1 Flow Importance and Intactness Scores

The results of overall flow importance scores indicate that there is little variation throughout the study area (0.9 to 2.3) (Figure 7).This result was expected because of the relatively uniform distribution of geology, soils, stream type, and PAU area. In general, PAUs located in the plateau landscape position received slightly higher importance scores primarily due to the surface storage process, which is not as important in ravine and bluff PAUs due to due steeper topographic relief.

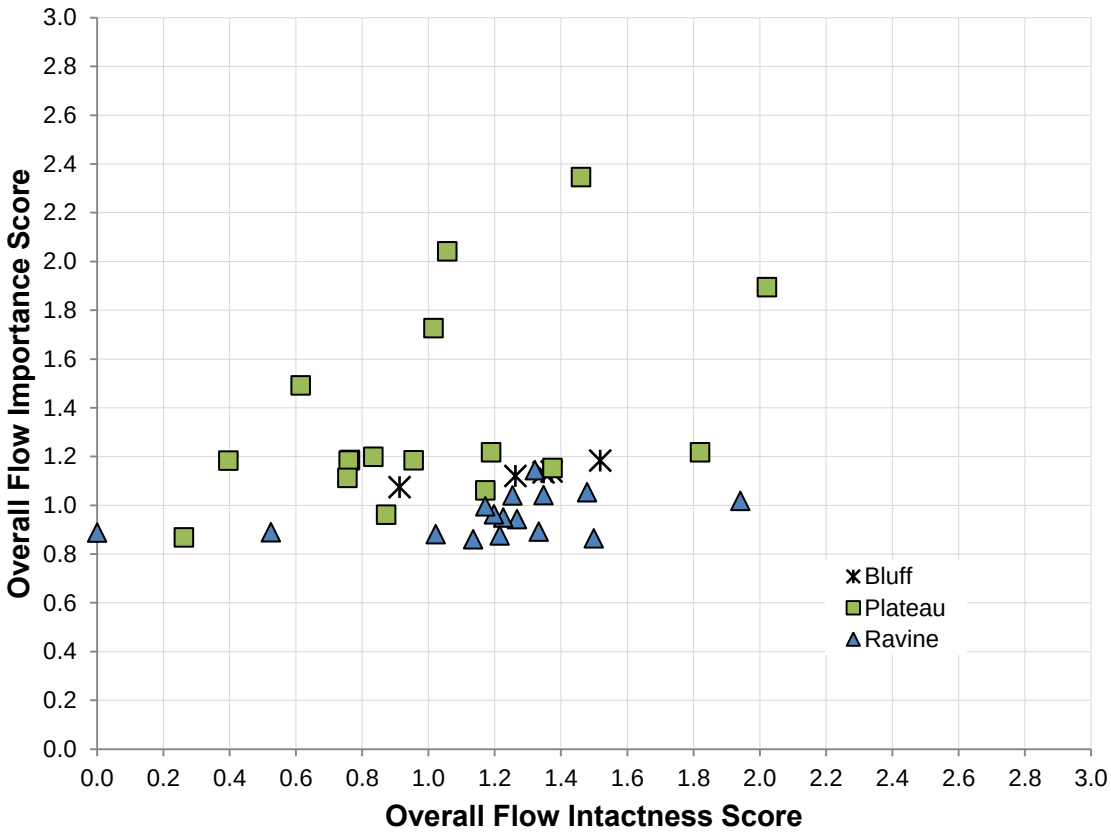


Figure 7. Watershed Based Analysis Overall Results

There was more variation in overall intactness of flow processes than importance (0.0 to 2.0). In general, PAUs in ravines and bluffs scored higher indicating that they are more intact. Based on the results of this analysis five PAUs score signifincantly higher than the remainder of PAUs. These PAUs inlcuded Swamp Creek E, F, and G, which are part of a much larger watershed draining to Lake Washington, and Japanese Gulch and Lower Chennault Beach S, which are part of the larger watersheds within the study area that drain to Puget Sound.

3.1.1 Delivery

The importance score for delivery has a narrow range (0.9 to 1.0) due to the relatively uniform distribution of precipitation within the study area (Map 7). However, the level to which delivery processes are intact is represented by impervious cover, which ranges from 8 to 63 percent within the study area. Based on this analysis, most of the study area is impaired to some extent by impervious surface, with most of the development occurring in the plateau PAUs (Map 7).

3.1.2 Surface Storage

Surface water storage processes are important primarily in the plateau landscape position (Stanley et al. 2011; Figure 8; Map 8). Lower Chennault Beach Creek South scored the highest for both importance and

intactness. This PAU naturally has a high density of wetlands, and under existing conditions the storage function of the wetlands has been preserved by the golf course. Low scores in bluffs and ravines are expected because PAUs in this landscape position naturally do not have a high density of depressional wetlands. PAUs in the bluff and ravine landscape position received low scores for storage intactness (0.0 to 0.5), but this is likely due to a natural lack of wetlands rather than a loss of wetlands due to development (Map 9).

