Ground Water Recharge Suitability Assessment
Fisher Creek Basin

TECHNICAL REPORT – PRELIMINARY DRAFT SKAGIT RIVER BASIN GROUND WATER RECHARGE MITIGATION PROGRAM

Skagit County, Washington

Prepared for

Upper Skagit Indian Tribe

Project No. EH130580A
March 12, 2014

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Skagit County, Washington

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March 12, 2014
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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (CONTINUED)

Page

TABLE OF CONTENTS (CONTINUED)

Page

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Purpose

This report presents the results of Associated Earth Sciences, Inc.'s (AESI's) evaluation of ground water recharge suitability for the purposes of enhancing instream flow in Fisher Creek and mitigation for rural residential water use in the Fisher Creek basin. The Fisher Creek basin is an approximately 10-square-mile watershed located in southwest Skagit County and northwest Snohomish County, about 7 miles south of Mount Vernon, Washington. Fisher Creek is a tributary to the South Fork of the Lower Skagit River. The location of the basin and surrounding physical features are shown on Figure 1.

The Upper Skagit Indian Tribe (Tribe) has entered into an agreement with the Washington State Department of Ecology (Ecology) to develop a demonstration project to create a streamflow enhancement/ground water mitigation program (Program) to address streamflow-related impacts of residential development on selected Skagit River tributaries. The program will start as a demonstration project for the Fisher Creek basin (project area) and will include two components: 1) development of a managed ground water recharge project to enhance current instream flows in the Fisher Creek basin and to offset flow-related impacts from new ground water uses, and 2) creation of mitigation credit program to recover the costs of the ground water recharge project.

The purpose of our studies was to evaluate the potential to develop a ground water recharge project that would capture runoff in the project area during high-flow periods and release the water into an infiltration facility to recharge ground water. The intended result of the project is to increase instream flow in Fisher Creek during critical low-flow periods. Our study is separated into two primary tasks: 1) Ground Water Recharge Assessment, and 2) Pilot Project Preliminary Conceptual Design and Cost Estimate.

This report presents the results of Task 1 – Ground Water Recharge Assessment. The following sections of this report include a description of: 1) the project background and data sources, 2) project setting, 3) geologic conditions, 4) hydrogeologic conditions, 5) project area surface water, 6) project area water quality, 7) development potential, and 8) ground water recharge suitability.

1.2 Project Background

On April 14, 2001, Ecology adopted the Skagit River Instream Flow Rule (*Washington Administrative Code* [WAC] 173-503), which established minimum instream flows for the mainstem Skagit River and several tributaries. The result of the 2001 rule was that any new consumptive water uses put to beneficial use after April 14, 2001, including permit exempt wells, are subject to interruption when the instream flow in the Skagit River is not being met.

In 2006 Ecology amended the 2001 Skagit River Instream Flow Rule to establish a finite water budget or "reservations" of water for out-of-stream uses that provided uninterruptible water supplies for new agricultural, residential and commercial/industrial uses in 25 tributary basins to the Lower Skagit River. The rule amendment also established a mitigation approval process. On October 3, 2013, the Washington Supreme Court overruled the amendment, effectively removing the reservation system and reverting back to the 2001 Instream Flow Rule. Presently, this means that all new surface and ground water uses throughout the Skagit River basin, including the tributary basins like Fisher Creek, must be fully mitigated for their impacts to the minimum instream flow in the mainstem Skagit River.

Ecology has entered into a contract with the Tribe to formulate a demonstration Program to enhance streamflows in Fisher Creek and mitigate for new ground water uses in the Fisher Creek basin. The goal of the project described in this report is to demonstrate if a managed ground water recharge can provide enhanced streamflow which will effectively mitigate for ground water development.

1.3 Data Review

The majority of the data presented in this report has been summarized from the technical reports and other sources cited herein. A general summary of the most pertinent information reviewed is provided below. A detailed listing of references for this project is included in Section 10.0.

- Parcel, land use, and zoning maps from Skagit and Snohomish Counties.
- Soils surveys for Skagit and Snohomish Counties from the U.S. Department of Agriculture National Resource Conservation Service (USDA NRCS).
- Reports and maps published by the United States Geological Survey (USGS) and the Washington State Department of Natural Resources (WDNR), and Skagit Conservation District (SCD).
- Water well records for selected wells located within the project area obtained from the Ecology online well log database (Ecology, 2014).
- Streamflow data for the Skagit River and Fisher Creek obtained from the USGS and Ecology.

2.0 SETTING

2.1 Project Area Description

The project area is the Fisher Creek drainage basin located in southwest Skagit County and northwest Snohomish County. Fisher Creek has a drainage area of approximately 10 square miles and is a tributary to the South Fork of the Skagit River (Figure 1). Ground surface elevations in the Fisher Creek basin range from less than approximately 10 feet in the Skagit River valley to over 1,300 feet in the mountainous area to the east. All elevations referenced in this report are relative to mean sea level unless otherwise noted.

The project area has a maritime climate with relatively warm and dry summers and cool and wet winters. Annual snowfall is generally on the order of a few inches per year. Annual precipitation in the basin ranges from approximately 30 inches in the valley to over 55 inches in the mountainous areas, based on data from the Parameter-Elevation Relationships on Independent Slopes Model (PRISM, Daly and others, 1994). Approximately half of the annual precipitation in the basin falls in the months of November through February.

2.2 Land Use and Zoning

Land use and zoning in the Fisher Creek basin is primarily rural residential (nearly 70 percent) and forestry (30 percent). In Skagit County, the existing zoning in the Fisher Creek basin consists of Rural Reserve (RRv), Secondary Forest (SF), Industrial Forest (IF), and very small areas of Agriculture (A) and Rural Business (RB) zoning. In Snohomish County, the existing zoning consists of Rural 5 Acre (R-5) and Forestry (F). The forestry parcels (SF, IF, and F) are primarily located in the mountainous area in the eastern portion of the basin. General land use zoning in the Fisher Creek basin are shown on Figure 2.

2.3 Surface Slopes

Surface slopes of 0-5 percent, 5-15 percent, and greater than 15 percent in the project area are shown on Figure 3. Slopes greater than 15 percent are prevalent throughout the mountainous area in the eastern portion of the basin, and along Fisher Creek and several tributaries toward the western portion of the basin. Slopes were classified based on Light Detection and Ranging (LiDAR) topographic data compiled by the Puget Sound LiDAR Consortium based on data collected in 2005 and 2006.

2.4 Wetlands

The approximate locations of wetlands as mapped by the National Wetland Inventory (NWI – U.S. Fish and Wildlife Service, 2012) are presented on Figure 3. The NWI database is an inventory system developed in 1974 by the U.S. Fish and Wildlife Service. The NWI database is useful for identifying the general location and extent of wetlands in the project area. Skagit

County does not have a wetland inventory database for regulatory purposes. Wetland delineation studies are required to determine the presence, extent, and classification of actual wetlands and wetland buffers.

Wetlands are functionally important features for both hydrologic processes, water quality, and wildlife habitat. Hydrologically, wetlands can store precipitation and runoff and release flows over a longer time period to reduce peak flows and help maintain baseflow to streams. Wetlands also can trap or transform pollutants through a variety of physical, biological, and chemical processes maintaining good water quality and improving polluted water. The SCD has noted that there are several large palustrine, forested, scrub-shrub, and emergent wetlands in the Fisher Creek basin that appear to store a large quantity of runoff and release it more gradually than runoff from the surrounding non-wetland area (SCD, 2007). These wetlands were not field-verified as a part of the SCD (2007) study. The SDC (2007) also noted that historic ditching in pasture areas has most likely reduced the overall area of upland wetland that occurred prior to settlement in the 19th century.

2.5 Olympic Pipeline

The location of the Olympic natural gas pipeline is shown on Figure 3. The Olympic Pipeline Company, operated by British Petroleum Pipelines, oversees a 400-mile interstate petroleum transmission pipeline system between Blaine, Washington and Portland, Oregon. The pipeline was constructed in the 1960's and bisects the Fisher Creek basin (Figure 3). It is located adjacent and parallel to Fisher Creek for approximately 1.75 miles in the central portion of the basin (Figure 3).

2.6 Fish Habitat

The known and presumed distribution of anadromous and resident salmonid species in Fisher Creek was determined as a part of the salmonid habitat limiting factors study by the Northwest Indian Fisheries Commission (NIFC) in 2001, and is presented on Figures 4A and 4B. The known distribution includes habitat where the presence of salmonids has been documented by published sources, survey notes, biologist observations, or by knowledge from a Technical Advisory Group consisting of private, federal, state, tribal, and local government personnel (NIFC, 2001). The known distribution also includes habitat used by any life stage for any length of time, including intermittent streams that may only contain water during peak flows when they provide off-channel refuge habitat (NIFC, 2001). The presumed distribution includes habitat where the presence of salmonids have not been documented but which is downstream of any known fish passage barrier and otherwise conforms to species-specific habitat criteria (NIFC, 2001).

The Fisher Creek basin is a coho dominant system which also supports Endangered Species Act (ESA) listed steelhead, as well as chum, and cutthroat trout (Figure 3). In addition, the floodplain west of the basin supports ESA listed bull trout, and chinook. Migratory support is important for returning adults to reach their natal streams and is as important to support rearing and juvenile outmigration. Passage is limited in several places due to migration barriers such as road culverts. Passage limitations and/or barriers contribute to instream flow disturbances.

