Skagit River Basin Ground Water Mitigation Program

TECHNICAL REPORT – PRELIMINARY DRAFT
PILOT PROJECT CONCEPTUAL DESIGN
FISHER CREEK BASIN

Skagit County, Washington

Prepared for

Upper Skagit Indian Tribe

Project No. EH130580A
June 18, 2014

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Prepared for:
Upper Skagit Indian Tribe
25944 Community Plaza Way
Sedro-Woolley, Washington 98284

Prepared by:
Associated Earth Sciences, Inc.
2911 ½ Hewitt Avenue, Suite 2
Everett, Washington 98201
425-259-0522
Fax: 425-252-3408

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1.0 INTRODUCTION

1.1 Purpose

This report presents the results of Associated Earth Sciences, Inc.'s (AESI's) preliminary conceptual design of a ground water recharge project in the Fisher Creek Basin. The purpose of the project is to mitigate for rural residential water use and enhance instream flow in Fisher Creek. 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 pilot a demonstration streamflow enhancement/ ground water mitigation program (Program) to address streamflow-related impacts of residential development in the Fisher Creek basin. The Program 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 prepare a preliminary conceptual design for a ground water recharge project that would capture and store runoff in the project area during high-flow periods and infiltrate the water adjacent to the stream to augment streamflow during the low-flow period. Our study is separated into two primary tasks: 1) Ground Water Recharge Suitability Assessment, and 2) Pilot Project Preliminary Conceptual Design and Cost Estimate.

The results of Task 1 were presented in a draft technical report "Ground Water Recharge Suitability Assessment – Fisher Creek Basin" prepared by AESI and dated March 12, 2014. This report presents the results of Task 2 – Pilot Project Conceptual Design and Cost Estimate. The following sections of this report include a description of: 1) the project background, 2) field investigations, 3) surface water – ground water system, 4) conceptual design, 5) cost estimate, 6) uncertainties, and 7) preliminary monitoring and maintenance requirements.

1.2 Project Background

On April 14, 2001, the Washington State Department of Ecology (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

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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 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 Project Sites

Two potential project areas were identified during the suitability assessment (Task 1, AESI 2014). The approximate locations of the identified areas are shown on Figure 2. The Starbird/Bulson area is generally located just east of the intersection of Starbird Road and Bulson Road in Skagit County (Figure 2). 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 2). A conceptual design was only developed for two potential sites (Site 1 and Site 2) in the Starbird/Bulson area at this time, because access to a perennial reach or tributary to Fisher Creek required additional landowner outreach. Further evaluation of a project site (Site 3) in the 324th/44th area may now be considered based on a potential access point to Fisher Creek.

1.3.1 Starbird/Bulson Area

A majority of the Starbird/Bulson area is mapped as a peat (**Qp**) deposit that is bisected by Starbird Creek, as shown on the "Geologic Map," Figure 3 (Dragovich et al., 2002). The northern portion of the area also includes alluvial fan deposits (**Qa$_f$**) and glaciomarine outwash (**Qgom$_e$**).

Dragovich et al. (2002) indicated that the **Qp** deposits in this area consist 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. The peat deposits are identified as the Milltown Peat Area in the *Peat Resources of Washington* (Rigg, 1958) and were described as brown to dark brown fibrous and woody peat to a depth of approximately 10 feet below ground surface (bgs). All depths referenced in this report are relative to ground surface (bgs) unless otherwise noted. Beneath the woody peat is generally an olive sedimentary peat to a depth of roughly 20 feet (Rigg, 1958). The peat deposit is reported to be underlain by blue, soft clay, sand, and gravel (Rigg, 1958).

The alluvial fan deposits generally consist of poorly sorted clays, silty sandy gravel and gravelly sandy silt of debris-flow origin (Dragovich et al., 2002). Alluvial fan deposits are generally

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considered geologically hazardous areas, not because of the alluvial fan itself, but due to the likelihood of the geologic event that created the fan to re-occur (Skagit County, 2006). The **$Qgom_e$** typically consists of loose sand, gravel, and silt, with occasional silt beds and is often interlayered with the Everson glaciomarine drift **($Qgmd_e$)** in most of the Fisher Creek basin indicating submarine deposition (Dragovich et al., 2002).

The surface soils in the Starbird/Bulson area are generally mapped as Mukilteo muck, Tokul gravelly loam, and Barneston very gravelly sandy loam (Natural Resources Conservation Service [NRCS], 1989), as shown on the "Soils Map," Figure 4. The Mukilteo muck is the NRCS soil map unit for the peat in the area. The NRCS (1989) describe the Mukilteo muck as very deep very poorly drained soils in flat depressional areas. The seasonal high water table is at or above the ground surface from October to May (NRCS, 1989).

The Tokul gravelly loam is a moderately deep, moderately well-drained soil on glacially modified hills. 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, 1989). 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.

The Starbird/Bulson area includes a portion of the wetland complex mapped by the National Wetlands Inventory (NWI). Although a surface water body is not mapped in this area, it is a large flat area that has been frequently inundated by backwater from Starbird Creek due in some part to an obstructed/damaged culvert where the creek passes under Starbird Road and beaver dam activity in the area.

Two potential project sites were identified in the Starbird/Bulson area (Site 1 and Site 2, Figure 2). We were able to obtain landowner permission to access the properties and collect site-specific information necessary for developing a conceptual design for a project. Site 1 consists of approximately 25 acres of a 40-acre parcel located northeast of the intersection of Starbird Road and Bulson Road (Figure 2). The property is zoned Rural Reserve (SCC 14.16.320). The 25-acre project site is currently used for cattle grazing. Site 2 consists of east and west locations totaling approximately 13 acres located at the end of Rose Road (Figure 2). The site is zoned Rural Reserve (SCC 14.16.320).

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2.0 FIELD INVESTIGATIONS

2.1 General

AESI conducted several types of field activities at the project sites for this study. The purpose of the field investigations was to collect the baseline information necessary to develop a conceptual model of the surface water and ground water system at the project sites to support the conceptual design of the pilot project. The field investigations included: 1) completing six hand-augered soil borings, 2) installing five drive-point piezometers and staff gages, 3) conducting falling head slug tests on three of the piezometers, 4) performing routine water level monitoring, and 5) collecting soil samples for porosity testing. AESI also subcontracted with Herrera Environmental Consultants, Inc. (Herrera) to assess the project sites' hydrology, soils, and vegetation and Philip Duoos to conduct a geophysical survey of the subsurface conditions of the project sites. The field investigation activities described in this report were performed in April and May 2014.

Photo 1. Hand Auger Soil Boring Method

2.2 Soil Borings

Subsurface geologic/soil conditions at Sites 1 and 2 were observed by completing six shallow hand-augered soil borings (Photos 1 and 2). The locations of the borings are presented on Figure 5.

The soil borings were completed by experienced, licensed geologists from AESI, and interpretive logs of the subsurface conditions encountered at each boring is included in Appendix A. Descriptions contained in the exploration logs are based on visual classification of the soils encountered. The depths indicated on the logs where conditions changed represent gradational variations between soil types in the field. Representative soil samples were collected

Photo 2. Hand Auger with Peat Sample

from the explorations, placed in sealed plastic bags and returned to our office for further visual evaluation. Soil conditions encountered in each boring are briefly described below.

- HB-1 was completed to a depth of 6 feet and encountered very soft, wet, dark brown peat (**Qp**) with layers of soft clayey silt, and sandy which are interpreted as interfingered layers of alluvial fan deposits (**Qa_f**) in the peat. Ground water was observed at a depth of approximately 1 foot.

- HB-2 was completed to a depth of 8 feet and encountered soft, wet, dark brown peat (**Qp**).

- HB-3 was completed at a depth of 4 feet when the hand auger refused to advance past what appeared to be a buried wood obstruction. The boring encountered topsoil to a depth of 0.5 feet, followed by 3 feet of medium stiff, brown-grey, sandy silt, which was interpreted as alluvial fan deposits (**Qaf**). The alluvial fan deposits were underlain by peat (**Qp**).