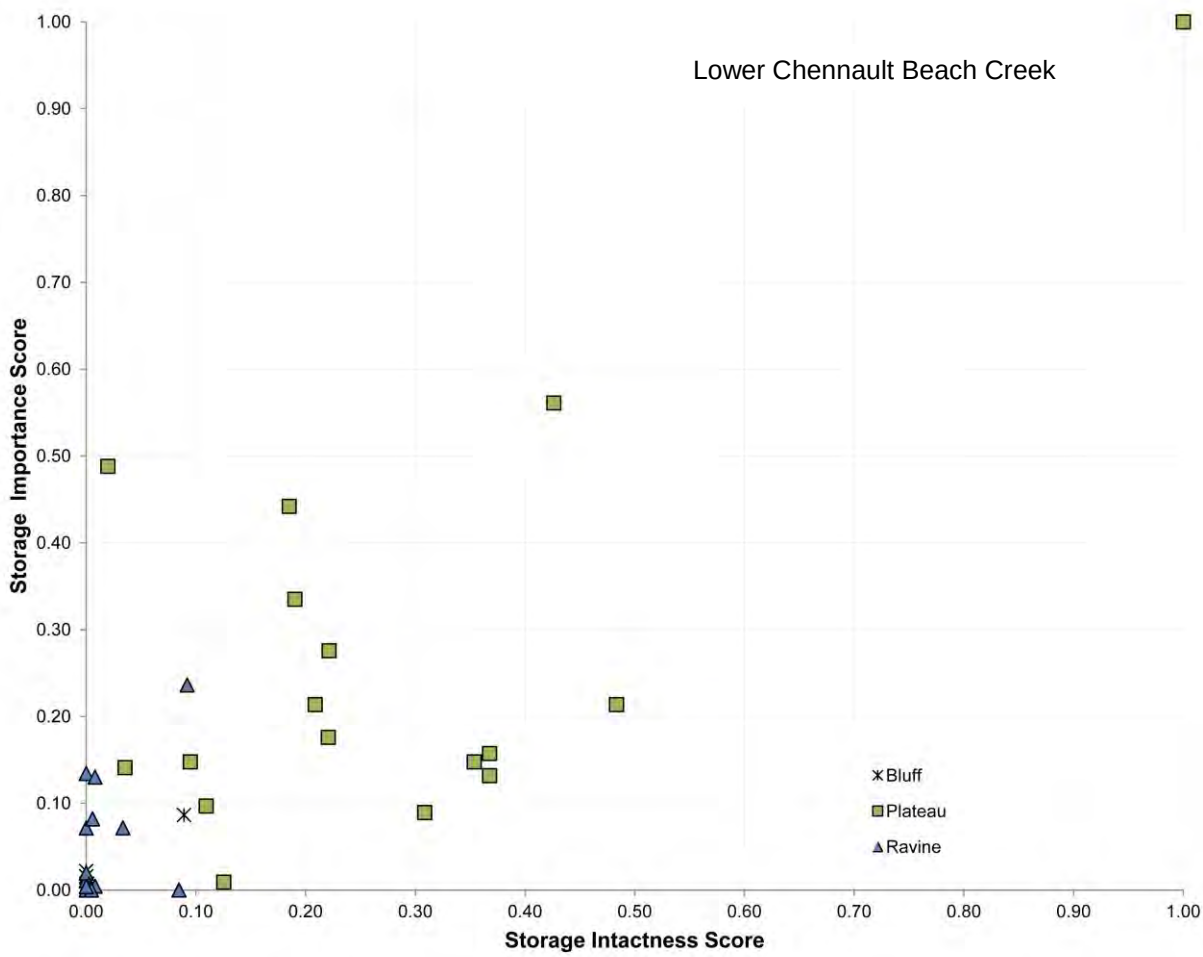


Figure 8. Watershed Based Analysis Storage Results

3.1.3 Recharge

Although most of the study area is located on a low permeability plateau, based on the work performed by Ecology (Stanley et al. 2011) recharge is an important process throughout the study area (Figure 9, Map 10). The results of the Watershed Characterization work indicate that recharge is important in the ravine and bluff landscape positions, which is at least partially due to exposed advanced outwash deposits (Map 10). However, within the study area, exposed outwash deposits are more likely to be areas of groundwater expression rather than recharge. Because the methods developed for analysis at a coarse spatial scale do not seem to correlate well with observations a the smaller scale and because

more detailed site specific information regarding groundwater movement is not available, the recharge process was dropped from the total score. However, recharge was evaluated for PAUs located in a plateau watershed scale to indicate locations where infiltration may be an importance process and to evaluate the relative degradation of that process within this portion of the study area (Map 11).