Fish passage barriers have been evaluated by the Washington State Department of Fish and Wildlife (WDFW) Fish Passage Program. The WDFW has developed and maintains a centralized database for fish passage, and other information from inventories throughout the state. The Fish Passage and Diversion Screening Inventory (FPDSI) database includes 37 potential fish passage barriers (partial and total) in the Fisher Creek basin (Figures 4A and 4B).

The SCD (2007) evaluated habitat quality in the Fisher Creek basin and noted that the creek channels and adjacent riparian areas in the Fisher Creek basin contain fish habitat features of varying function. Fish passage barriers and lack of riparian vegetation are noted as two key factors in limiting the function and value of wildlife habitat in the basin (SDC, 2006).

Instream water quality is also important to support salmonids and other aquatic species. Surface water quality in the basin is discussed in Section 6.0.

2.7 Soils

Soils in the Fisher Creek basin were mapped by the NRCS in the 1980s as a part of soil surveys conducted for Skagit County (NRCS, 1989) and Snohomish County (NRCS, 1983). Soil scientists create the surveys by observing the landforms, slopes, drainage, vegetation, and underlying geology, and digging holes to study soil horizons down to the parent material below the rooting zone of the vegetation. The soils were grouped in map units of similar characteristics including depth to restrictive layer, drainage class, and depth to water table. These characteristics were then used to assign an interpretive Hydrologic Soil Group to each map unit.

The Hydrologic Soil Groups are generally related to the infiltration capabilities of the soils. Group A soils have a high infiltration rate and consist mainly of deep, well drained to excessively drained sands or gravelly sands. Group B soils have a moderate infiltration rate and depth, are fairly well drained, and have a fine texture to coarse texture. Group C soils have a slow infiltration rate. These soils generally have moderately fine or fine textured restrictive layers that impede the downward movement of water. Group D soils have a very slow infiltration rate and consist of relatively thin, very fine-grained material that have a high water table and overlie nearly impervious material. Group B/D and C/D soils are naturally Group D soils, primarily due to a high water table, that may have characteristics of Group B or C soils if drained.

Soil map units in the Fisher Creek basin are outlined on Figure 5 and color coded by Hydrologic Soil Group classification. Only approximately 2 percent of the basin is classified as Group A. Group B soils account for approximately 33 percent of the basin area, although most Group B soils in the basin are associated with the bedrock hills to the east. Nearly half of the basin (46 percent) is classified as Group C soils, and approximately 19 percent of the basin is classified as Group D, B/D, or C/D.

The primary Group A soil in the basin is mapped as Barneston very gravelly sandy loam. Nearly all of the Group B soils in the basin are mapped as either Cathcart loam (27 percent of basin) or Winston gravelly loam (5 percent of basin). Nearly all of the Group C soils in the basin are mapped as Tokul gravelly loam (44 percent of basin). A brief description of these soil units is given below.

2.7.1 Barneston Very Gravelly Sandy Loam (Group A)

The Barneston very gravelly sandy loam is a very deep, somewhat excessively drained soil located on terraces, and in areas between terraces (NRCS, 1989). It typically has a high permeability and a depth to ground water greater than 80 inches.

2.7.2 Cathcart Loam (Group B)

The Cathcart loam is a very deep, well-drained soil associated with foothills and mountain foot slopes (NRCS, 1989). These Group B soils are closely associated with the near-surface bedrock geologic units located in the eastern portion of the Fisher Creek basin.

2.7.3 Winston Gravelly Loam (Group B)

The Winston gravelly loam is a very deep, somewhat excessively drained soil located on terraces, terrace escarpments, and outwash plains (NRCS, 1983). It formed in weathered glacial outwash and volcanic ash and is underlain by glacial outwash. It typically has a moderately high permeability and a depth to ground water greater than 80 inches.

2.7.4 Tokul Gravelly Loam (Group C)

The Tokul gravelly loam is a moderately deep, moderately well-drained soil on glacially modified hills. It forms in weathered glacial till, glaciomarine drift, glacial outwash, and volcanic ash and is underlain by glacial sediments. Compact glacial till or glaciomarine drift is often present at a depth of 20 to 40 inches and acts as a restrictive layer for the vertical migration of water. It is a moderately well-drained soil with moderate permeability and a depth to a seasonal perched water table of approximately 18 to 36 inches from November to May (NRCS, 1983).

3.0 GEOLOGIC CONDITIONS

3.1 General

The geologic conditions in and around the Fisher Creek basin are described in the following sections based primarily on: 1) work by Dragovich and others (2002) and the USGS (2009a, 2009b), 2) a review of selected water well reports for the project area, and 3) our review of regional geologic maps, technical documents previously prepared by AESI, and other published technical documents. A surficial geologic map of the project is presented on Figure 6. Four geologic cross sections describing surface and subsurface geologic conditions are presented on Figures 7A and 7B. The approximate locations of the cross sections are shown on Figure 6.

3.2 Regional Geology

The project area is located within the Puget Lowland in Skagit and Snohomish Counties. The regional geology of the Puget Lowland consists of a complex series of sediments deposited during the repeated advance and retreat of continental glaciers, and alluvial sand and gravel deposits associated with the present and ancient Skagit River. The glacial and alluvial sediments are generally underlain by bedrock consisting of sedimentary units, metamorphic and igneous rocks.

During the past 2.4 million years, continental glaciers repeatedly flowed southwestward from British Columbia into the low-lying region between the Olympic and Cascade Mountains. The most recent glacial period occurred during the Fraser Glaciation. The Fraser Glaciation consisted of multiple stades (episodes of glacial advance) and interstades (episodes of glacial retreat). The Vashon Stade of the Fraser Glaciation began approximately 17,000 years before present (ybp) when the Puget Lobe of the Cordilleran ice sheet extended into western Skagit County and eventually covered the entire Puget Sound basin prior to retreating (USGS, 2009a). The Everson Interstade began approximately 13,500 ybp as the climate warmed and the Puget Lobe retreated allowing marine waters to enter the Puget Sound. The rapidly melting and retreating ice floated on the marine waters creating interfingered marine, estuarine, deltaic, and fluvial deposits.

3.3 Local Geology

The eastern roughly 25 percent of the Fisher Creek basin is underlain at the ground surface predominately by bedrock (Oligocene- to Eocene-aged sedimentary rocks - **OEcb**). The rest of the basin is dominated by glacial and nonglacial pre-Fraser sediments, and by glacial sediments deposited during the Vashon Stade and Everson Interstade of the Fraser Glaciation. The three most common surficial glacial units in the basin are the Everson glaciomarine drift **(Qgmd$_e$)**, Everson glaciomarine outwash **(Qgom$_e$)**, and Vashon till **(Qgt$_v$)** which account for 19.5 percent, 26 percent, and 17 percent of the basin area, respectively (Figure 6). The stratigraphic relationship between the primary geologic units in the project area is shown on geologic cross sections (Figures 7A and 7B). A description of the geologic units located in the immediate vicinity of the project site is briefly reviewed below from oldest to youngest.

3.3.1 Oligocene to Eocene Sedimentary Rocks (OEcb)

The primary bedrock unit in the study area includes the Oligocene to Eocene sedimentary rocks referred to as the rocks of Bulson Creek (Dragovich and others, 2002). This unit was divided into a lower conglomerate lithofacies and an upper finer-grained lithofacies. The lower lithofacies consists of pebble and cobble conglomerate with minor interbeds. The upper facies consists of well-sorted, coarse- to medium-grained sandstone with interbeds of conglomerate, pebbly sandstone, siltstone, fossiliferous siltstone, coal, and shale. The presence of marine megafossils, and terrestrial plant fossils in the upper portion of this facies, indicated a transition from fluvial to estuarine or nearshore marine environment (Dragovich and others, 2002.)

3.3.2 Whidbey Nonglacial deposits (Qc_w)

The pre-Fraser Whidbey nonglacial deposits (**Qc_w**) consist mostly of sand with interbeds of silt, clay, sandy clay, and silty clay. Peat and wood are common and the depositional environment is interpreted to be a slowly aggrading meandering stream and adjacent floodplain (Dragovich and others, 2002). The unit is not exposed at the land surface in the project area but does appear prominently in the geologic cross section C-C' (Figure 7B).

3.3.3 Older Glacial Till and Outwash (Qot, Qoo)

For the purposes of this report, we have referred to all pre-Fraser glacial deposits as older outwash (**Qoo**) and till (**Qot**). These deposits are not exposed at the land surface in the Fisher Creek basin, but the (**Qot**) does appear in the geologic cross section B-B' (Figure 7A). The **Qoo** consists of pre-Fraser glacial or nonglacial sediments, mostly composed of sand and gravel with lesser clay or silt interbeds that are tentatively correlated with the Possession Glaciation (Dragovich and others, 2002). The **Qot** consists of clay, silt, sand, and gravel with scattered cobbles and boulders. This unit likely also includes glaciomarine drift.

3.3.4 Olympia Nonglacial Deposits (Qc_o)

The pre-Fraser Olympia nonglacial interval occurred between about 21,000 and 60,000 ybp. While organic materials are rare in glacial deposits, particularly those associated with the overlying Fraser Glaciation, organics are relatively abundant in the Olympia nonglacial deposits (**Qc_o**), including logs, and wood fragments. Most of the **Qc_o** sediments were deposited in a meandering river environment resulting in a compositionally heterogeneous unit of sand, gravelly sand, organic-rich sand, silt sand, silt, silty clay and peat (Dragovich and others, 2002).