- HB-4 was completed to a depth of 3 feet when the hand auger refused to advance past a wood obstruction. The boring encountered topsoil to a depth of 0.5 feet, followed by 2 feet of medium stiff to stiff, brown-grey, sandy silt and clayey silt, which was interpreted as alluvial fan deposits (**Qaf**). The alluvial fan deposits were underlain by peat (**Qp**).

- HB-5 was completed to a depth of 3 feet when the hand auger refused to advance past a large gravel or cobble obstruction. The boring encountered topsoil to a depth of 0.25 feet, followed by 2.75 feet of medium dense, gravelly, very silty sand and sandy silt, which was interpreted as glaciomarine outwash (**$Qgom_e$**). Ground water was observed at a depth of 2 feet.

- HB-6 was completed to a depth of 7 feet and encountered very soft, wet, dark brown peat (**Qp**).

2.3 Piezometers

Ground water conditions in the peat at Sites 1 and 2 were investigated by installing five shallow drive-point piezometers at the approximate locations shown on Figure 5. Piezometers P-1 and P-2 consisted of 3 feet of 1.25-inch-diameter stainless steel Johnson 10-slot screens and 5 feet of 1.5-inch-diameter galvanized steel risers driven into the peat using a slide hammer. All threaded couplers were prepared with teflon tape. The screen interval on P-1 and P-2 was installed from approximately 3.2 to 6.2 feet, and approximately 1.7 feet of riser pipe remained above ground surface.

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Photo 3. Watersource Well Point and Riser

Piezometers P-3, P-4, and P-5 were constructed from 3-foot-long, 1.25-inch-diameter Watersource well points and 5 feet of 1.5-inch-diameter galvanized steel risers (Photos 3 and 4). All threaded couplers were prepared with teflon tape. The screen intervals on P-3, P-4, and P-5 were installed between approximately 3.6 to 6.2 feet. The top of casing elevations for each piezometer were surveyed to the nearest 0.01 foot by Pacific Surveying and Engineering. Well completion details for the piezometers are included in Appendix A.

Each piezometer was developed to remove fine-grained material from inside the screened interval resulting in improved conductivity between the piezometer well screen and the surrounding native soil. A 1-inch-diameter foot valve with check ball attached to $^{5}/_{8}$-inch-diameter high-density polyethylene tubing was used to gently surge and remove water from each piezometer. After the initial formation water was removed, tap water was added to each piezometer to further aid in development, until visible turbidity had significantly diminished.

Photo 4. Piezometer P-5

2.3.1 Slug Tests

Horizontal hydraulic conductivity for the peat was estimated by conducting falling head slug tests in piezometers P-1, P-2, and P-3. A slug test is a common alternative to an aquifer test (e.g., pumping test) to test the hydraulic conductivity of low-permeability materials (Fetter, 1994). Initially our field program called for conducting a small aquifer test. However, once we observed the fine-grained nature of the peat and how slowly water moved back into a small dug hole, we chose to conduct slug tests instead.

A falling head slug test involves a short-term introduction of water via a well or boring into a subsurface interval of sediment (Campbell et al., 1990). Monitoring the fall of water in the well/boring as it returns to quasi-equilibrium conditions produces the data on the basis of which

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numerous researchers have developed methods to determine hydraulic conductivity (Campbell et al., 1990).

Falling head slug tests were performed by adding tap water to each of the subject piezometers until they were filled completely to the top of the casing. Water level fall was monitored every 5 seconds via downhole pressure transducers installed in each piezometer. The first falling head tests were monitored for approximately 6 hours as water levels fell back to the static level. A second slug of water was then introduced and monitored for approximately 22 hours. Data from the second slug test at each piezometer were imported into the AQTESOLV software for analysis.

The results of the slug test analysis indicated that the horizontal hydraulic conductivity of the peat in the immediate locations of P-1, P-2, and P-3 is approximately 0.02, 0.03, and 0.1 feet per day (ft/d), respectively. The slug test analysis data sheets from AQTESOLV are provided in Appendix B.

2.4 Staff Gages

Staff gages were installed in Starbird Creek at five locations between the two project sites (Figure 5) for the purpose of monitoring surface water elevations (Photo 5). Staff gages are used for a quick visual indication of the surface water level in a stream or other open body of water. The staff gages consisted of a 3.33-foot-long section of porcelain enameled iron graduated gage fixed to an approximate 6-foot-long section of 2-inch angle iron driven into the stream bed. Each staff gage section is marked from 3.33 to 6.66 feet. The water level of the stream is read directly from the 0.01-foot graduation marks on the staff gage. The top of each staff gage (i.e., the 6.66-foot mark) was surveyed to the nearest 0.01 foot by Pacific Surveying and Engineering.

Photo 5. Staff Gage SG-1

2.5 Water Level Monitoring

Water levels in each piezometer were measured using a downhole water level indicator that consists of a $^{3}/_{8}$-inch-wide plastic-coated steel tape marked to the nearest 0.01 foot that gives an audible signal when it touches the top of the water level. The depth to water is measured to the nearest 0.01 foot from the top of the piezometer casing. The ground water elevation in the piezometer is calculated by subtracting the measured depth-to-water from the surveyed top of casing elevation.

Surface water levels at each staff gage are read directly from the staff gage. The surface water elevation is calculated by subtracting 6.66 feet from the surveyed top of each staff gage to

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determine the elevation of the staff gage at the 0.00-foot mark, and adding the surface water level to that elevation.

Water level elevations at piezometers P-1 through P-5 and staff gages SG-1 through SG-5 have been monitored periodically since they were installed. Water level elevations on a given day can be used to determine flow direction and gradient, and how ground water and surface water might be interacting in the system at a particular snapshot in time. Seasonal or long-term water level monitoring can indicate how the flow direction and gradient may change over time, and how much seasonal fluctuation in water levels occurs. Ground water level data collected to date is presented in Table 1. Surface water elevation data collected to date is presented in Table 2.

Table 1
Ground Water Level Elevations

	P-1		**P-2**		**P-3**		**P-4**		**P-5**	
Top of Casing Elevation	336.22		335.77		335.76		337.41		337.49	
Ground Surface Elevation	334.5		334		334		335.5		335.8	
Date	**DTW**	**Elev**	**DTW**	**Elev**	**DTW**	**Elev**	**DTW**	**Elev**	**DTW**	**Elev**
4/9/2014	2.38	333.84	1.83	333.94	1.85	333.91				
4/29/2014	2.64	333.58	1.93	333.84	1.91	333.85	2.69	334.72	2.38	335.11
5/6/2014	2.44	333.78	1.87	333.90	1.82	333.94	2.10	335.31	2.32	335.17
5/13/2014	2.41	333.81	1.95	333.82	1.82	333.94	2.46	334.95	2.29	335.20
6/3/2014	3.43	332.79	2.56	333.21	2.60	333.16	3.06	334.35	2.80	334.69

Notes:

All elevations in feet relative to NVGD 88.

DTW: Measured depth to water below top of casing elevation.

Elev: Water level elevation calculated by the top of casing elevation minus measured depth to water.

Data logger/pressure transducers were also installed in piezometers P-1, P-2, P-4, and P-5 and at staff gage SG-1 to record water levels at 15-minute intervals. These data can be used to demonstrate how quickly the ground water system responds to recharge via precipitation inputs. Water level data obtained from the pressure transducers collected to date is presented in Figure 6.

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Table 2
Surface Water Level Elevations

	SG-1		SG-2		SG-3		SG-4		SG-5	
Stage 0.00 feet Elevation	326.91		328.39		329.65		329.50		339.04	
Minimum Stream Depth Elevation	330		331		332.9		333		NA	
Date	**SG Level**	**Elev**	**SG Level**	**Elev**	**SG Level**	**Elev**	**SG Level**	**Elev**	**Tape Down**	**Elev**
4/9/2014										
4/29/2014	5.11	332.02	5.34	333.73	4.56	334.21	5.43	334.93		
5/6/2014	5.34	332.25	5.48	333.87	4.74	334.39	5.54	335.04	1.87	337.17
5/13/2014	5.40	332.31	5.71	334.10	4.82	334.47	5.50	335.00		
6/3/2014	4.54	331.45	4.66	333.05	4.24	333.89	5.07	334.57	2.10	336.94

Notes:

All elevations in feet relative to NVGD 88.