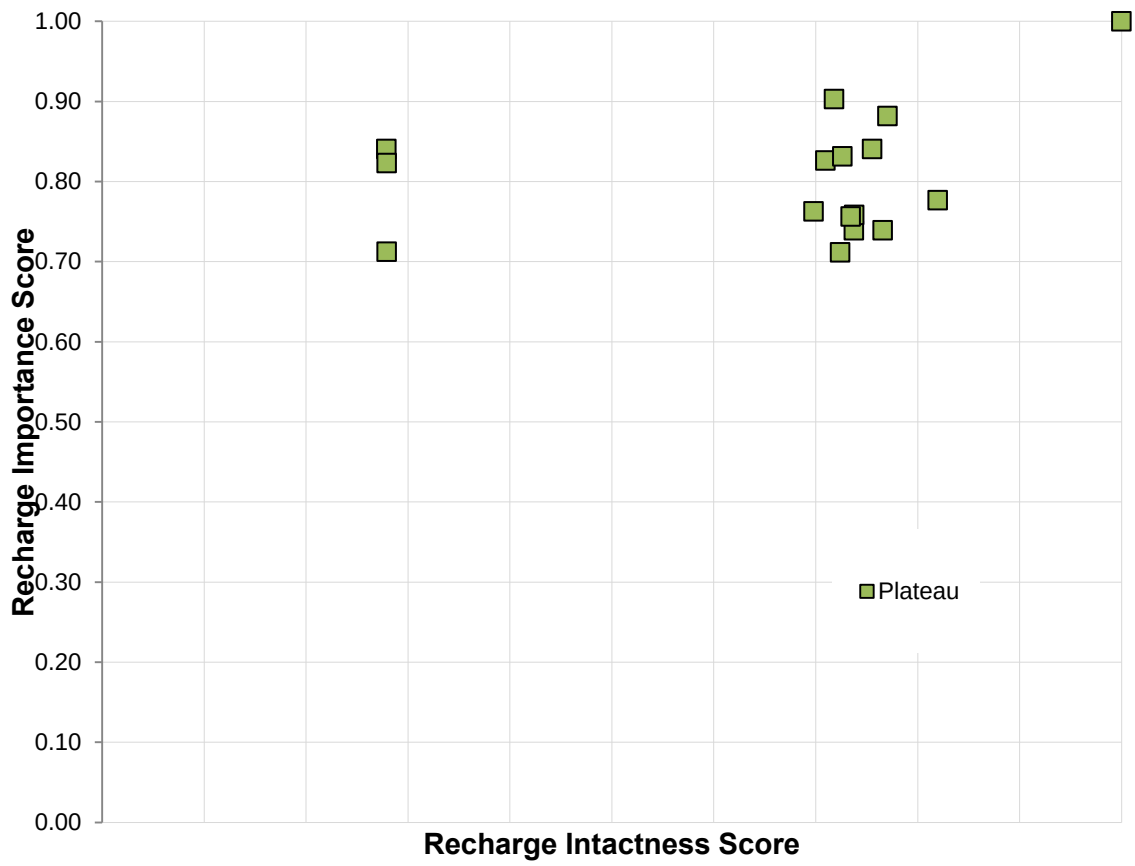


Figure 9. Watershed Analysis Recharge Results

3.1.4 Discharge

Based on the work performed by Ecology, discharge is generally not an important process throughout the study area, except in a few plateau PAUs (Stanley et al. 2011, Figure 10, Map 12). This result is expected because the study area does not have extensive floodplains or areas where hydric soils are intercepted by slopes, which are the two metrics used to quantify this process in the Ecology model. The intactness of discharge process varies throughout the study area and is lowest in PAUs with high levels of development and surface water infrastructure (Map 13).