3.3.5 Fraser Glaciation

The Fraser Glaciation is the most recent period of Cordilleran ice sheet advance into Washington State and consisted of multiple stades and interstades. The near-surface sediments located in the project area are dominated by deposits of the Vashon Stade and the Everson Interstade of the Fraser Glaciation.

Vashon Glaciolacustrine and Distal Outwash (Qgl$_v$)

Glaciolacustrine and distal outwash deposits (**Qgl$_v$**) of glacial and/or nonglacial origin are well-sorted, fine-grained clay and silts associated with low-energy lacustrine and distal fluvial environments, indicating the advancing glaciers were a long distance from the depositional environment at the time. These deposits are typically underlying the **Qga$_v$** (where present) and overlie the **Qc$_o$**. The **Qgl$_v$** is not exposed at the land surface in the Fisher Creek basin, but is important in the subsurface geologic cross sections (Figures 7A and 7B).

Vashon Advance Outwash (Qga$_v$)

Vashon advance outwash (**Qga$_v$**) deposits consist of primarily medium and coarse sand and gravel deposited in the high-energy glacial fluvial environment in front of the advancing glaciers. The **Qga$_v$** is moderately well sorted and is commonly overlain by till (**Qgt$_v$**) along a sharp contact, and overlies or is interbedded with the **Qgl$_v$**, where present (USGS, 2009b). The **Qga$_v$** is only exposed at the land surface in a small area near the East Fork Little Fisher Creek (Figures 6, 7A and 7B).

Vashon Till (Qgt$_v$)

Till is composed of a non-stratified, unsorted mixture of clay, silt, and gravel in various proportions, scattered cobbles and boulders and rare lenses of sand or gravel (Dragovich and others, 2002). Till is deposited directly under advancing or retreating glaciers, which results in a very dense sediment that typically has extremely low permeabilities. The **Qgt$_v$** commonly underlies the **Qgmd$_e$** in the study area and is generally laterally continuous and relatively thick. Subsurface data indicate the Vashon till is locally in excess of 100 feet thick in the study area (Figures 6, 7A and 7B).

Everson Glaciomarine Outwash (Qgom$_e$)

Everson glaciomarine outwash **(Qgom$_e$)** is widespread throughout the western portion of the basin in relatively thin and discontinuous layers (Figure 6). The **Qgom$_e$** typically consists of loose sand, gravel, and silt, with occasional silt beds. The average grain size is smaller in the **Qgom$_e$** than in the recessional outwash (**Qgo$_e$**). The **Qgom$_e$** is interlayered with the Everson glaciomarine drift **(Qgmd$_e$)** in most of the Fisher Creek basin indicating submarine deposition, although it may include minor amounts of terrestrial outwash deposits (USGS, 2009b).

Everson Recessional Outwash (Qgo_e)

The Everson recessional outwash (**Qgo_e**) consists of terrestrial to marine recessional outwash sand, sandy gravel, gravelly sand and sandy cobbly gravel with scattered boulders (Dragovich and others, 2002). The deposits are likely from a fluvial braided channel environment. The **Qgo_e** is only present in small, thin pockets in the southeastern portion of the Fisher Creek basin (Figures 6, 7A and 7B).

Everson Glaciomarine Drift ($Qgdm_e$)

Glaciomarine drift typically consists of silt- and clay-rich material deposited as floating glaciers melted and deposited a mixture of clay, silt, sand, gravel, and boulders into marine water. The **$Qgmd_e$** in the Fisher Creek basin is composed of a clast rich diamicton containing clay, gravel, sand, and silt with abundant boulder dropstones, and a silt- and clay-rich unit with few dropstones (USGS, 2009b). The **$Qgmd_e$** typically has very low permeabilities. Like the **$Qgom_e$** the **$Qgmd_e$** is abundant in the western portion of the Fisher Creek basin in relatively thin, discontinuous layers (Figures 6, 7A and 7B).

3.3.6 Holocene Deposits

Landslide Deposits (Qls)

Landslide deposits (**Qls**) consist primarily of poorly sorted unstratified, soft to cohesive diamicton composed of boulders, cobbles, and gravel in a soft sand or clay matrix. These deposits include slum-earth flows, debris slumps or flows, and rock avalanches (talus) (USGS, 2009b). Several small- to medium-size deposits of landslide material are mapped in the eastern portion of the project area (Figure 6).

Peat (Qp)

The peat deposits (**Qp**) in the basin consists of mostly poorly stratified, brown to black, soft fibrous to woody peat and muck of bogs and swamps of abandoned channels, kettles, and other depressions (Dragovich and others, 2002). A relatively large peat deposit is mapped just east of the intersection between Starbird and Bulson Roads in the project area (Figure 6).

Alluvium (Qa)

The alluvium (**Qa**) in the basin consists of active or abandoned channel and flood overbank deposits associated with the present and ancient Skagit River as well as alluvial fan deposits located near the toe of the bedrock hills in the eastern portion of the basin (Figure 6).

4.0 HYDROLOGIC CONDITIONS

4.1 General

Water is present in the pore spaces of soils and sediment throughout the project area. This "ground water" is part of the continuous hydrologic cycle which, in the natural state, begins with infiltration of precipitation and runoff (recharge) and ends with discharge to streams, wetlands, and ultimately to the Skagit River or Puget Sound.

Ground water under saturated conditions flows preferentially through materials with greater porosity and permeability, such as clean gravels and sands. Where geologic conditions limit discharge, ground water accumulates in permeable zones, which, if they can support production from wells, are termed "aquifers". The sustainability of wells, or the long-term aquifer capacity, depends both on the extent of the aquifer, its rate of recharge and natural discharge, and the amount of withdrawal by producing wells. Geologic units with low permeabilities that restrict ground water movement and are not considered a viable water source are termed “confining” units. Most confining units aren’t completely impermeable and transmit water very slowly from one aquifer to another and are commonly termed “leaky confining layers”

Unconfined or “water-table” aquifers typically occur close to the land surface where the upper portion of the saturated zone is at atmospheric pressure and is free to rise and decline in response to ground water recharge and discharge. Recharge can occur from downward seepage through the unsaturated zone, or through lateral or upward ground water flow through a leaky confining layer. Discharge from an unconfined aquifer can occur as lateral ground water flow to surface water bodies (streams, rivers, wetlands, lakes, etc.) or as vertical ground water flow to another aquifer.

Confined, or “artesian” aquifers are overlain by a confining layer. Recharge can occur either in a recharge area where the aquifer unit is exposed at the land surface, or by slow downward ground water flow through a leaky confining layer. Ground water in confined aquifers is under pressure greater than atmospheric pressure.

Ground water resources located beneath the project area are present in both unconfined and confined aquifers. These units have been described primarily by the USGS (2009a, 2009b, 2011) and are briefly summarized below.

4.2 Surficial Outwash Aquifer

The unconfined surficial aquifer present in the basin is generally located within the recessional (**Qgo**$_e$) and glaciomarine (**Qgom**$_e$) outwash units (Figure 6). The aquifer is generally limited to relatively thin, laterally discontinuous pockets of sand, gravel, and cobbles with minor lenses of silt in clay. Thickness of the unit typically ranges from 10 to 50 feet. The depth to the water table can be very shallow seasonally and fully saturated in localized areas. The aquifer is typically underlain by a relatively thick layer of glacial till (Figures 7A and 7B).

The median value for the estimated hydraulic conductivity (measure of the rate at which water can move through an aquifer) for the outwash aquifer is 47 feet per day (ft/d), with a range of 0.04 to 1,322 ft/d (USGS, 2009b). Due to its laterally discontinuous and shallow nature, there are few water supply wells completed in this aquifer. The wells that do exist in this aquifer are typically older, dug wells.

Fisher Creek and its tributaries are presumed to be in hydraulic continuity with the surficial outwash aquifer, meaning that there is interconnection between the ground water and surface water. Where surface waters are present in areas mapped as the outwash aquifer, the stream may be gaining flow from ground water discharge to the stream or losing flow as surface water infiltrates through the streambed into the aquifer. These gaining or losing reaches of the stream network likely vary seasonally throughout the basin.

4.3 Advance Outwash Aquifer

The advance outwash aquifer is located within the Vashon advance outwash (**Qga**$_{v}$) and is present under a majority of the western half of the Fisher Creek basin (Figures 7A and 7B). The thickness of the advance outwash aquifer is typically from 10 to 100 feet, and up to 200 feet in isolated areas. The aquifer consists of mostly sands and gravel with minor silt and is overlain by a relatively thick layer of glacial till (**Qgt**$_{v}$) except for a small area where it outcrops near the East Fork Little Fisher Creek in the western portion of the basin (Figures 6, 7A and 7B).

The median value for the estimated hydraulic conductivity for the advance outwash aquifer is 48 ft/d with a range of 2.6 to 722 ft/d (USGS, 2009b). The advance outwash aquifer is typically highly productive in the Fisher Creek basin with a large number of wells completed in this unit.