SG Level: Reading of water level on staff gage.

Elev: Water level elevation calculated by adding the SG level to the stage 0.00 elevation.
SG-5 is a temporary stake installed in the existing pond on Site 2. The water level elevation is determined by measuring down from the top of the staff gage elevation (339.04).

2.6 Geophysical Investigation

A geophysical investigation of the peat at the two project sites was conducted by Philip Duoos, Geophysical Consultant, on April 29 and May 2, 2014 (Photos 6 and 7). A brief summary of the methods and results of the investigation is provided here. The full report is included as Appendix C of this report. The purpose of the geophysical investigation was to estimate the thickness of the peat (**Qp**) (e.g., depth to underlying material). The underlying material is presumed to be Vashon till (**Qgt_v**) or possibly Everson glaciomarine drift (**$Qgmd_e$**) based on the geologic interpretation of the subsurface conditions from water well reports for nearby wells (Ecology, 2014), work by the United States Geological Society (USGS; 2009, 2011), and the numerical and information in Rigg (1958).

Seismic surveys were performed along four profile lines on Site 1 that included measurements of the shear wave (s-wave) velocities using the multichannel analysis of surface waves (MASW) and the compressional wave (p-wave) velocities by using the refraction method. A ground penetrating radar (GPR) survey line was also performed in a profile line perpendicular to the seismic survey lines. A similar survey was also performed at Site 2 along one profile line for the seismic surveys and a perpendicular GPR profile line.

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Figure 6
Water Level Hydrographs

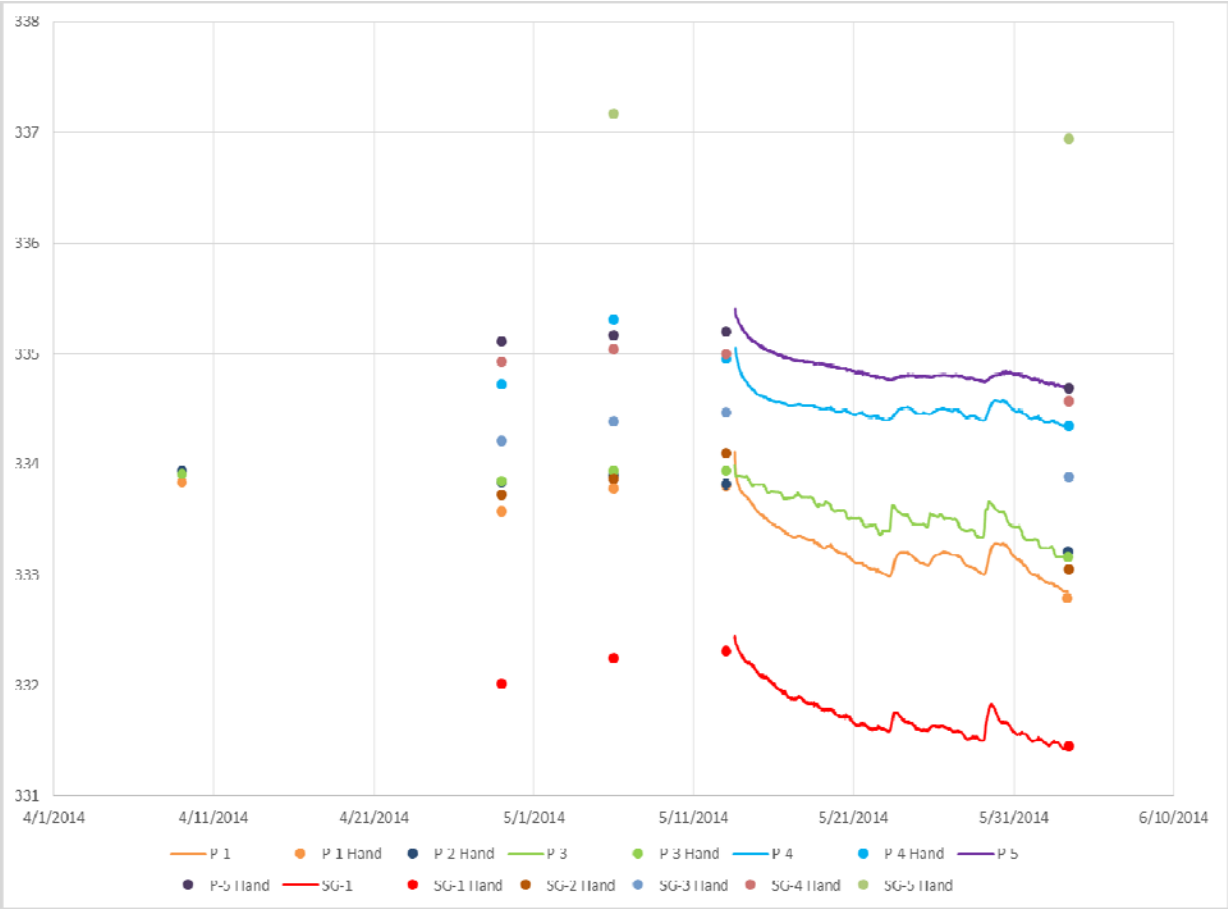

Photo 6. Slide hammer used for seismic surveys

Photo 7. Data acquisition from seismic surveys

In general, thickness of the peat (**Qp**) beneath Site 1 varied in depth from approximately 5 feet to 30 feet. The geophysical explorations indicate that the **Qp** thickens from west to east across Site 1, which was consistent with previous investigations and interpretations of the area. The geophysical survey on Site 2 was conducted near the edge of the mapped extent of the Qp (Figure 3), and near hand-boring HB-1 which encountered interlayered peat (**Qp**) and alluvial fan (**Qaf**) deposits at relatively shallow depths. The geophysical explorations indicated that the thickness of the **Qp** at the edge of the peat deposit on Site 2 was on the order of 3 to 5 feet.

2.7 Vegetation Assessment

A preliminary assessment of existing conditions focusing on the hydrology, soils, and vegetation currently present at the potential project sites was completed by Herrera in May 2014.

Herrera noted peat soils that were saturated near the ground surface in three hand-dug soil pits on Site 1. Herrera noted that the peat had a "greasy" feel, and was highly decomposed with little recognizable organic matter. The ground surface of the peat deposit was hummocky with relatively drier conditions interspersed with visibly wetter areas. These observations were consistent with those observed by AESI during the completion of hand borings at Site 1. Vegetation on Site 1 was observed to contain three dominant species including reed canarygrass (*Phalaris arundinacea*), common rush (*Juncus effuses*) and buttercup (*Ranunculus repens*). Reed canarygrass is considered a non-native, invasive freshwater plant that poses a major threat to ecosystems by limiting plant species diversity.

Herrera also noted peat and mineral soils were present at Site 2, consistent with observations by AESI in hand-borings HB-1, HB-2, HB-3, HB-4, and HB-5. The east portion of Site 2 consists of an open field with reed canarygrass and skunk cabbage (*Lysichiton americanum*) that transitions to a more diverse forested setting with shrub understory to the south of the existing pond. The west site consists of a forested vegetation community with a shrub understory.

2.8 Peat Porosity and Effective Porosity

Porosity is a measure of the ratio of void space to the total volume in a soil medium that can be occupied by either air, water, or both. The porosity of the peat at the project sites is an important factor in determining the volume of ground water that can be stored in the pore spaces of the peat. The total porosity can be determined in a laboratory by determining the total volume of solids (organic material and mineral soil in the peat) in a known volume of soil.