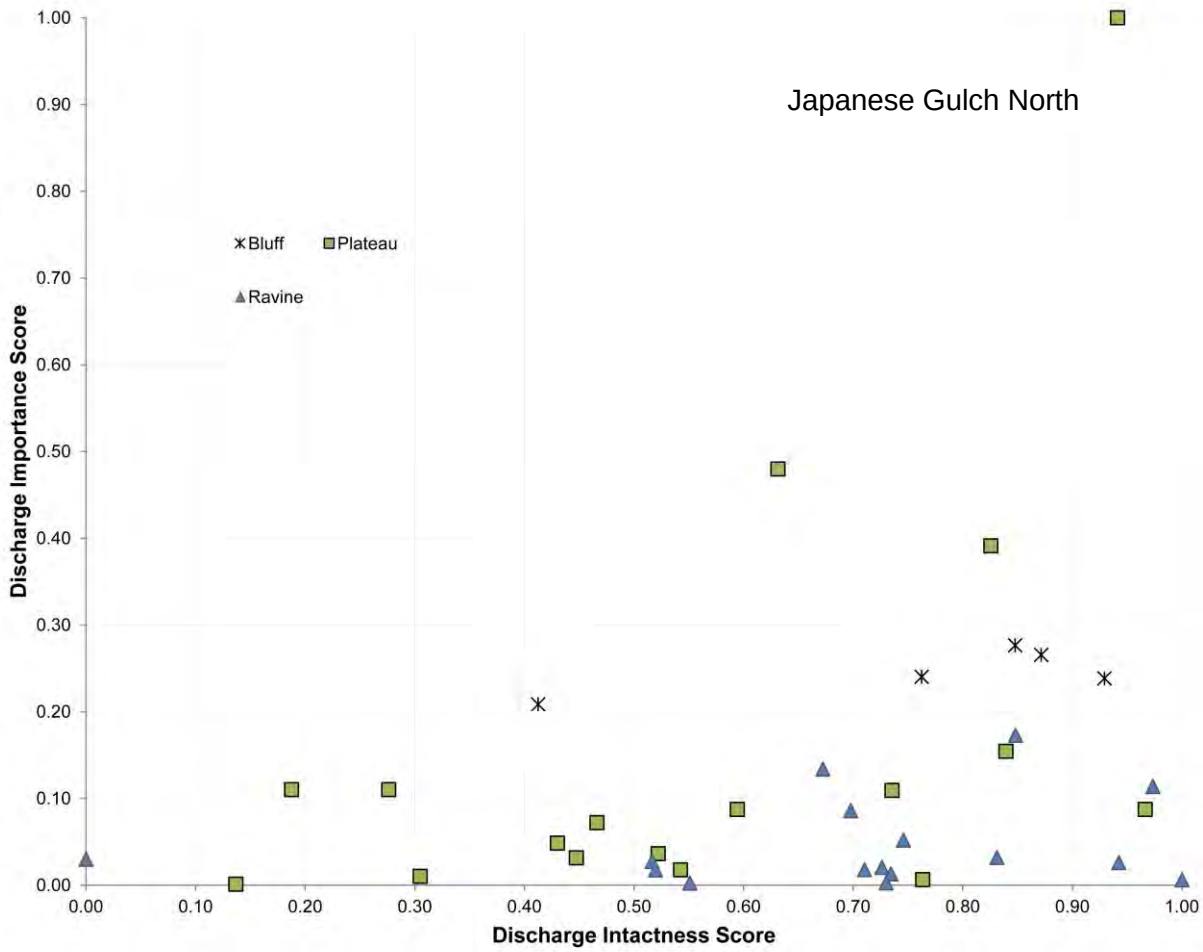


Figure 10. Watershed Based Analysis Discharge Results

3.2 Integrated Secondary Score

Results from the analysis of secondary processes suggest the following general trends:

- PAUs in the ravine landscape position have the highest potential for sediment delivery;
- PAUs located in larger watersheds had the highest habitat values and PAUs in smaller watershed have lower habitat values; and
- PAUs located in the headwaters of larger watersheds have the highest scores for connectivity.

Specific numeric results for the integrated secondary scores for each PAU in the Targeted Stormwater Strategies Category are summarized in Table 8 and on Maps 14, 15, 16, and 17.

Table 8. Summary of Integrated Secondary Scores

Watershed/PAU	Water Quality Score	Habitat Score	Connectivity Score	Overall Score
Big Gulch				
Big Gulch North	0.6	0.4	0.5	1.5
Big Gulch South	0.4	0.4	0.5	1.3
Big Gulch West	0.5	0.4	0.0	0.9
Big Gulch Southeast	0.4	0.4	1.0	1.5
Brewery Creek				
Brewery Creek East	0.9	0.0	0.0	0.9
Brewery Creek West	0.5	0.0	0.0	0.5
Chennault Beach				
Chennault Beach Creek/Upper Chennault Beach Creek West	0.9	0.0	0.0	0.9
Upper Chennault Beach Creek	0.6	0.0	0.0	0.6
Lower Chennault Beach Creek North	0.8	0.0	0.0	0.8
Edgewater				
Edgewater East	0.5	0.0	0.0	0.5
Edgewater West	0.6	0.0	0.0	0.6
Goat Trail Ravine	0.6	0.0	0.0	0.6
Hulk Creek				
Hulk Creek East	0.6	0.0	0.0	0.6
Hulk Creek North/Hulk Creek South	0.4	0.0	0.0	0.4
Japanese Creek				
Japanese Creek South	0.3	0.1	1.0	1.4
Japanese Creek Mid	0.6	0.1	1.0	1.7
Lunds Gulch Creek				
Lunds Gulch East	0.5	0.4	0.5	1.4
Lunds Gulch North/Central/South	0.6	0.0	0.0	0.7
Lunds Gulch SE	0.5	0.4	0.5	1.4
Lunds Gulch SW	0.6	0.0	0.0	0.6
Lunds Gulch West	0.5	0.4	0.0	0.9
Naketa Beach	0.9	0.0	0.0	0.9
Norma Creek				
Norma Creek East	0.6	0.2	0.5	1.3
Norma Creek West	0.5	0.1	0.0	0.6
Olympic View	0.7	0.0	0.0	0.7
Picnic Point Creek				
Picnic Point Ravine	0.5	0.4	0.5	1.4
Picnic Point Ravine East	0.4	0.3	0.5	1.2