The glacial till confining unit (**Qgt**$_{v}$) creates significant hydraulic separation between the advance outwash aquifer and the surficial outwash aquifer for a vast majority of the project area. This hydraulic separation means that ground water withdrawals from the advance outwash aquifer likely have limited impact on the surface water bodies, including Fisher Creek and its tributaries, in hydraulic continuity with the surficial outwash aquifer. Ground water in the advance outwash aquifer likely discharges predominantly into the alluvium in the Skagit River valley as the Vashon advance outwash sediments (**Qga**$_{v}$) are truncated at the valley margin (Figure 7A).

4.4 Interglacial Alluvial Aquifer

The interglacial alluvial aquifer is located within the Olympia nonglacial deposits (**Qco**) and is present under a majority of the western half of the basin (Figures 7A and 7B). The aquifer unit consists primarily of sand, gravel, silt, and clay with minor lenses of gravel and cobbles (USGS, 2009b), and is typically 10 to 50 feet thick with isolated areas up to 100 feet thick. In most of the project area the interglacial alluvial aquifer is overlain by either glacial till (**Qgt_v**) and/or the glaciolacustrine and distal outwash deposits (**Qgl_v**) creating confined conditions.

The median value for the estimated hydraulic conductivity for the interglacial alluvial aquifer is 57 ft/d with a range of 1.4 to 393 ft/d (USGS, 2009b). The interglacial alluvial aquifer is typically productive in the Fisher Creek basin with a large number of wells completed in this unit.

Stratigraphically, the interglacial alluvial aquifer is generally below both the advance outwash aquifer and surficial outwash aquifer, and typically underlies glacial till and/or the glaciolacustrine and distal outwash confining units (Figures 7A and 7B). Significant hydraulic separation between the interglacial alluvial aquifer and the surficial outwash aquifer is present throughout the project area by one or more confining units. Ground water in the interglacial alluvial aquifer likely discharges predominantly into the alluvium in the Skagit River valley as the Olympia nonglacial deposits (**Qco**) are truncated at the valley margin (Figure 7A).

4.5 Older Outwash and Alluvial Aquifer

The older outwash aquifer consists of the older outwash deposits (**Qoo**) and Whidbey nonglacial alluvial deposits (**Qc_w**) and is interpreted to be present under much of the western half of the basin (USGS, 2009b). The extent and thickness of the aquifer is based on the logs from eight wells in and around the Fisher Creek basin, and information from Dragovich and others (2002). The limited well log data suggest the thickness of the older outwash and alluvial aquifer is typically 50 to 100 feet thick.

Stratigraphically, the older outwash and alluvial aquifer is the deepest aquifer present in the project area. Ground water is confined by a number of overlying till and glaciolacustrine and distal outwash units. There is no significant hydraulic connection between this aquifer and the surficial outwash aquifer present in the upland area, and there may be very limited interaction between the aquifer and the alluvial sediments in the Skagit River valley.

4.6 Sedimentary Bedrock Aquifer

The sedimentary bedrock aquifer is located in the eastern portion of the basin and presumably underlies the glacial units throughout the project area. Many of the wells completed in the sedimentary bedrock aquifer are located along the margin of eastern bedrock surface where glacial sediments generally are not thick enough to support an aquifer (Figures 7A and 7B).

The unit consists primarily of pebble and cobble conglomerate and coarse-grained sandstone (**OEc**$_b$) and is likely unconfined where it crops out, and confined where it is fully saturated and overlain by glacial confining units (USGS, 2009).

4.7 Ground Water Supply

Ground water supplies in the Fisher Creek basin are generally derived from aquifers with limited hydraulic continuity with surface waters in the basin and represent a small percentage of the overall water budget in the basin.

A preliminary review of the Ecology well log database (Ecology, 2014) for water supply wells in the project area indicates that only a small number of wells are completed in the surficial outwash aquifer. Of the 374 water supply wells in the project area, 10 are completed at a depth of less than 25 feet. These wells also have large-diameter casing (18 to 48 inches) indicating that they are likely older dug wells completed in the surficial outwash aquifer. There are also 16 additional wells completed at a depth of 25 to 50 feet, some of which may be completed in the surficial outwash aquifer.

Based on this preliminary review, we estimate that approximately 3 to 5 percent of the water supply wells in the Fisher Creek basin are completed in the surficial outwash aquifer. The remaining wells (95 to 97 percent of wells) are likely completed in one of the deeper aquifers. As discussed above, there is generally significant hydraulic separation between these deeper aquifers and the surficial outwash aquifer that is in presumed hydraulic continuity with Fisher Creek.

The USGS (2009b) estimated a water budget for the Fisher Creek basin. A water budget is essentially partitioning the fate of precipitation in a watershed into surface runoff, evapotranspiration, and ground water recharge. For the Fisher Creek basin, the USGS (2009b) estimated 18 percent of precipitation generates surface runoff, 42 percent of precipitation is lost through evapotranspiration, and 40 percent recharges the ground water system. Of the ground water recharge, approximately 35 percent discharges to Fisher Creek or its tributaries, 64 percent discharges to the Skagit River or Puget Sound, and approximately 1 percent is withdrawn by water supply wells (USGS, 2009b).

5.0 SURFACE WATER

5.1 Skagit River

The Skagit River drains approximately 3,120 square miles in Canada, and in Whatcom, Skagit, and Snohomish Counties. It is the third largest river on the west coast of the contiguous United States and accounts for approximately 20 percent of the fresh water flowing into Puget Sound. The Skagit River basin occupies two Water Resource Inventory Areas (WRIAs): WRIA 4 – Upper Skagit, and WRIA 3 – Lower Skagit.

The 2001 Instream Flow Rule established flows for the Skagit River as measured at the USGS streamflow station near Mount Vernon (USGS #12200500). The USGS has maintained this station since 1940. The instream flows vary seasonally and are presented on Figure 8, along with the period of record of average decadal average flows. The instream flows vary seasonally between 10,000 and 13,000 cubic feet per second (cfs) (Figure 8). Peak flows in the Skagit River are typically observed in the late spring and early summer as the winter snowpack melts in the headwaters in the North Cascade Mountains. In a typical year, flow in the Skagit River drops below the minimum instream flow in September and October, before late fall and winter rains start.

For the period of record of the USGS gauge, the Skagit River drops below the minimum instream flow for a median of approximately 87 days, per year (Figure 9). The maximum number of days of flow below the instream flow level occurred in 1944 (236 days). The minimum number of days below the instream flow level occurred in 1959 (15 days). The maximum and minimum number of days below the instream flow level since 2001 was 190 days (2001) and 38 days (2004), respectively.

For the period of record, the 10-percent exceedance value is 164 days, meaning 90 percent of the years have had less than 164 days when the flow in the Skagit River has been less than the minimum instream flow level. The Skagit River has only had 2 years with greater than 164 days where the flow was less than the minimum instream flow level since 1952 (1993 and 2001).

5.2 Fisher Creek

The Fisher Creek is a tributary to the South Fork of the Lower Skagit River and drains an approximately 10-square-mile watershed located in southwest Skagit County and northwest Snohomish County. The USGS, Ecology, and Skagit County have all conducted various levels of streamflow monitoring in the Fisher Creek basin. The locations of streamflow monitoring stations throughout the basin are presented in Figure 10.

The USGS collected flow at a continuous record streamflow station at Cedardale Road (USGS #12200701) from October 1, 2006 through September 30, 2008 (Water Years 2007-2008).

A mean daily streamflow hydrograph for each water year is presented on Figure 11. The hydrographs exhibit a typical pattern for a small, precipitation-dominated watershed in the Puget Lowland. Flows increase dramatically with the onset of late fall rains. Flows are typically maintained between 5 and 10 cfs throughout the winter and spring with short duration peak flows up to approximately 40 cfs.

Flows are typically very low (approximately 0.5 – 1 cfs) during the dry summer and early fall months. This low baseflow range is indicative of a watershed with relatively little ground water contribution to the stream. Typically, ground water discharge to the stream during the dry season is what maintains streamflow during that period. This observation is consistent with our understanding of the surficial outwash aquifer. Due to its relatively thin and discontinuous nature, the surficial outwash aquifer can only provide limited baseflow in Fisher Creek and its tributaries.

Ecology has recently established six continuous record streamflow stations throughout the Fisher Creek basin (John Rose, Ecology, personal communication, e-mail dated February 10, 2014). Five stations were established in July 2012 (Figure 10), and a sixth station (Fisher Creek at Franklin Road Bridge) was established in October 2013. At this time, Ecology has not developed the stage-discharge relationships (rating curves) necessary at each site to calculate a continuous record of streamflow. However, a hydrograph of monthly spotflow measurements at each site is presented on Figure 12. Not surprisingly, the data exhibit a similar pattern to the USGS data collected at Cedardale Road, with seasonal peakflow in the winter and spring, with relatively low summer flows. Ecology observed zero streamflow (e.g., a dry streambed) on a number of occasions during the dry season at the monitoring stations in Starbird Creek at Bulson Road and West Fork Little Fisher Creek near Countyline Road.

The USGS, Ecology, and Skagit County have also made periodic spotflow measurements at a number of locations in the basin over the years. These locations are shown on Figure 10. These sites typically only have a handful of measurements, but they do indicate three more locations in the basin where the stream has gone dry seasonally: Fisher Creek at Bulson Road (Ecology), Fisher Creek at Starbird Road (USGS #12200699), and East Fork Little Fisher Creek at Franklin Road (USGS 1220070120).