Effective porosity is generally considered the porosity that is available for fluid flow and can be an important factor in how water moves though a soil. The best estimate for effective porosity of peat soils can be determined in a laboratory by testing the volume of water that drains vertically from a saturated known volume of soil in a specified time. The methodology is to determine "air-filled-porosity" described in Byrne and Carty (1968) as a robust laboratory method for the determination of the drainage properties of peat substrates. The method involves fully saturating

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the peat core and determining the volume of water that drains from the core until the rate of draining becomes nearly zero..

Two samples of the **Qp** were collected from Site 1 (ST-1 and ST-2, Figure 5) for laboratory analysis on June 3, 2014 by AESI. Each sample consisted of collecting three soil cores in 3-inch-diameter, 30-inch thin-walled steel Shelby tube soil samplers by gently pressing them into the peat. The soil level inside and outside the samplers was measured periodically to check if the soil was being compressed during sampling. Sample ST-1 was collected from a depth of approximately 1.5 to 3 feet. Sample ST-2 was collected from a depth of approximately 1 to 2.5 feet.

The samplers were removed from the surrounding soil by digging around them to carefully collect the sampler without losing any soil from the bottom of the sampler. The void space above the soil sample was loosely packed with paper towels. The samplers were capped with plastic caps, sealed with duct tape, and transported to AESI's laboratory in Kirkland in an upright position for analysis.

Preliminary results for the total porosity and effective porosity of each sample are presented in Table 3.

Table 3
Laboratory Results for the Porosity of Peat

Sample	Total Porosity	Effective Porosity
ST-1	--	5%
ST-2	33%	6%

3.0 SURFACE WATER – GROUND WATER SYSTEM

3.1 Surface Water System

The surface water system of the project areas is also presented on Figure 7. Starbird Creek generally flows from north to south along the eastern edge of the potential project areas. During the field investigations we mapped other surface water drainage features in the area as shown on Figure 7. Surface water elevation data are presented in Table 2.

Based on surface water elevation data collected May 6, 2014, there was 2.79 feet of hydraulic potential (difference in water level elevations) in the surface water flow system between Site 2 (SG-4: 335.05 feet) and Site 1 (SG-1: 332.25 feet). There was also 1.62 feet of hydraulic potential between SG-2 at the northeast corner of the Site 1 to SG-1. On June 3, 2014, the hydraulic potential between SG-2 and SG-1 (1.60 feet) was similar to what was observed on May 6.

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The surface water elevation of an existing pond on Site 2 (SG-5) was measured as 337.17 feet on May 6, 2014 (Figure 7).

3.2 Ground Water Flow System

Elevation data for the ground water within the peat at the potential project areas is presented on Figure 7. The ground water monitoring data collected to date indicate that the shallow ground water flow direction is generally from north to south from Site 2 to Site 1. Water level data collected to date is presented in Table 1. During our field activities, the ground water table within the peat has generally been present just below the ground surface (~0.1 to 1 foot).

Water level data from May 6, 2014 indicates that the ground water elevation on Site 2 (335 feet) is approximately 1 foot higher than the elevation on Site 1 located approximately 1,000 feet to the south, which results in a very slight overall ground water gradient (slope) of approximately 0.001 (5 feet per mile). Water level data from June 3, 2014 indicate about a 1.5-foot difference in ground water elevation from Site 2 to Site 1, which indicates a hydraulic gradient of approximately 0.0015.

3.2.1 Ground Water Flow Velocity

Given the relatively flat overall ground water gradient and the very low hydraulic conductivity values estimated from the slug tests, ground water flow velocities in the peat are expected to be very low. The average linear velocity of ground water is determined by dividing the Darcy's Law velocity (Darcy flux) by the effective porosity of the peat by the following equation:

$$\mathbf{V = K*I/n_e}$$

Where: V= ground water velocity in ft/d
K = hydraulic conductivity in ft/d (0.1)
I = hydraulic gradient, dimensionless (0.0015)
n_e = effective porosity, dimensionless (0.06)

Based on these variables the overall ground water velocity within the peat is on the order of 0.0025 ft/d.

3.2.2 Ground Water Discharge to Surface Water

The stream and drainage ditches located on the sites offer potential locations for ground water discharge to surface water. On Site 2, the water level monitoring data indicate the near-creek hydraulic gradient significantly increases to approximately 0.02. Assuming a near-stream K of 0.1 ft/d, the local ground water flow velocity to the ditch on Site 2 is estimated at approximately 0.03 ft/d. A ground water discharge rate of approximately 132 cubic feet per day (ft^3/d) or 0.002

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cubic feet per second (cfs) to the ditch on Site 2 has been calculated by considering the length (approximately 2,000 feet) and depth (approximately 2 feet) of the ditch.

The same calculations have been completed for the ditch located on the southern portion of Site 1. Assuming an overall ground water gradient of 0.006 for the area immediately adjacent to the ditch, and a hydraulic conductivity value of 0.1 ft/d, the ground water flow velocity would be approximately 0.01 ft/d. Therefore, the ground water discharge to the ditch along Starbird Road (2,000 feet long and 2.5 feet deep) would be approximately 48 ft^3/d or 0.0005 cfs.

3.3 Site 1 Water Balance

A monthly water balance for the 25-acre pasture that is the potential project area on Site 1 was calculated in order to further understand the interactions between the surface water and ground water system. A water balance is generally calculated as the system water inputs are equal to the water outputs and the positive/negative change in ground water storage. Generally a water balance will calculate to approximately zero on an annual basis. The water balance can be positive or negative on a monthly basis with changes in ground water storage as ground water levels increase in the winter and decrease in the summer. The water balance is presented in Table 4. Note that the water balance calculations are presented as November – October. The water balance components for Site 1 are described below.

3.3.1 Water Balance Input

Precipitation

The average annual precipitation input is assumed to be 44.1 inches, which equals 91.9 acre-feet (ac-ft) over the 25-acre project area. The precipitation values were based on the 1981 - 2010 averages from the Parameter-Elevation Relationships on Independent Slopes Model (PRISM; Daly et al., 1994) for the site.

Runoff

The project area receives approximately 7.3 ac-ft per year (af/y) of surface water runoff as input from an approximately 4.4-acre area located immediately to the west of the pasture. The runoff volumes from this area were estimated using the Western Washington Hydrology Model (WWHM). WWHM is a continuous simulation hydrology model that utilizes the Environmental Protection Agency (EPA) Hydrologic Simulation Program-Fortran (HSPF) as the computational engine. WWHM is an HSPF-based modeling software package with regionally specific HSPF parameters that have been calibrated for the soils, surficial geology, and land covers typical of the Puget Sound region of western Washington. WWHM also includes local meteorological data to drive the simulations. The current model version is capable of simulating a continuous record of all water balance parameters in a basin for the period of metrological data from 1948 – 2009.

Runoff from the 4.4-acre area was simulated in WWHM using the Everett precipitation record multiplied by a factor of 1.2 (45.9 inches per year [in/y]). Land cover consisted of 0.3 acres of

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impervious surface, and 4.1 acres of pervious soils were simulated as Group C. Of the pervious soils, 2 acres were modeled as flat/pasture, 1.7 acres were modeled as flat/lawn, and 0.4 acres were modeled as moderate lawn. This distribution was based on the National Land Cover Database (NLDC; Fry et al., 2011), aerial photographs, and site observations.

3.3.2 Water Balance Outputs

Deep Ground Water Recharge

Vertical ground water infiltration is generally controlled by the vertical hydraulic conductivity of the soil, which is generally assumed to be one or two orders of magnitude below the horizontal hydraulic conductivity. The average hydraulic conductivity for the three slug tests performed on the peat equal 0.05 ft/d, indicating a reasonable vertical K value would be on the order of 0.005 to 0.0005 ft/d, or approximately 1 inch per month (in/m). This estimate is comparable to regional estimates for the vertical hydraulic conductivity of till which range from approximately 0.001 to 0.01 ft/d (USGS, 1998). Therefore, for the purposes of the water budget, the vertical ground water recharge from the peat into the underlying Qgt_v and/or $Qgmd_e$ was estimated at approximately 1 in/m.