Watershed/PAU	Water Quality Score	Habitat Score	Connectivity Score	Overall Score
Picnic Point Ravine West	0.5	0.4	0.0	0.9
Smugglers Gulch Creek				
Smugglers Gulch North/Olympic View North	0.9	0.0	0.0	0.9
Smugglers Gulch South	0.6	0.2	0.0	0.8
Swamp Creek				
Swamp Creek A	0.4	0.0	1.0	1.4
Swamp Creek C	0.4	0.0	1.0	1.4
Swamp Creek D	0.4	0.0	1.0	1.4

4.0 STORMWATER STRATEGIES

The purpose of these stormwater strategies is to provide a framework for prioritization, decision making and implementation of stormwater and land use strategies that target key impaired processes within each PAU, are cost effective, feasible, and are consistent with other City Plans. These strategies are also intended to focus on retrofit and capital projects, augment the city's stormwater comprehensive plan, and address actions that would not be covered by the 2012 Ecology Stormwater Management Manual. It is assumed that new development and significant redevelopment would be covered under the Ecology manual, when it is adopted and integrated into City codes, which requires LID and comprehensive stormwater management practices.

4.1 General Management Categories

Flow importance and intactness scores were developed for each PAU using a landscape analysis that developed scores to represent watershed processes. Based on the combination of these scores, three relatively broad, yet distinct, management categories were identified (Figure 11).