6.0 WATER QUALITY

6.1 Fisher Creek

Water quality standards for surface waters in Washington State have been established by Ecology (WAC 173-201A) to protect waters of the state consistent with public health and recreation and the protection of fish and other wildlife. The water quality standards are established in a three part approach by: 1) designating the uses of a water body, 2) assigning narrative and numerical water quality standards based on the designated uses, and 3) establishing an anti-degradation policy to protect waters of higher quality than the standards. The designated uses for Fisher Creeks are presented in Table 1. The numerical water quality criteria for temperature, dissolved oxygen, turbidity, total dissolved gas, and pH are based on the aquatic life uses of a water body. The recreational uses establish the numerical standard for bacteria. All other uses establish the standards for toxic, radioactive, deleterious materials and aesthetics.

Table 1
Surface Water Use Designations for Fisher Creek (WAC 173-201A)

Aquatic Life Uses	Recreation Uses	Water Supply Uses	Misc. Uses
Core Summer Habitat	Primary Contact	Domestic, Industrial, Agricultural, Stock	Wildlife Habitat, Harvesting, Commerce/Navigation, Boating, Aesthetics

Surface water quality in the State of Washington is also protected by the federal Clean Water Act (CWA). Section 303(d) of the CWA requires that every 2 years all states must perform a water quality assessment of surface waters in the state. In Washington, Ecology compiles the assessment and categorizes surface waters based on the status of water quality. This assessment is called the 303(d) list and is submitted to the federal Environmental Protection Agency (EPA) for approval. The current 303(d) list (Ecology, 2012b) was approved by the EPA in December 2012. Current 303(d) listings for Fisher Creek area are presented on Figure 10 and include impairments to water temperature, dissolved oxygen, and fecal coliform. Lack of native riparian stream and wetland vegetative cover and/or riparian habitat degradation can be among contributing factors to water quality impairments in temperature, dissolved oxygen, and turbidity.

Water quality in Fisher Creek has been monitored by Skagit County under the Skagit County Water Quality Monitoring Program (Skagit County, 2013). The primary focus of the program is to identify trends in water quality both in and outside of agricultural areas in the County. Fisher Creek has been monitored since October 2003. Field parameters pH, dissolved oxygen, temperature, turbidity, conductivity, and salinity have been monitored twice monthly. Laboratory analysis for fecal coliform has also been performed twice monthly. Laboratory analyses of nitrates (nitrite + nitrate), nitrate, total kjehldahl nitrogen (TKN), phosphorus, orthophosphate, ammonia, and total suspended solids have been generally conducted on a monthly or quarterly basis. Water quality data collected by Skagit County are compared against the numerical water quality standards in Table 2.

6.1.1 Temperature

The numerical standard for water temperature of <16°C is based on the 7-day average of daily maximum temperatures (7-DADMax), which requires a temperature data logger installed in the stream. Skagit County (2013) has collected spot temperature data on a twice-monthly schedule. These data indicate that water temperature in the lower reach of Fisher Creek likely meets the numerical standard (Table 2). The 2012 303(d) list indicates the lower portion of Fisher Creek is Category 1 (meets standards) for water temperature for the reach that extends approximately 1 mile upstream from the confluence with Hill Ditch (listing #6414). This listing is based on unpublished data from Ecology from a water temperature study performed in August 2001 (presented in the 303(d) listing documents [Ecology, 2012b]) that shows a 7-DADMax of 14.4°C for the week ending August 12, 2001).

Unpublished data from Ecology (presented in the 303(d) listing documents [Ecology, 2012b]) from the same period (week ending August 12, 2001) indicates a 7-DADMax of 18.1°C for Fisher Creek at Starbird Road. As a result, the reach extending approximately 0.5 miles downstream and 0.8 miles upstream of Starbird Road is included in the 303(d) list (Ecology, 2012b) as polluted by elevated temperature (listing #6425). The reach is currently listed as Category 4A (has an approved Total Daily Maximum Load [TMDL] in place) due to its inclusion in the Lower Skagit River Tributaries Temperature TMDL (Ecology, 2008) that was approved by the EPA in August 2008.

6.1.2 Dissolved Oxygen

The numerical standard for dissolved oxygen is the lowest 1-day minimum of 9.5 milligrams per liter (mg/L). The available data from Skagit County indicates that the dissolved oxygen concentration in Fisher Creek is frequently below that standard, particularly during the low-flow period in the summer and early fall. Fisher Creek is currently on the 303(d) list (Ecology, 2012b) as a Category 5 stream (polluted waters that require a TMDL or other Water Quality Improvement [WQI] project).

6.1.3 Turbidity

The available data from Skagit County (2013) indicate that turbidity levels in Fisher Creek are generally good. The numerical standard for turbidity is less than 5 nephelometric turbidity units (NTU) over the background condition. The geometric mean turbidity value is 1.92 NTU indicating generally very low turbidity aside from periodic spikes. The turbidity has only been greater than 10 NTU on nine occasions that generally occurred in the late fall or winter and are associated with storm runoff events.

6.1.4 pH

The pH values in Fisher Creek have all been within the numerical standard for the period of monitoring by Skagit County.

6.1.5 Total Coliform

The numerical standard for total coliform in Fisher Creek is based on Primary Contact for the designated recreation uses. Although the geometric mean value for the Skagit County data set is 71 colony forming units (cfu) per 100 milliliters (mL), approximately 37 percent of the dataset exceeds the numerical standard of 100 cfu/100mL. The Lower Skagit River and many of its tributaries have been known to be impaired by fecal coliform bacteria since the early 1990s. Ecology along with local governments developed and submitted a TMDL to EPA for approval (Ecology, 2000). The EPA approved the TMDL in September 2000. Fisher Creek is listed as Category 4A (has an approved TMDL in place) on the 2012 303(d) list due to its inclusion in the Lower Skagit River TMDL.

Table 2
Water Quality Data – Fisher Creek at Franklin Road Bridge

	Temperature (°C)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	pH	Total Coliform (cfu/100mL)
Number of Samples	234	230	227	225	229
Maximum	14.4	14.54	40.7	8.10	3500
Minimum	0.3	7.53	0	6.63	2
Geometric Mean	8.15	11.0	1.92	7.56	71
Numerical Standard	< 16 °C 7-DADMax(1)	> 9.5 mg/L 1-day minimum	< 5 NTUs over background	6.5 – 8.5	<100 cfu/100mL

Notes
°C - degrees Celsius
mg/L - milligrams per liter
NTU - nephelometric turbidity units
cfu/100mL - colony forming units per 100 milliliters
(1) Measured as the 7-day average of the daily maximum temperatures (7-DADMax)

6.2 Stormwater

In general, stormwater within the Fisher Creek basin is managed somewhat informally, with surface runoff collecting in a series of county and privately maintained ditches. Stormwater is conveyed via open channels and through culverts and discharges to surface waters including wetlands, Fisher Creek, and its tributaries untreated. However, depending on the land use of developed areas, runoff does have the potential to become contaminated with sediment, fertilizers, pesticides, bacteria, oil, and metals. If stormwater is conveyed directly to surface waters, it may impact the water quality of the receiving water. Stormwater also has the potential to be a source of contaminants to ground water through infiltration.

Ecology manages both stormwater quality impacts from development in Western Washington through the Ecology *Stormwater Management Manual for Western Washington* (Stormwater Manual – Ecology, 2012a). Discharges of contaminated stormwater are also regulated under the National Pollutant Discharge Elimination System (NPDES) and through the Washington State Waste Discharge Permit Program. The Stormwater Manual specifies best management practices (BMPs) for treating stormwater in order to meet water quality standards. Some of the water quality BMPs in the Stormwater Manual are outlined below:

- Infiltration and Bioretention Treatment Facilities – removes pollutants (total suspended solids, heavy metals, phosphates, and organics) and recharges aquifers.
    - Examples: Infiltration Basins, Infiltration Trenches, Bioretention

- Filtration Facilities – removes pollutants (total suspended solids, phosphorous, insoluble organics)
    - Examples: Linear Sand Filter, Large Sand Filter

- Wetpool Facilities – provides various water quality treatment
    - Examples: Wetponds, Stormwater Wetlands

7.0 DEVELOPMENT POTENTIAL

7.1 General

The development potential of the Fisher Creek basin was completed to estimate the quantity of potential mitigation water needed to satisfy potential new development in the basin as well as development that occurred since the Skagit River Instream Flow Rule was adopted.

The data source for the analysis is parcel attribute data tables acquired from Skagit and Snohomish Counties in November 2013. We joined the attribute data tables to a Geographic Information System (GIS) layer of parcels to view the spatial distribution of all attribute data, and the parcel data was clipped to only include those parcels that intersected the Fisher Creek basin boundary. The steps used to estimate the development potential are outlined below.

7.2 Parcel Categories

Prior to categorizing the parcels, we first determined which parcels that intersected the Fisher Creek basin boundary fell primarily outside the basin. We reviewed each parcel in GIS to evaluate the likelihood that an existing or future well on that parcel would be located inside or outside the basin. Parcels that were located primarily outside the basin boundary were removed from the analysis.

The remaining parcels were assigned one of 4 categories: Timber, Common Space, Developed, and Undeveloped. Of the 627 parcels in the Fisher Creek basin, 24 are categorized as Timber land, 20 parcels are Common Space, 161 are Undeveloped, and 422 are Developed (Table 3, Figure 13).