Ground Water Discharge to Surface Water

Ground water discharge to surface water from Site 1 is estimated at approximately 48 ft^3/d as described in Section 3.2.2. Although this estimate likely varies throughout the year, it was considered a constant since it represents such a small fraction of the overall water balance. Annually, ground water discharge to surface water is approximately 0.4 ac-ft.

Evapotranspiration (ET)

Evapotranspiration (ET) from Site 1 was estimated at 20.5 in/y, which is equal to 42.7 af/y. ET was calculated based on the estimated daily plant water use from reed canarygrass presented in Schilling and Kiniry (2007) for the growing season (May-September). The growing season total ET for reed canarygrass (16.3 inches [in]) compares similarly to the growing season ET estimates for Pasture/Tuff – Anacortes presented in the *Washington Irrigation Guide* (WIG) (United States Department of Agriculture [USDA], 1985; 14.4 in). For the purposes of the water budget calculations, the non-growing season ET was estimated at 0.6 in/m.

Surface Water Runoff

Surface water runoff from the existing conditions at Site 1 was estimated at 31 af/y. The runoff volumes from this area were estimated using WWHM simulations for 25 acres of flat/pasture, with Group C soils. The peat soils are classified as Mukilteo Muck (Group B/D) by the NRCS (1989). Group B/D soils are considered to have runoff characteristics similar to Group D (low infiltration, high runoff potential) due to ground water conditions at or near the ground surface, which is consistent with observations of ground water at Site 1.

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3.3.3 Water Balance Calculation

The monthly water balance for the site was calculated as inputs minus outputs. On an annual basis the calculations balance to 0.1 ac-ft. As expected the water balance on a monthly scale fluctuates from a net gain of 7.6 ac-ft (November) to a net loss of -7.6 ac-ft (July), which is attributed to seasonal changes in shallow ground water storage (i.e., ground water levels increasing via infiltration of precipitation and decreasing via ET). Given a peat porosity of 30%, the water balance calculations suggest an average annual ground water fluctuation of approximately 2 feet.

3.4 Site 2 Water Balance

A monthly water balance was also calculated for the 2.54-acre area that is a potential project area on Site 2. The water balance is presented in Table 5. The water balance components are described below.

3.4.1 Water Balance Input

Precipitation

The average annual precipitation input is assumed to be 44.1 inches, which equals 9.2 ac-ft over the 2.5-acre project area. Like Site 1, the precipitation values were based on the 1981 - 2010 averages from the Parameter-Elevation Relationships on Independent Slopes Model (PRISM; Daly et al., 1994).

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Table 4
Monthly Water Balance for Site 1
(all values in acre-feet)

	Month	Units	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Input	Precipitation [1]	AF	14.3	10.6	11.1	7.4	8.4	7.5	6.9	5.6	3.0	3.3	4.8	9.1	91.9
	Surface Runoff [2]	AF	1.1	1.3	1.2	0.9	0.8	0.5	0.3	0.3	0.1	0.1	0.1	0.6	7.3
	Total Input	**AF**	**15.4**	**11.9**	**12.3**	**8.2**	**9.2**	**8.0**	**7.2**	**5.8**	**3.1**	**3.4**	**4.9**	**9.7**	**99.2**
Output	Deep Ground Water Recharge [3]	AF	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	25.0
	Ground Water Discharge to Surface Water [4]	AF	0.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	0.4
	Evapotranspiration [5]	AF	1.3	1.3	1.3	1.3	1.3	1.3	6.4	6.9	8.4	6.6	5.7	1.3	42.7
	Surface Runoff [6]	AF	4.4	6.2	5.9	4.2	4.0	2.6	1.1	1.0	0.2	0.1	0.2	1.1	31.0
	Total Output	**AF**	**7.8**	**9.6**	**9.3**	**7.6**	**7.4**	**6.0**	**9.6**	**10.0**	**10.7**	**8.9**	**8.0**	**4.5**	**99.1**
	Water Balance [7]	AF	7.6	2.4	3.1	0.6	1.8	2.0	-2.4	-4.2	-7.6	-5.5	-3.0	5.2	0.1

Notes:
1) Precipitation data from PRISM Data Explorer (http://prismmap.nacse.org/nn/), 1981-2010, Longitude: -122.314, Latitude: 48.315, applied to a 25-acre overall wetland footprint.
2) Calculated from WWHM runoff simulations for 4.4 acres draining to project (0.3 AC FLAT/IMP, 2 AC C/MOD/PAST, 1.7 AC C/FLAT/LAWN, 0.4 AC C/LAWN/MOD).
3) Assumes 1 inch per month of vertical ground water seepage to the underlying Qgtv or Qgmd, applied to 25 acres, see text for discussion.
4) Calculated as 48 cubic feet per day by Darcy's Law, see text for discussion.
5) Based on evapotranspiration of reed canarygrass from Schilling and Kiniry (2007) for the growing season (total of 16.8 inches). For comparison WIG for Pasture/Turf - Anacortes totals 14.4 inches per growing season. Non-growing season ET was estimated as 0.6 inches per day.
6) Calculated from WWHM runoff simulations for 25 acres of pasture (25 AC C/FLAT/PAST).
7) Calculated as total monthly inputs minus total monthly outputs. Positive numbers indicate ground water recharge to the peat through infiltration; negative numbers indicate ground water removed from the peat through evapotranspiration.

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Table 5
Monthly Water Balance for Site 2
(all values in acre-feet)

	Month	Units	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Input	Precipitation [1]	AF	1.4	1.1	1.1	0.7	0.8	0.7	0.7	0.6	0.3	0.3	0.5	0.9	9.2
	Total Input	**AF**	**1.4**	**1.1**	**1.1**	**0.7**	**0.8**	**0.7**	**0.7**	**0.6**	**0.3**	**0.3**	**0.5**	**0.9**	**9.2**
Output	Deep Ground Water Recharge [3]	AF	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.5
	Ground Water Discharge to Surface Water [4]	AF	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.3
	Open Water Evaporation [4]	AF	0.02	0.02	0.02	0.02	0.05	0.07	0.12	0.13	0.17	0.14	0.09	0.04	0.9
	Evapotranspiration [5]	AF	0.1	0.1	0.1	0.1	0.5	0.6	0.7	0.5	0.5	0.1	0.1	0.1	3.4
	Surface Runoff [6]	AF	0.3	0.5	0.5	0.3	0.3	0.2	0.1	0.1	0	0	0	0.1	2.5
	Total Output	**AF**	**0.7**	**0.8**	**0.8**	**0.7**	**0.7**	**0.5**	**0.6**	**0.9**	**0.9**	**0.8**	**0.7**	**0.4**	**8.7**
	Water Balance [7]	AF	0.7	0.2	0.3	0	0.1	0.1	-0.3	-0.4	-0.8	-0.6	-0.3	0.4	-0.4
	Runoff (Through Flow) [8]	AF	6.9	10.4	10.2	7.3	7.1	4.6	1.9	1.8	0.4	0.2	0.5	1.6	52.8

Notes:
1) Precipitation data from PRISM Data Explorer (http://prismmap.nacse.org/nn/), 1981-2010, Longitude: -122.314, Latitude: 48.315, applied to a 2.5-acre overall project footprint.
2) Assumes 1 inch per month of vertical ground water seepage to the underlying Qgtv or Qgmd, applied to 2.5 acres, see text for discussion.
3) Calculated as 40 cubic feet per day by Darcy's Law, see text for discussion.
4) Calculated by applying a 0.7 pan coefficient to pan evaporation data from Puyallup 2W weather station (output from WWHM) for the 0.5-acre existing pond.
5) Based on evapotranspiration of reed canarygrass from Schilling and Kiniry (2007) for the growing season (total of 16.8 inches). For comparison WIG for Pasture/Turf - Anacortes totals 14.4 inches per growing season. Non-growing season ET was estimated as 0.6 inches per day.
6) Calculated from WWHM runoff simulations for 2 acres of pasture (2 AC C/FLAT/PAST)
7) Calculated as total monthly inputs minus total monthly outputs. Positive numbers indicate ground water recharge to the peat through infiltration and changes in water level in the existing pond, negative numbers indicate ground water removed from the peat through evapotranspiration and changes in water level in the existing pond via evaporation.
8) Calculated from WWHM runoff simulations for 108 acres draining to the N-S ditch on Site 2.