1. Preserve
2. Repair
3. Targeted Management Strategies

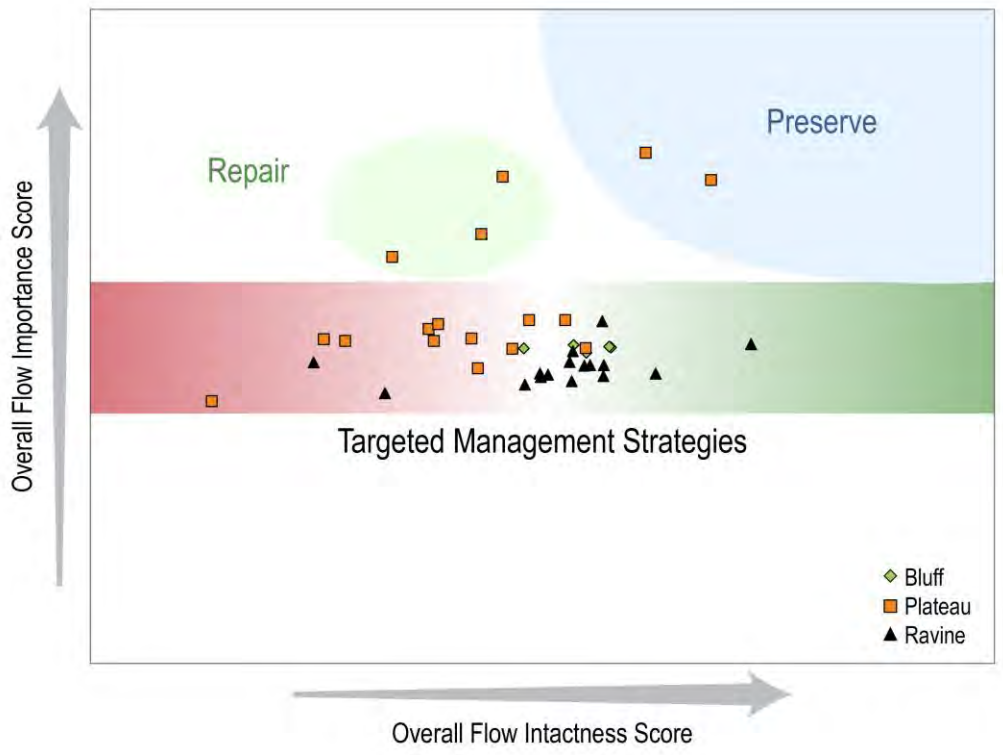


Figure 11. Management Categories

PAUs with high importance scores (greater than the average plus 1 standard deviation) and high intactness scores (greater than the average plus 1 standard deviation) were designated "Preserve". PAUs with high importance scores and lower intactness scores were designated "Repair" and a third management category, "Targeted Management Strategies", was created for PAUs lower importance scores and a range of intactness scores. Because PAUs in the Targeted Management Strategies category have similar importance scores for flow processes, secondary watershed processes, such as water quality, habitat, and connectivity, were also used as a measure of importance and used to develop appropriate management strategies based on PAU specific conditions. Overarching goals for each category were identified to guide decision making. For example, the overarching goal for the PAUs in the Preserve category is to acquire and/or protect existing undisturbed wetlands and forest; the overarching goal for PAUs in the Repair category is to retrofit highly impaired processes. Specific strategies recommended for each PAUs have considerable overlap and many strategies benefit more than one watershed process (see Section 3).

4.2 Prioritization

Two tiers of prioritization were implemented depending on the management category (Table 9, Map 19). Based on the relatively high importance scores, PAUs in the Preserve and Repair categories were given the highest priority for implementation. For PAUs in the Targeted Management Strategies category, with generally lower importance scores, an integrated secondary score, representing attributes of water quality, habitat, and hydrologic connectivity, was developed (See Methods Report). This score was then used to prioritize PAUs with similar importance scores. PAUs with a higher value for the integrated secondary score have a higher priority than PAUs with a lower value score. Prioritization is intended to provide a framework for stormwater strategy decision making. Existing limitations, opportunities, known problems, and feasibility criteria should also be used to make final decisions.

Table 9. Summary of Prioritization

Management Category/PAU	Priority	Secondary Score
Preserve		
Japanese Gulch North	Highest Priority	n/a*
Lower Chennault Beach South		n/a*
Repair		
Swamp Ck E	Highest Priority	n/a*
Swamp Ck F		n/a*
Swamp Ck G		n/a*
Targeted Stormwater		
Japanese Ck Mid	Higher Priority	1.7
Big Gulch North		1.5
Lunds Gulch SE		1.4
Lunds Gulch East		1.4
Swamp Ck A		1.4
Swamp Ck C		1.4
Japanese Ck South		1.4
Picnic Point Ravine		1.4
Swamp Ck D		1.4
Big Gulch South		1.3
Big Gulch Southeast		1.3
Norma Ck East		1.3
Picnic Point Ravine East		1.2
Picnic Point Ravine West		0.9
Naketa Beach		0.9
Big Gulch West		0.9
Lunds Gulch West		0.9
Chennault Beach Ck/Upper Chennault Beach Ck West		0.9
Brewery Ck East		0.9
Smugglers Gulch North/Olympic View North		0.9
Lower Chennault Beach Ck North		0.8
Smugglers Gulch South		0.8
Olympic View		0.7
Lunds Gulch North/Central/South		0.7
Upper Chennault Beach Ck		0.6
Norma Creek West		0.6
Hulk Creek East		0.6
Goat Trail Ravine		0.6
Lunds Gulch Southwest		0.6
Edgewater West		0.6
Edgewater East	Lower Priority	0.5
Brewery Ck West		0.5
Hulk Creek North/Hulk Creek South		0.4

4.3 General Strategies

General strategies were developed for the study area and were organized into three categories (1) Regional Engineered Strategies, (2) On-Site Strategies, and (3) Additional Strategies. These strategies are intended to focus on efforts that would not be required by development/redevelopment projects. New and redevelopment projects must meet the requirements of the City's Surface Water Management Program.

4.3.1 Municipal Strategies

Municipal engineered strategies are intended to cover large projects that would serve areas greater than a single site and would require detailed analysis and engineering design. These strategies would likely involve public rights-of-way or facilities that would be owned and maintained by the City (Table 2). A bold "**X**" in Table 10 indicates strategy primarily benefits key watershed process, a small "x" indicates minor benefits to that watershed process.

Table 10. Summary of Municipal Strategies

Municipal Strategy	Key Watershed Process			
	Delivery	Surface Storage	Recharge	Water Quality
Detention/retention pond		**X**		**X**
Constructed wetlands		x		**X**
Restore depressional wetlands		X		**X**
Cisterns		x		
Permeable pavement	**X**		X	**X**
Bioretention Cells and Planters	x	x	X	**X**
Bioretention Swale	**X**		X	**X**

These projects would likely be funded as a Capital Improvement Projects (CIP) and may be incorporated into street or other city facility improvement plans. These projects would also include large restoration projects either funded through the Capital Facility Plan, grants, or an off-site mitigation program.