Table 3
Categories for Parcels

Fisher Creek Basin	Timber (1)	Common Space (2)	Undeveloped	Developed (3)	Total
Parcels (4)	24	20	161	422	627

Notes

(1) Timber parcels include those in Skagit County with land use codes for Designated Timber (984), Classified Timber (831), and zoning codes in Snohomish County for DF Timber Acres Only (880), DF Timber Ac w/ImpAcBldg (881).

(2) Common Space parcels include publicly owned land (including Skagit County, Dike District #3, Dike District #13, The Nature Conservancy, WSDOT, State of Washington) and known open space, known open space in rural subdivisions, and private roads.

(3) Includes 82 parcels developed after the Skagit River Instream Flow Rule (WAC 173-503-040) was established April 14, 2001.

(4) Only parcels that fell completely within, or a majority in, the Fisher Creek basin were counted.

7.2.1 Timber

There are 24 parcels totaling 2,277 acres of timber lands in the Fisher Creek basin (Table 3, Figure 13). In Skagit County, there are 15 parcels totaling approximately 1,752 acres that are designated land use codes "Designated Timber" and "Classified Timber." In Snohomish County, there are 9 parcels totaling approximately 525 acres that are designated with zoning codes "DF Timber Acres Only" and "DF Timber Ac w/ImpAcBldg." These parcels are primarily located within the Pacific Denkmann Pilchuck Tree Farm located in the eastern portion of the basin.

7.2.2 Common Space

There are 20 parcels totaling approximately 117 acres that were categorized as Common Space (Table 3, Figure 13). Future development on these parcels is considered unlikely. These parcels include publicly owned land and known open space in rural subdivisions.

In Skagit County, parcels owned by Skagit County, Dike District #3, Dike District #13, The Nature Conservancy, and the Washington State Department of Transportation (WSDOT), dedicated open space in the Rosario Terrace and Starbird Estates subdivisions, and private roads were categorized as common space. In Snohomish County, common space includes parcels owned by the State of Washington, dedicated open space in two rural cluster subdivisions, and a private road.

7.2.3 Undeveloped

There are 161 undeveloped parcels totaling approximately 1,310 acres in the Fisher Creek basin that were identified by reviewing a number of fields in the assessor parcel attribute data (Table 3, Figure 13).

In Skagit County, parcels with a null value (blank) in the "Year Built" field, and a 0 (zero) value in the "Building Value" were categorized as undeveloped. There were 91 parcels identified as undeveloped by this method. Nine additional parcels were also identified as undeveloped because these parcels have relatively low values in the "Building Value" field and no water source listed in the "Utilities" field, or are known agricultural properties. The assumption for these parcels is that there is likely a non-residential structure on the property, but a water source has not been developed. Therefore, in Skagit County, 100 parcels totaling approximately 811 acres were categorized as undeveloped.

In Snohomish County, parcels with a 0 (zero) value in the "MarketImprovValue" field were categorized as undeveloped. Additionally, six other parcels were categorized as undeveloped that had very low market improvement values ($3,500 - $12,200) and Zoning Code Descriptions that indicated non-residential land use (e.g., Non Residential Structure, Sr Cit Exemption Residual, Septic and Well). Two other parcels were also identified as undeveloped.

A review of the parcel data suggested that these two parcels were developed with agricultural structures only, and for the purposes of evaluating future residential development could be considered undeveloped. Therefore, in Snohomish County, 61 parcels totaling 499 acres were categorized as undeveloped.

7.2.4 Developed

The remaining 422 parcels (totaling approximately 3,026 acres) in the basin were categorized as developed (Table 3, Figure 13). This includes 257 parcels in Skagit County and 165 parcels in Snohomish County.

Ecology has identified which developed parcels are subject to the Skagit River Instream Flow Rule (WAC 173-503). These parcels were developed, as determined by Ecology (John Rose, Ecology, personal communication, e-mail dated January 31, 2014), under the "reservation system" that the state supreme court nullified in 2013. Essentially, the parcels that were developed under the "reservation system" are those which the water was put to beneficial use after April 14, 2001. In Snohomish County, Ecology determined 30 parcels were developed under the "reservation system." Ecology identified 34 such parcels in Skagit County.

7.3 Existing Dwellings

There are approximately 426 existing dwellings in the Fisher Creek basin as of 2013 (Table 4). We estimated the number of existing dwellings in Skagit County by assuming a single existing dwelling for each developed parcel. In Snohomish County, all developed parcels were also assumed to have a single dwelling with the exception of four parcels that the parcel attribute data indicated had more than one residence. The result is 257 existing dwellings in Skagit County and 169 existing dwellings (on 165 developed parcels) in Snohomish County.

7.4 Maximum Potential New Dwellings

We estimated that the maximum number of potential new dwellings in the Fisher Creek basin ranges from 395 to 698 (Table 4).

Table 4
Existing and Maximum Potential Dwellings

Fisher Creek Basin	Timber (1)	Common Space (2)	Undeveloped	Developed (3)	Total
Existing Dwellings	0	0	0	426	426
Maximum Potential New Dwellings					
Standard Development/Existing Zoning (4)	79	0	213	103	395
CaRD / RCS Development (5)	111	0	297	290	698

Notes

(1) Timber parcels include those in Skagit County with land use codes for Designated Timber (984), Classified Timber (831), and zoning codes in Snohomish County for DF Timber Acres Only (880), DF Timber Ac w/ImpAcBldg (881).

(2) Common Space parcels include publicly owned land (including Skagit County, Dike District #3, Dike District #13, The Nature Conservancy, WSDOT, State of Washington) and known open space, known open space in rural subdivisions, and private roads. No new dwellings were considered on these parcels.

(3) Includes 64 parcels developed after the Skagit River Instream Flow Rule (WAC 173-503-040) was established April 14, 2001.

(4) Development density consistent with standard development in Skagit County and existing zoning in Snohomish County.

(5) Development density consistent with CaRD development in Skagit County and Rural Cluster Subdivision (RCS) in Snohomish County.

The range represents the maximum allowable density for each undeveloped and developed parcel in the basin considering standard and cluster development. Both Skagit and Snohomish Counties allow for more dense development than standard zoning through the CaRD (Skagit County – Conservation and Reserve Developments) and RCS (Snohomish County – Rural Cluster Subdivision) processes. Potential new dwellings were assigned to both undeveloped and previously developed parcels until the maximum allowed density was achieved. With standard development, we estimated 103 potential new dwellings on developed parcels (e.g., through subdividing previously developed parcels), 213 potential new dwellings on undeveloped parcels, and 79 potential new dwellings on timber lands (Table 4). More dense development was also considered by assuming all parcels were developed through CaRD and RCS. Under this scenario we estimated 290 potential new dwellings on developed parcels, 297 potential new dwellings on undeveloped parcels, and 111 potential new dwellings on timber lands (Table 4).

In Skagit County, the existing zoning in the Fisher Creek basin consists of Rural Reserve (RRv), Secondary Forest (SF), Agriculture (A), and Industrial Forest (IF) zoning with a maximum density of 1 dwelling per 10, 20, 40, and 80 acres, respectively. With a CaRD development the maximum density allowed for RRv zoning is 1 dwelling per 5 acres.

In Snohomish County, the existing zoning in the Fisher Creek basin consists of Rural 5 Acre (R-5) and Forestry (F) with a maximum density of 1 dwelling per 5 acres, and 20 acres, respectively. With RCS development the maximum density allowed is approximately 1 dwelling per 3 acres, and 13 acres for R-5 and F zoning, respectively.

The estimated range for the new dwellings in Table 4 is considered the maximum potential for the basin. As noted above, the method assumed that all parcels could be subdivided to their maximum potential without regard to parcel-specific characteristics that may limit that potential. Limiting factors such as proximity to sensitive areas (e.g., steep slopes, wetlands, shorelines), existing infrastructure (wells, drainfields, roads, utilities), and existing dwellings were not considered when estimating the maximum potential new dwellings for the basin.

7.5 Projected Consumptive Water Demand

We estimated the projected consumptive water demand for 10-, 20-, 30-, 40-, and 50-year time frames in the basin (Table 5). The projected number of dwellings for each time frame was estimated assuming future development occurs in the basin at a rate similar to what occurred between 2001 and 2011. Between 2001 and 2011 in Skagit County, an average of approximately 2.0 percent per year of the available potential dwellings (e.g., undeveloped and developed parcels that could be subdivided according to the existing zoning, not including timber land) were developed. In Snohomish County, an average approximately 1.5 percent of the available potential dwellings were built per year.

It is important to project future development in the basin in a manner such as this rather than simply presenting the maximum potential dwellings available in the basin, many of which may never be built. A more realistic approximation of the number of homes and; therefore, future water demand, was achieved by looking at past development patterns in the basin.

Over a 50-year time span, we estimate approximately 171 dwellings potentially could be built in the basin. In the 2006 Amendment to the Instream Flow Rule, Ecology assumed that each residential use will not exceed 350 gallons per day. This assumption is consistent with a recent technical report by Golder Associates (2013) to Skagit County and Ecology. Assuming that each new water user will be limited to withdrawing 350 gallons per day (gpd) of water, approximately 33.5 acre-feet/year (af/y) (20.8 gallons per minute [gpm], 0.05 cfs) of consumptive water use is associated with those parcels, assuming 175 gpd consumptive water demand per dwelling (Table 5).