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3.4.2 Water Balance Outputs

Deep Ground Water Recharge

The vertical ground water recharge from the peat into the underlying Qgt_v and/or $Qgmd_e$ was estimated at approximately 1 in/m (as described in Section 3.3.2) applied to the 2.5-acre project site.

Ground Water Discharge to Surface Water

Ground water discharge to surface water from the project site is estimated at approximately 40 ft^3/d. This value was calculated by the methods described in Section 3.2.2, applied to a 600-foot length of ditch that would be downgradient of the project site. Annually, ground water discharge to surface water is approximately 0.3 ac-ft.

Open Water Evaporation

Open water evaporation from the existing 0.5-acre pond on Site 2 was calculated by applying a 0.7 pan coefficient to the monthly evaporation data from the Puyallup 2W weather station. The open water evaporation equals 21.4 in/y (0.9 af/y).

Evapotranspiration (ET)

ET from the 2.5-acre area was estimated at 20.5 in/y, which is equal to 3.4 af/y. ET was calculated based on the estimated daily plant water use from reed canarygrass presented in Schilling and Kiniry (2007) for the growing season (May-September). For the purposes of the water budget calculations, the non-growing season ET was estimated at 0.6 in/m.

Surface Water Runoff

Surface water runoff from the existing conditions at Site 2 was estimated at 2.5 af/y. The runoff volumes from this area were estimated using WWHM simulations for 2 acres of flat/pasture, with Group C soils. No runoff was assumed from the 0.5-acre existing pond because it is in a closed depression with no overflow pathway.

3.4.3 Water Balance Calculation

The monthly water balance for the site was calculated as inputs minus outputs. On an annual basis, the calculations balance to -0.4 ac-ft. The water balance on a monthly scale fluctuates from a net gain of 0.7 ac-ft (November) to a net loss of -0.8 ac-ft (July), which is attributed to seasonal changes in shallow ground water storage and surface water storage in the existing pond.

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Runoff (Through Flow)

The project site also includes a ditch that flows from north to south to the west of the existing pond. The ditch does not currently flow into the existing pond. However, a potential water storage project on either site may be able to incorporate runoff in this ditch as a source of water. In terms of the existing water balance, this runoff is considered through flow (water that flows through the site, but does not factor in the water balance calculations). Based on LiDAR elevation data, the ditch has a contributing area of approximately 108 acres. The runoff volume from this area was estimated using the WWHM using the Everett precipitation record multiplied by a factor of 1.2 (45.9 in/y). Land cover was based on the NLDC (Fry et al., 2011. Soil types were based on the NRCS Hydrologic Soil Group ratings (NRCS, 1989). Slopes were based on LiDAR elevation data.

The total annual through flow was estimated as 52.8 ac/y.

4.0 CONCEPTUAL DESIGN

4.1 General

The general conceptual design for the ground water mitigation program is a wetland rehabilitation/water storage project. The project would include the construction of a surface water impoundment with wetland features that would store water during the winter and spring, and release the water to the shallow ground water system immediately adjacent to Starbird Creek during the low-flow season. The potential project areas on both Site 1 and Site 2 have peat soils and a seasonally high ground water table which can support wetland vegetation. The goals of the conceptual design are to preserve, enhance, and/or create additional wetland functions on a site and provide additional water storage that can be released as mitigation and streamflow enhancement.

To achieve these goals, a number of concepts were considered for both sites. In doing so, we made an effort to maximize the storage volume of the project while attempting to minimize permitting requirements, construction costs, and other impacts related to trucking import material to the site or export material from the site. Note that although the concept for Site 2 described below is for a standalone project, the storage capacity of a project at that location could also be incorporated as additional storage that could be conveyed to a project on Site 1.

4.2 Wetland Rehabilitation/Water Storage Project

A wetland rehabilitation/water storage project on Site 1 and/or Site 2 will create a surface water impoundment with variable slopes, hummocks (areas of drier soils above the seasonal high water level), and varying water depths that will support emergent, shrub, and forested wetland vegetation communities. To achieve this, the project will require the excavation of the peat below the existing grade to create areas of deeper water and placing the excavated material to create hummocks.

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4.2.1 Wetland Rehabilitation Features

The wetland rehabilitation concept can be applied to both Site 1 and Site 2 and will incorporate sinuous edges, habitat structure, and planting plans that will be designed to improve the existing functions on each site by:

- Helping to control the presence of invasive, non-native reed canarygrass.
- Creating additional water storage capacity, retention time, and seasonal ponding by means of excavation, grading, and a constricted outlet with potential to improve water quality and hydrologic functions.
- Removing grazing activity (Site 1) and providing persistent vegetation with potential to improve water quality and hydrologic functions.
- Providing areas of ponding with stable water levels and persistent vegetation with potential to support amphibian breeding habitat between February 1 and May 31.
- Providing a diversity of hydroperiods across the site capable of providing habitat for a diversity of aquatic species including permanently flooded, seasonally flooded, and saturated areas.
- Increasing plant richness (number of plant species) on the sites in support of diversifying habitat niches for invertebrates, birds, and mammals by planting native species and creating variable water depths including areas with seasonal inundation from 0 to 3 feet and hummocks above the seasonal high water table.
- Grading to provide a complex interspersion of habitats capable of supporting a diversity of wildlife by providing a mosaic of permanently vegetated wetlands, sinuous edge habitat, hummocks, and open water.
- Improving habitat for wildlife by providing large downed wood and standing snags

4.2.2 Water Storage Features

Currently, both sites are generally flat, with a seasonal water table at or very near the ground surface, with ditches to help improve surface drainage. This type of setting produces significant surface runoff, particularly for Site 1, during the winter and spring, as indicated in the existing conditions water balance calculations (Section 3.3). The project would increase the storage capacity of the site to capture surface water runoff by removing peat from both below and above the water table, and potentially providing for additional impoundment of surface water above the existing grade. Details regarding the water storage features are provided below and in Table 6.

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- Excavation will create a diverse grading plan with variable water depths and upland features throughout the project area.

- Excavated side slopes will be variable with an average 4:1 horizontal to vertical ratio.

- Maximum water surface elevation may be up to approximately 0.7 feet above the existing grade on Site 1. The maximum water surface elevation on Site 2 would likely be approximately the water level of the existing pond.

- Excavated material will be placed to create hummocks above the seasonal high water level in the form of a sinuous berm around the perimeter of the project and islands inside the project footprint. A geotechnical evaluation will be necessary to determine if the peat material is suitable for a berm or if imported material would be necessary to impound water above the existing grade.

- Grading quantities would be approximately 59,000 cubic yards of cut and place, with limited or zero haul of material off-site for Site 1. Grading quantities for Site 2 would be approximately 9,000 cubic yards of cut and place, with limited or zero haul of material off-site.

- The grading plan would create variable water depths, with a majority of the project between 2.5-3 feet deep at maximum water level (Table 6).

- Project could create approximately 35 ac-ft of active water storage on Site 1 and approximately 7 ac-ft on Site 2

4.2.3 Project Discharge Features

Water from the constructed project will be discharged via a controlled outlet structure(s) to the shallow ground water adjacent to Starbird Creek. Direct discharge of the project outflows to the creek is not considered at this time due to concerns about water temperature of the project discharge impacting the water temperature in the stream.