4.3.2 On-Site Management Strategies

On-site management strategies are intended to be applied at the site scale (Table 11). These strategies would be appropriate for a variety of land-use types such as parks, houses, small commercial developments, public buildings, churches, and schools; although implementation of these strategies, such disconnect downspouts may not be appropriate for larger sites such as schools or in locations where runoff would be directed to adjacent private property. In general, these strategies require little engineering and could be promoted through outreach, education or other incentives programs.

Table 11. Summary of On-Site Management strategies

On-Site Management Strategy	Key Watershed Process			
	Delivery	Surface Storage	Recharge	Water Quality
On-Site Strategies				
Soil amendment/restoration	**X**		x	x
Plant trees	**X**	x		x
Rain Gardens	**X**	x	**X**	**X**
Vegetated filter strips	**X**		x	**X**
Disconnect downspouts	**X**		**X**	**X**
Cisterns		x		

4.3.3 Additional Strategies

Additional management strategies are intended to focus on restoration and protection of forest vegetation as a mechanism of improving basin hydrology and watershed processes (Table 12). These projects will likely focus on existing parks and will be consistent with the City's GMA Comprehensive Plan, Parks, Open Space, Recreation & Arts Plan, and the Critical Areas Mitigation Plan (CAMP). In addition, public education is included as a key strategy and could consist of general information, information specific and programs to targeted audiences such as landscaping services, streamside landowners, or could target school curriculum.

Table 12. Summary of Additional Management Strategies

Additional Management Strategy	Key Watershed Process			
	Delivery	Surface Storage	Recharge	Water Quality
Additional Strategies				
Protect/acquire open space	**X**		x	**X**
Restore upland vegetation	**X**	x		**X**
Restore buffer vegetation	**X**	x		**X**
Education				x

4.4 Integration with City Plans

This Stormwater Strategies Plan is intended to be integrated with other City adopted Plans; primarily , the Surface Water Management Program and NPDES MS4 Permit, the Comprehensive Land Use Plan, and the CAMP.

Currently the City has a Stormwater Master Program which is intended to manage surface so that "water quality is continually being improved by minimizing or eliminating pollution to the ground and water courses; to reduce, limit or eliminate erosion in our water courses; and to restore, to the extent possible the natural nature of our water courses." This program meets the requirements of the NPDES

MS4 Permit and has several rules and ordinances intended to regulate stormwater runoff. As part of this program, the City has adopted the 2005 Ecology Storm Water Management Manual for Western Washington to address runoff from new and re-development projects. However, much of Mukilteo is developed; therefore, this plan provides a framework for indentifying and prioritizing strategies that address existing concerns.

The strategies recommended in this plan are also consistent with the Comprehensive Land Use Plan. Specifically, the recommendations support three goals documented in the Comprehensive Plan:

> GD6: Protect and enhance the City's critical areas, habitats, and shoreline management zones to support fish and wildlife resources and provide physical and visual access opportunities.
>
> GD7: Provide a system of parks, recreational, and cultural facilities that incorporates both public entities (City, County, State, Port of Everett, and schools), private assets to expand opportunities within the City, views of the water and mountain scenery and public access along the shoreline.
>
> GD8: Promote a sustainable Mukilteo by balancing the needs of the environment and current population without jeopardizing future Mukilteans' capability to meet their own needs.

The CAMP identifies several locations within the City that could be used to provide off-site mitigation for unavoidable impacts to critical areas. Each location identified in this plan is included in the PAU sheets in Appendix A. Because off-site mitigation also benefits the watershed functions evaluated in this analysis, the recommendations in this Plan support the recommendations in the CAMP; many of the sites identified in the CAMP are located in PAUs with the high priority.

4.5 Specific Recommendations

Specific strategies have been developed for each PAU based on (1) known limitations such as steep slopes, (2) feasibility, (3) and this analysis of specific watershed processes. The methods used to identify appropriate strategies for each PAU are discussed in the following sections. Implementation of any specific strategy would require additional site specific analysis such as a land survey, infiltration/soil testing, wetland delineation, and engineering.

4.5.1 Limitations

Within the study area there are limitations to strategies that rely on infiltration such as permeable pavement, bioretention cells and planters, rain gardens, and bioretention swales. Infiltration is not considered appropriate in locations adjacent to a steep slope or landslide hazard area (King County 2009; Clark County 2009; Thurston County 2010). Additionally, infiltration is not appropriate in locations, such as Paine Field, where industrial spills are possible.

4.5.2 Feasibility

The feasibility of individual strategies varies throughout the study area and depends on land ownership, existing topography, soils, hydrology and land cover. For example, land acquisition and buffer restoration projects would be most feasible in PAUs where parks and open spaces already exist and could be enhanced or increased in size by additional acquisition and would be less feasible in PAUs with extensive existing private development.