Table 5
Projected Consumptive Water Demand

Projected Future Development [1]	Number of Dwellings	Annual Consumptive Water Demand [2] (acre-feet)	Annual Consumptive Water Demand [2] (gallons per minute)	Annual Consumptive Water Demand [2] (cubic feet per second)
10-year	45	8.8	5.5	0.01
20-year	85	16.7	10.3	0.02
30-year	124	24.3	15.1	0.03
40-year	151	29.6	18.4	0.04
50-year	171	33.5	20.8	0.05

Notes

(1) Projected future need based on 2.0% of potential dwellings built per year in Skagit County and 1.5% of potential dwellings built per year in Snohomish County.

(2) Annual consumptive water demand was calculated based on a 350 gallons per day total demand with 50% return flow per dwelling.

The consumptive water demand associated with dwellings built since the Skagit River Instream Flow Rule was adopted is presented in Table 6. As determined by Ecology, there were 64 dwellings built after the rule was adopted on April 14, 2001. The annual consumptive water demand associated with these dwellings is approximately 12.6 af/y (7.8 gpm, 0.02 cfs).

Table 6
Consumptive Water Demand for Dwellings Built 2001-2013

Existing Development	Number of Dwellings	Annual Consumptive Water Demand [1] (acre-feet)	Annual Consumptive Water Demand [1] (gallons per minute)	Annual Consumptive Water Demand [1] (cubic feet per second)
Parcels Developed 2001 -2013	64	12.6	7.8	0.02

Notes

(1) Annual consumptive water demand was calculated based on a 350 gallons per day total demand with 50% return flow per dwelling.

7.6 Mitigation Water Quantity

The target mitigation water quantity associated with the projected future development and with dwellings built since the 2001 Skagit River Instream Flow Rule was adopted are the total annual consumptive water demand, as presented in Tables 5 and 6. The target annual mitigation quantities for the 50-year projected future development scenario and the dwellings built from 2001 – 2013 are 33.5 acre-feet and 12.6 acre-feet, respectively (Tables 5 and 6).

However, in accordance with the 2001 Skagit River Instream Flow Rule, all consumptive water right permits, including permit exempt wells (*Revised Code of Washington* [RCW] 90.44.050), that were put to beneficial use after April 14, 2001 must be fully mitigated only when the minimum instream flow in the mainstem Skagit River is not being met. As discussed in Section 5.1, the total number of days that the instream flow is not met can vary considerably year to year. Over the period of record for the Skagit River gauge near Mount Vernon (USGS #12200500) the 10-percent exceedance value is 164 days, meaning the total number of days in a year in which flow in the Skagit River is less than the minimum instream flow has only exceeded 164 days 10 percent of the time. The Skagit River has only been below the minimum instream flow level more than 164 days twice since 1952 (1993 and 2001).

The mitigation quantity based on the Skagit River instream flow was also calculated by assuming a consumptive water demand of 175 gpd per dwelling over a 164-day mitigation period. The mitigation quantity calculated this way for the projected future development and with dwellings built since the 2001 Skagit River Instream Flow Rule was adopted are presented in Tables 7 and 8, respectively.

Table 7
Projected Future Dwellings and Mitigation Water Demand for 164 days of Mitigation

Projected Future Development (1)	Number of Dwellings	Annual Mitigation Water Demand (2) (acre-feet)	Annual Mitigation Water Demand (2) (gallons per minute)	Annual Mitigation Water Demand (2) (cubic feet per second)
10-year	45	4.0	2.5	0.01
20-year	85	7.5	4.6	0.01
30-year	124	10.9	6.8	0.02
40-year	151	13.3	8.3	0.02
50-year	171	15.1	9.3	0.02

Notes
(1) Projected future need based on 2.0% of potential dwellings built per year in Skagit County and 1.5% of potential dwellings built per year in Snohomish County.
(2) Annual consumptive water demand was calculated based on a 350 gallons per day (gpd) total demand with 50% return flow per dwelling (175 gpd consumptive use) and 164 days per year of mitigation.

Table 8
Dwellings Built 2011-2013 and Mitigation Water Demand for 164 days of Mitigation

Existing Development	Number of Dwellings	Annual Consumptive Water Demand (1) (acre-feet)	Annual Consumptive Water Demand (1) (gallons per minute)	Annual Consumptive Water Demand (1) (cubic feet per second)
Parcels Developed 2001 - 2013	64	5.6	3.5	0.01

Notes
(1) Annual consumptive water demand was calculated based on a 350 gallons per day (gpd) total demand with 50% return flow per dwelling (175 gpd) and 164 days per year of mitigation.

8.0 GROUND WATER RECHARGE ASSESSMENT

8.1 General

The ground water recharge assessment includes a GIS-based approach to identify preliminary areas that might be suitable for a ground water recharge project (preliminary site assessment) and the identification and description of two potentially suitable projects areas.

8.2 Preliminary Site Suitability Assessment

A preliminary assessment of the suitability of particular areas in the Fisher Creek basin for the infiltration of surface water indicates a number of areas where infiltration may be feasible. Key factors for this assessment include the surficial geology and soils characteristics of the basin. Using GIS, we created an overlay showing where the surficial geology and soils data with high to moderate infiltration potential overlap to identify areas that may be conducive to infiltration. Figure 14 depicts an overlay of selected surficial geology units (outwash units **Qgom**$_e$, **Qgo**$_e$, **Qga**$_v$) and Group A and B soils.

The USGS (2009b) describes the **Qgom**$_e$ and **Qgo**$_e$ units as a recessional outwash aquifer with a thickness that ranges between 10 and 50 feet and is unconfined where it is not fully saturated or exposed at the ground surface (see Section 4.1). The infiltration potential of the **Qgom**$_e$ and **Qgo**$_e$ likely depends largely on the depth to ground water in a particular area, which can vary both spatially and seasonally. The NRCS soils data does provide some insight on depth to water. In fact, the primary distinguishing factor between Winston gravelly loam (Group B) and the Tokul gravelly loam (Group C) appears to be depth to ground water. Unfortunately, there are very few wells that are completed in the shallow unconfined aquifer that provide information regarding the depth to ground water and seasonal fluctuation. As such, the overlay of the NRCS soils data and the surficial geology likely provides the best information available to identify the areas of the basin with the greatest infiltration potential.

The sedimentary bedrock (**OEc**$_b$) is also present at or very near the ground surface throughout much of the western portion of the basin. Although the **OEc**$_b$ can be a productive aquifer and it is overlain by predominantly Group B soils in many portions of the basin, a ground water recharge project to infiltrate water into this unit was not considered a feasible opportunity to provide baseflow to streams in the Fisher Creek basin for the following reasons. Wells in the basin that are completed in the **OEc**$_b$ are generally completed in water-bearing zones at depths of 100 to 500 feet below the ground surface. This indicates that there is likely limited hydraulic continuity between the bedrock water-bearing zones and surface water bodies. Furthermore, the movement of water through a bedrock aquifer predominately occurs through fractures and fracture zones. Very little is known about the structure and extent of the fracture systems in the **OEc**$_b$. As such, it would be nearly impossible to predict with any certainty the timing, quantity, and location where a ground water recharge project would benefit a stream in the Fisher Creek basin.

8.3 Potential Project Areas

Two potential project areas were identified as the Starbird/Bulson and $324^{th}/44^{th}$ Areas (Figure 14). These areas were chosen due to the proximity of Groups A or B soils, glacial outwash geology and the surficial outwash aquifer in presumed hydraulic continuity with key reaches or tributaries of Fisher Creek, and potential land availability. Details of these areas are provided below. A summary of the two areas is presented in Table 9.

8.3.1 Starbird/Bulson Area

The Starbird/Bulson area is generally located just east of the intersection of Starbird Road and Bulson Road in Skagit County (Figure 14). The location to the south of Starbird Road includes a constructed pond that occupies an area of approximately ¾ acre. The pond appears to function much like a detention pond that stores runoff from the surrounding property and roadside ditches. The pond is part of a wetland complex mapped by the NWI (Figure 3) that also encompasses approximately 1,500 lineal feet of Starbird Creek. Discharge from the pond likely occurs as overland flow and/or shallow subsurface flow into the wetland complex and eventually Starbird Creek.

The pond is located in an area mapped as peat (**Qp** – Figure 6), which is generally a relatively thin deposit overlying glacial till (**Qgt**$_v$) and adjacent to glaciomarine outwash (**Qgom**$_e$). It is uncertain at this point how shallow ground water may interact between the **Qp** and **Qgom**$_e$ in the Starbird/Bulson area.

Another location of interest within the Starbird/Bulson area is located just north of Starbird Road. This area is also part of the peat (**Qp** – Figure 6) deposit that Starbird Creek bisects and includes a portion of the wetland complex mapped by the NWI. Although a surface water body is not mapped in this area, it is a large flat area that is frequently inundated by backwater from Starbird Creek due in some part to an obstructed/damaged culvert where the creek passes under Starbird Road.

The soils in both locations (Figure 5) include Mukilteo muck (Group B/D) and Tokul gravelly loam (Group C). The location to the south of Starbird Road also includes an area of Barneston very gravelly sandy loam (Group A). The source of water for a ground water recharge facility in these locations includes runoff from pasture areas, Starbird Road, and the existing roadside ditch network in the area. The location north of Starbird Road also has the potential to divert high flows directly from Starbird Creek.