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Table 6
Water Storage Details

	Site 1		Site 2	
	Area in Acres	**Percent of Total Area**	**Area in Acres**	**Percent of Total Area**
Footprint of Project	25	100%	2.5	100%
Upland/Wetland Forest	5	20%	0.5	20%
Scrub-Shrub Wetland	2.5	10%	0.25	10%
Emergent Marsh Wetland (maximum water depth 2.5-3 feet)	12.5	50%	1.25	50%
Open Water (maximum water depth > 3 feet)	5	20%	0.5	20%
Total Storage Volume of Wetland	35 ac-ft		7 ac-ft	

If the existing soils adjacent to the stream are not suitable for discharge, water from the project may be discharged to a sand/gravel-filled trench or similar feature adjacent to the stream to provide temperature moderation prior to entering the stream. The controlled outlet structure would exit the project at an elevation approximately equal to the seasonal low water level in Starbird Creek.

4.2.4 Project Operation Features

The project will be operated to provide both mitigation and streamflow enhancement water. Mitigation will be provided during days when the Skagit River is below the instream flow level. To achieve this, the mitigation discharge will be controlled automatically and linked via satellite telemetry, SCADA (supervisory control and data acquisition), or other similar means to the real-time USGS stream gage for the Skagit River at Mount Vernon (USGS #12200500). Streamflow enhancement will be delivered to the stream for a set period during the low-flow season.

4.2.5 Secondary Water Source

The primary water source for the project will be direct precipitation and runoff from the contributing area to the project site. During below average precipitation years and to maximize the potential mitigation/enhancement discharge volume from the project, a secondary water source may need to be developed. Possible secondary water sources include utilizing an existing water right associated with Site 1, or conveying additional surface water runoff to the project site (e.g., the drainage ditch through flow on Site 2).

4.3 Project Monthly Water Balance – Site 1

A monthly water balance for a project on Site 1 was calculated in order to understand how much stored water might be available for mitigation/enhancement on a monthly scale under average precipitation conditions. The water balance was calculated in a similar manner to the

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calculations for the existing conditions with adjustments as necessary to capture the project features. The water balance is presented in Table 7. The water balance components are briefly described below.

4.3.1 Monthly Water Balance Inputs

Precipitation

The average annual precipitation input is the same as for the existing site conditions: 44.1 inches, which equals 91.9 af/y over the 25-acre project footprint (Section 3.3.1).

Runoff

The runoff input is the same as for the existing site conditions: 7.3 af/y as described in Section 3.3.1.

4.3.2 Monthly Water Balance Outputs

Deep Ground Water Recharge

Deep ground water recharge is assumed to be the same as the existing condition (1 in/m) as described in Section 3.3.2. The water level in the project may be impounded above the existing seasonal high ground water elevation by approximately 0.7 feet for only a minor portion of the year. The water level will also likely be drawn down below the typical seasonal ground water low elevation by approximately 1 foot for a portion of the year. Given the low vertical hydraulic conductivity of the peat and underlying Qgt_v / $Qgmd_e$ any changes in deep ground water recharge as a result of the project are presumed to be negligible.

Ground Water Discharge to Surface Water

Ground water discharge to surface water from the project site is assumed to be the same as the existing condition (95 ft^3/d) as described in Section 3.3.2. As discussed, the water level in the project may only be impounded above the existing seasonal high ground water elevation by approximately 0.7 feet for only a portion of the year. The water level will also be drawn below the typical seasonal ground water low elevation by approximately 1 foot for a portion of the year. Given the low hydraulic conductivity of the peat, any changes in the ground water discharge volume to surface water as a result of the project are presumed to be negligible.

Evapotranspiration (ET)

Evapotranspiration (ET) was estimated at 22.1 in/y (45.5 af/y) for the 25-acre footprint of the project (Table 7). This represents an 8% increase in ET over the existing reed canarygrass dominated pasture setting (42.7 af/y, Table 7). ET was calculated based on estimates for Pasture/Tuff – Anacortes presented in the WIG for the growing season multiplied by a factor of 1.18 to adjust pasture ET to wetland ET (USGS, 2013). The resulting growing season ET

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estimate for the project is 17 inches. Non-growing season ET was estimated by applying a 0.7 coefficient to the average monthly pan evaporation data from the Puyallup 2E weather station to represent evaporation from an open body of water.

4.3.3 Monthly Water Balance Calculation

The monthly water balance for the project yields an annual net balance of 28.3 ac-ft. This volume is essentially the difference between the site runoff in the existing conditions minus the increase in ET from the existing to the potential future conditions. The water balance from November – June is estimated at 39.7 ac-ft. Note that the water balance from November – June exceeds the maximum storage volume for the pond (35 ac-ft). The excess volume (4.7 ac-ft) would discharge to Starbird Creek as overflow from the project during that period. During the period of July – September, the water balance deficit is -18.7 ac-ft, primarily as a result of ET during the growing season.

Under average monthly climate conditions for the site, the total potential mitigation/ enhancement volume for the project is estimated as 16.3 ac-ft. This volume is calculated as the maximum storage volume of the pond (35 ac-ft) minus the water balance deficit from July – September.

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Table 7
Monthly Water Balance Calculation for an Example Project – Site 1

	Month	Units	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Inputs	Precipitation [1]	AF	14.3	10.6	11.1	7.4	8.4	7.5	6.9	5.6	3.0	3.3	4.8	9.1	91.9
	Surface Runoff [2]	AF	1.1	1.3	1.2	0.9	0.8	0.5	0.3	0.3	0.1	0.1	0.1	0.6	7.3
	Total Input	**AF**	**15.4**	**11.9**	**12.3**	**8.2**	**9.2**	**8.0**	**7.2**	**5.8**	**3.1**	**3.4**	**4.9**	**9.7**	**99.2**
Outputs	Deep Ground Water Recharge [3]	AF	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	25.0
	Ground Water Discharge to Surface Water [4]	AF	03	0. 03	0. 03	0. 03	0. 03	0. 03	0. 03	0. 03	0. 03	0. 03	0. 03	0. 03	0.4
	Wetland Evapotranspiration [5]	AF	1.1	0.9	0.6	1.2	2.5	3.5	3.2	8.4	10.9	8.2	4.6	0.3	45.5
	Total Output	**AF**	**3.2**	**3.0**	**2.7**	**3.3**	**4.6**	**5.7**	**5.3**	**10.5**	**13.0**	**10.3**	**6.7**	**2.5**	**70.9**
	Water Balance [6]	AF	12.2	8.9	9.6	4.9	4.6	2.3	1.9	-4.7	-9.9	-7.0	-1.8	7.2	28.3

Maximum Storage	35.0
Water Balance from November - June	39.7
Water Balance from July-September	-18.7
Total Mitigation/Enhancement Volume [7]	**16.3**

Notes:

1) Precipitation data from PRISM Data Explorer (http://prismmap.nacse.org/nn/), 1981-2010, Longitude: -122.314, Latitude: 48.315, applied to a 25-acre overall wetland footprint.
2) Calculated from WWHM runoff simulations for 4.4 acres draining to wetland (0.3 AC FLAT/IMP, 2 AC C/MOD/PAST, 1.7 AC C/FLAT/LAWN, 0.4 AC C/LAWN/MOD).
3) Assumes 1 inch per month of deep ground water recharge to Qgtv or Qgmd, applied to a 25-acre overall wetland footprint.
4) Calculated by Darcy's Law (See section 3.X), assumes discharge of 125 cubic feet per day.
5) Calculated based on WIG for Pasture/Turf - Anacortes, multiplied by a factor of 1.18 to adjust pasture ET to wetland ET (USGS, 2013) for the growing season. Calculated by applying a 0.7 pan coefficient to pan evaporation data from Puyallup 2W weather station (output from WWHM) for the non-growing season.
6) Calculated as the monthly inputs minus the monthly outputs.
7) Calculated as the difference between maximum storage provided in the project and the water balance from July-September.

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4.4 Project Monthly Water Balance – Site 2

A monthly water balance was also calculated to see how much stored water might be available for mitigation/enhancement from a project located on Site 2. The water balance is presented in Table 8. The water balance components are briefly described below.

4.4.1 Monthly Water Balance Inputs

Precipitation

The average annual precipitation input is the same as for the existing site conditions: 44.1 inches, which equals 9.2 af/y over the 2.5-acre project footprint (Section 3.4.1).