4.5.3 Specific Watershed Process

Ecology has identified several strategies for managing stormwater runoff. Many BMPs benefit multiple watershed processes (see Tables 2, 3, and 4). However, most of the strategies do not benefit all watershed processes. This analysis identified the specific watershed processes that primarily benefit from implementation of each strategy. A menu of BMPs was then developed for each PAU based on the results of this analysis with the intention of selecting BMPs that focus on specific watershed processes that are either important or degraded in each PAU. The following sections summarize which strategies were determined to be most appropriate for each watershed process evaluated in this analysis.

Delivery

The delivery processes received high scores for importance throughout the study area. However, it scored mid to low for intactness throughout the study area due to relatively high levels of impervious surface cover. Therefore, the BMPs specific to the delivery process are recommended for all of the PAUs and generally focus on reducing effective impervious surface and restoring forest cover (Table 13).

Table 13. Strategies recommended for the entire study area[1]

Municipal Strategies targeting delivery
Permeable pavement
Bioretention Swale
On-Site Strategies targeting delivery
Soil amendment/restoration
Rain Gardens
Vegetated filter strips
Disconnect downspouts
Additional Strategies targeting delivery
Protect/acquire open space
Restore upland vegetation
Restore buffer vegetation

Note 1. Strategies that rely on infiltration may not be appropriate in locations adjacent to steep slopes or subject to industrial spills.

Recharge

The recharge process scored high for importance throughout the study area; however as discussed in the previous section, recharge was not considered as an important process in ravine and bluff PAUs. In general, this process is also relatively intact in plateau, except for the Japanese Gulch South, Lunds Gulch SE, and Big Gulch Southeast PAUs. Strategies that specifically benefit the recharge processes are recommended in these three PAUs (Table 14). Strategies in Table 14 shown in bold primarily benefit recharge processes; non-bold strategies have secondary benefits to recharge.

Table 14. Strategies recommended for Japanese Gulch South, Lunds Gulch SE, and Big Gulch SE

Municipal Strategies targeting recharge
Permeable pavement
Bioretention Cells and Planters
Bioretention Swale
On-Site Strategies targeting recharge
Rain Gardens
Disconnect downspouts

Many of the strategies that focus on delivery processes shown in Table 3, also benefit recharge; however, rain gardens and disconnecting downspouts are BMPs that specifically focus on the recharge process.

Surface Storage

Surface storage processes generally scored low in importance throughout the study area except for Lower Chennault Beach Creek S, Swamp D, Swamp E, Swamp F, and Japanese Creek North PAUs, which had higher importance scores for surface storage. All of the PAUs except Lower Chennault Beach Creek S and Swamp E received low scores for intactness. Therefore, strategies that focus on restoring surface water storage, summarized in Table 15, are recommended for these PAUs.

Table 15. Strategies recommended for Swamp D, and F, and Japanese Creek North

Municipal Strategies targeting surface storage
Detention/retention ponds
Restore Depressional Wetlands

Water Quality

Although water quality was not directly evaluated in this analysis, the 303(d) list was used to identify PAUs with known water quality problems. The Norma Creek West and Swamp Creek C, D, E, and F PAUs all have stream segments on Ecology's 303(d) list of impaired waterbodies; strategies specifically addressing water quality are recommended for these PAUs (Table 16).

Table 16. Strategies recommended for Norma Creek West and Swamp Creek C, D, E, and F

Municipal Strategies targeting water quality
Detention/retention pond
Constructed wetlands
Restore depressional wetlands
Permeable pavement
Bioretention Cells and Planters
Bioretention Swale
Table 8 Continued
On-Site Strategies targeting water quality
Rain Gardens
Vegetated filter strips
Disconnect downspouts
Additional Strategies targeting water quality
Protect/acquire open space
Restore upland vegetation
Restore buffer vegetation

4.6 PAU Fact Sheets

Although there is significant overlap in the suite of recommended strategies among the PAUs based on the results of the analysis, land use patterns, topography and known opportunities, each PAU has a unique set of recommendations summarized in PAU Fact Sheets located in Appendix A. Each PAU fact sheet summarizes the following information about the PAU:

GENERAL INFORMATION

- PAU size
- Percent impervious cover
- Percent wetland cover
- Land use based on Zoning

MAPS

- Steep slopes
- Location map indicating streams and public land
- Stormwater infrastructure

ANALYSIS RESULTS

- Landscape Position
- Management Category
- Priority

RECOMMENDATIONS

- Key watershed processes
- Key Strategies
- Known Constraints
- Water quality concerns (303d List)
- Known Problems
- Known Opportunities (CAMP and Smugglers Gulch Pre-Design Report)

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