Locations in the Starbird/Bulson area appear to be potential good sites for a ground water recharge project. Due to the locations' proximity to the NWI mapped wetland complex and Starbird Creek a potential project could include a constructed and/or expanded wetland that would be engineered to store peakflow during the winter and spring, and release flows into the shallow subsurface via native or engineered soils in hydraulic continuity with Starbird Creek, directly to the wetland areas adjacent to the creek, or directly into the creek to enhance instream flows. Further site-specific evaluation is necessary to fully evaluate the existing surface water – ground water interactions at each location.

8.3.2 324th/44th Area

The 324th/44th area is generally bound by the Skagit – Snohomish County line to the north, 324th Street NW to the south, 44th Avenue NW to the west, and English Grade Road to the east (Figure 13). This area is largely mapped as glaciomarine outwash (**Qgom**$_e$), and glaciomarine drift (**Qgdm**$_e$ - Figure 6). The surficial outwash aquifer is likely present in the outwash (**Qgom**$_e$) and in hydraulic continuity with Fisher Creek and/or an unnamed tributary to Starbird. Soils in the area (Figure 5) consist primarily of Tokul gravelly loam (Group C) and Winston gravelly loam (Group B) with lesser areas of Bellingham silty clay (Group C/D), Terric medisaprists (Group C), and Puget silty clay loam (Group C). The area also includes two wetlands mapped by the NWI (Figure 3).

The source of water for a ground water recharge facility in this area includes runoff from the property, English Grade Road, 324th Street NW, and the existing roadside ditch network. A ground water recharge facility in this area would likely involve some component of surface storage (e.g., detention pond, or engineered wetland) that would discharge to the surficial alluvial aquifer in hydraulic continuity with Fisher Creek or tributary via infiltration in the Group B soils. Another option may be to convey outflow from the facility to a wetland in hydraulic continuity with the creek, or directly to the creek as surface discharge. The project may be able to incorporate a small existing pond in a pasture on one of the parcels in the area. Further site-specific evaluation is necessary to fully evaluate the existing surface water – ground water interactions at each location.

Table 9
Summary Details for Potential Project Areas

Project Area	**Starbird/Bulson**	**Starbird/Bulson**	**324th/44th**
Location	**South of Starbird**	**North of Starbird**	
Site Features	Large flat pasture with existing ¾-acre pond, adjacent to Starbird Creek, NWI mapped wetlands present.	Large flat pasture, adjacent to Starbird Creek, NWI mapped wetlands present.	Large flat pasture at toe of slope to bedrock hills to east, near Starbird Creek tributary, and unnamed/unmapped tributary to Fisher Creek, existing small pond.
Site Geology	Peat (Qp), Till (Qgt_v), Outwash ($Qgom_e$)	Peat (Qp), Outwash ($Qgom_e$)	Glaciomarine Drift ($Qgdm_e$), Outwash ($Qgom_e$)
Site Soils	Mukilteo muck (B/D), Tokul gravelly loam (C), Barneston very gravelly sandy loam (A).	Mukilteo muck (B/D), Tokul gravelly loam (C)	Bellingham silty clay (C/D), Terric Medisaprists (C), Tokul gravelly loam (C), Winston gravelly loam (B), Puget silty clay loam (C).
Potential Water Source	Runoff from property, road runoff from Starbird Road, existing ditch network.	Runoff from property, road runoff from Starbird Road, existing ditch network, high-flow diversion from Starbird Creek.	Runoff from property road runoff from English Grade Road and/or 32th Street, existing ditch network.
Infiltration Potential	High in A soils, Low in B/D and C Soils.	Low	Moderate in B soils, Low in B/D and C Soils.
Storage Options	Use and/or expand existing pond, construct new pond or wetland.	Construct new pond or wetland.	Use and/or expand existing pond, construct new pond or wetland.
Discharge	Directly to Starbird Creek, Infiltration to native soils, Infiltration to engineered soils.	Directly to Starbird Creek, Directly to wetland complex, Infiltration to native soils, Infiltration to engineered soils.	Directly to Starbird Creek tributary, Directly to Fisher Creek tributary, Directly to wetland, Infiltration to native soils.
Benefitted Reach	Lower reach of Starbird Creek, Fisher Creek from mouth to confluence with Starbird Creek. Approximately 3.5 total miles of stream.	Lower reach of Starbird Creek, Fisher Creek from mouth to confluence with Starbird Creek. Approximately 4 total miles of stream.	TBD. Approximately 3.0 miles of Fisher Creek from mouth to confluence with Starbird Creek. A potential to benefit approximately 1 additional mile of stream (Fisher Cr. or Starbird tributary).
Other Considerations	Existing pond depth currently unknown	Potentially integrate project with fish passage/drainage issues related to obstructed/damaged culvert at Starbird Road	May need to engage with multiple landowners to coordinate discharge pathway

9.0 FUTURE WORK

9.1 Pilot Project Preliminary Conceptual Design

Task 2 of our work includes preparing a preliminary/conceptual design and cost estimate for a pilot project that will be appropriately sized to provide mitigation for new ground water use in the Fisher Creek basin and potentially for streamflow enhancement. The preliminary/ conceptual design will be based on site-specific data that will be collected once landowner permission to access the potential project areas is secured. Field work is expected to include soil borings and/or test pits to evaluate site-specific near-surface and subsurface conditions at the pilot project site and infiltration tests in selected locations to estimate the infiltration potential on-site. The conceptual design will include details related to the storage and infiltration of peak flow in the winter and spring to deliver flow to the stream during the summer in fall.

9.1.1 Storage

The storage parameters for the pilot project will be outlined conceptually in Task 2. Potential storage options include surface storage (e.g., pond, constructed wetland) as well as ground water storage through infiltration. Surface storage options may include using, redeveloping, or expanding existing ponds or wetlands depending on the specific site characteristics. We anticipate that the storage parameters for the pilot project will incorporate recommendations in the Stormwater Manual (Ecology, 2012a) for water quality treatment BMPs to maintain or improve the quality of water stored for release to the stream.

9.1.2 Infiltration

Infiltration will likely be a component of the pilot project. We anticipate that if water is stored in a surface storage facility, the outflow will be infiltrated into either native soils/surficial geologic unit, or an imported soil if no suitable native soils are available in the pilot project location. Infiltration would likely occur a short distance from the stream channel, in an area of high hydraulic continuity between the stream and the soil/surficial geologic unit. The purpose of infiltration would be to provide an additional water quality benefit prior to the water entering the steam. The process of infiltration and migration of water to the stream via shallow subsurface flow will improve water quality by removing pollutants and moderating water temperature. The conceptual details of these processes will be outlined in Task 2.

9.2 Streamflow Enhancement and Habitat Recovery Opportunities

The Tribe has recognized the potential to support instream flow enhancement through this project in addition to meeting future mitigation needs. As discussed in Section 7.7, the future mitigation need in the Fisher Creek basin ranges from approximately 4 to 15 acre-feet of water over a 164-day mitigation time frame for the 10-year and 50-year development period, respectively (Table 7). The Tribe is interested in evaluating opportunities for streamflow enhancement as a component to the pilot project. In other words, could the size and scope of the project easily and efficiently be scaled to provide additional water storage that can be released to enhance streamflow during the low-flow period? Can other potential project sites be developed efficiently to provide additional storage for streamflow enhancement? These questions will be evaluated during Task 2.

The Tribe also recognizes that mitigation and streamflow enhancement are important components to an integrative, pertinent and holistic approach to the habitat recovery efforts in the watershed. The Tribe intends to foster habitat recovery efforts through the partners of the interagency review team (IRT) for this project, other local entities, and private interests. Habitat recovery is expected to address prioritization of culvert passage impairments and/or barriers for reconstruction, as well as riparian stream and wetland habitat restoration.

9.3 Additional Data

In addition to the site-specific data that will be collected during Task 2 (Section 9.1), we anticipate compiling additional data and relevant information for the project area as this project evolves. We are currently compiling stream and air temperature data from Ecology, and anticipate generating continuous streamflow records for the Ecology stream gauging stations once rating curves are developed for the site. These data may be incorporated into future drafts of this report. We also anticipate the IRT participants may have additional data or information that may be included in future drafts.

Additionally, the Tribe is requesting Ecology to support development of a stormwater runoff model for the Fisher Creek basin to better understand the contribution of runoff from an altered land cover assessment. The effort would utilize the Western Washington Hydrology Model (WWHM) to simulate runoff under historic forested watershed conditions, current conditions, and project future runoff from increased development. This data will improve mitigation and streamflow enhancement planning.

LIMITATIONS

We have prepared this report for the Upper Skagit Indian Tribe for the Skagit River Basin Recharge Mitigation Program. The information presented in the report is based on the above-described research and limited reconnaissance. Associated Earth Sciences, Inc. (AESI) has relied upon information provided by others in the description of the relevant geologic/hydrogeologic conditions.

Within the limitations of scope, schedule, and budget, AESI attempted to execute these services in accordance with generally accepted professional principles in the fields of geology and hydrogeology at the time this report was prepared. No warranty, express or implied, is made.

We appreciate the opportunity to be of service to the Tribe on this interesting project. If you should have any questions or require further assistance, please do not hesitate to call.

Sincerely,
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