4.3.2 Monthly Water Balance Outputs

Deep Ground Water Recharge

Deep ground water recharge is assumed to be the same as the existing condition (1 in/m). The water level in the project will likely not be impounded above the seasonal high water elevation in the existing pond on the site, and given the low vertical hydraulic conductivity of the peat and underlying Qgt_v / $Qgmd_e$, any changes in deep ground water recharge as a result of the project are presumed to be negligible.

Ground Water Discharge to Surface Water

Ground water discharge to surface water from the project site is assumed to be the same as the existing condition (40 ft^3/d) as described in Section 3.4.2. As discussed, the water level in the project will likely not be impounded above the seasonal high water elevation in the existing pond on the site, and given the low hydraulic conductivity of the peat, any changes in the ground water discharge volume to surface water as a result of the project are presumed to be negligible.

Open Water Evaporation

The open water evaporation from the project is assumed to be the same as the existing condition (0.9 af/y) because the total area of open water will remain approximately the same between the existing condition and the project (0.5 acres).

Evapotranspiration (ET)

Evapotranspiration (ET) was estimated at 22.1 in/y (3.7 af/y) for the 2-acre area of the project that will not be open water. This represents an 8% increase in ET over the existing reed canarygrass dominated pasture setting (3.4 af/y, Table 6). ET was calculated based on estimates for Pasture/Tuff – Anacortes presented in the WIG for the growing season multiplied by a factor of 1.18 to adjust pasture ET to wetland ET (USGS, 2013). The resulting growing season ET estimate for the project is 17 inches. Non-growing season ET was estimated by applying a 0.7 coefficient to the average monthly pan evaporation data from the Puyallup 2E weather station to represent evaporation from an open body of water.

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4.3.3 Monthly Water Balance Calculation

The monthly water balance for the project yields an annual net balance of 1.8 ac-ft. This volume is essentially the difference between the site runoff in the existing conditions minus the increase in ET from the existing to the potential future conditions. The water balance from November – June is estimated at 3.1 ac-ft. Note that the water balance from November – June is less than the maximum storage volume for the pond (7.0 ac-ft). The volume deficit (3.9 ac-ft) would need to be filled by a secondary water source (e.g., routing some through-flow into the project). During the period of July – September, the water balance deficit is -1.9 ac-ft, primarily as a result of ET during the growing season.

Under average monthly climate conditions for the site, the total potential mitigation/ enhancement volume for the project is estimated as 5.1 ac-ft. This volume is calculated as the maximum storage volume of the pond (7.0 ac-ft) minus the water balance deficit from July – September.

4.5 Project Operational Summary

A daily water balance for the project sites was also calculated to consider how annual variations in precipitation may influence the project and estimate the timing and quantity needs of a secondary water source for the project. The water balance was calculated for the years 2000 - 2012 in a similar manner to the monthly water balance with factors included to control the operation of the project. A summary of key operational information for an example project on Sites 1 and 2 are presented in Tables 8 and 9, respectively. The water balance components are briefly described below.

4.5.1 Daily Water Balance Inputs

The daily precipitation for the potential project sites was compiled from WWHM time series data for Everett. The precipitation record in WWHM only extended through July 27, 2011 so the remaining record was obtained from the Global Historical Climate Network (GHCN) station in Everett. Daily precipitation from Everett was multiplied by a factor of 1.1 to adjust the record to the project site. Daily precipitation values are not readily available from PRISM (Daly et al., 1994); however, the annual average precipitation for the period of 2000 – 2012 from PRISM for the project site compares well to the Everett time series data set multiplied by 1.1 (Table 8). The years 2011 and 2012 both experienced prolonged periods of little to no measureable precipitation from late July through early September.

The daily runoff input for Site 1 was calculated using WWHM as described in Section 3.3.1. The daily runoff input for Site 2 was also calculated using WWHM as described in Section 3.4.1, and supplemented as necessary with additional runoff from that is currently through flow from the drainage ditch to the west of the existing pond.

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Table 8
Monthly Water Balance Calculation for an Example Project – Site 2

	Month	Units	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Inputs	Precipitation [1]	AF	1.4	1.1	1.1	0.7	0.8	0.7	0.7	0.6	0.3	0.3	0.5	0.9	9.2
	Total Input	**AF**	**1.4**	**1.1**	**1.1**	**0.7**	**0.8**	**0.7**	**0.7**	**0.6**	**0.3**	**0.3**	**0.5**	**0.9**	**9.2**
Outputs	Deep Ground Water Recharge [3]	AF	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.5
	Ground Water Discharge to Surface Water [4]	AF	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.3
	Open Water Evaporation [5]	AF	0.02	0.02	0.02	0.02	0.05	0.07	0.12	0.13	0.17	0.14	0.09	0.04	0.9
	Wetland Evapotranspiration 6	AF	0.1	0.1	0.1	0.1	0.2	0.3	0.3	0.7	0.9	0.7	0.4	0.0	3.7
	Total Output	**AF**	**0.3**	**0.3**	**0.3**	**0.3**	**0.4**	**0.5**	**0.5**	**0.9**	**1.1**	**0.9**	**0.6**	**0.3**	**6.5**
	Water Balance [6]	AF	1.1	0.7	0.8	0.4	0.4	0.2	0.1	-0.5	-1.0	-0.7	-0.2	0.6	1.8
	Runoff (Through Flow) [7]		6.9	10.4	10.2	7.3	7.1	4.6	1.9	1.8	0.4	0.2	0.5	1.6	6.9	52.8

Maximum Storage	7.0
Water Balance from November - June	3.1
Water Balance from July-September	-1.9
Total Mitigation/Enhancement Volume [7]	**5.1**

Notes:

1) Precipitation data from PRISM Data Explorer (http://prismmap.nacse.org/nn/), 1981-2010, Longitude: -122.314, Latitude: 48.315, applied to a 2.5-acre overall project footprint.
2) Assumes 1 inch per month of deep ground water recharge to Qgtv or Qgmd, applied to a 2.5-acre overall footprint.
3) Calculated by Darcy's Law (see text for discussion), assumes discharge of 40 cubic feet per day.
4) Calculated by applying a 0.7 pan coefficient to pan evaporation data from Puyallup 2W weather station, for a 0.5-acre area.
5) Calculated based on WIG for Pasture/Turf - Anacortes, multiplied by a factor of 1.18 to adjust pasture ET to wetland ET (USGS, 2013) for the growing season. Calculated by applying a 0.7 pan coefficient to pan evaporation data from Puyallup 2W weather station (output from WWHM) for the non-growing season.
6) Calculated as the monthly inputs minus the monthly outputs.
7) Calculated as the difference between maximum storage provided in the project and the water balance from July-September.

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4.5.2 Daily Water Balance Outputs

The daily water balance outputs for deep ground water recharge, shallow ground water discharge to surface water, and ET were calculated as the monthly rates described in Sections 4.2.2 and 4.3.2 for Sites 1 and 2, respectively. These monthly values were distributed evenly for every day in the month.

4.5.3 Project Operation

Project operational constraints were superimposed on the daily water balance to demonstrate how a project on each site could have operated during the years 2000 - 2012. A summary of key elements in the project operation is provided in Tables 9 and 10. The operational constraints are described briefly below.

Maximum Storage

The maximum storage volume of the project was set at 35 ac-ft for Site 1 and 7 ac-ft for Site 2.

Minimum Storage

The minimum storage was calculated based on the results of the daily water balance and operation of the project. Operational constraints were adjusted to demonstrate that the minimum storage volume never dropped to zero (i.e., the project never goes completely dry). The minimum storage volume was the lowest during 2005 for both project sites.

Secondary Water Volume

The secondary water volume is controlled by several factors. In the example for Site 1 (Table 9), the secondary water volume was assumed to be from pumping water into the project by utilizing the existing water right associated with the site, and the following constraints: pumping rate of 150 gallons per minute (gpm) during June and July for the minimum volume required to increase the storage to 35 ac-ft. Although the existing water right is not subject to the Skagit River instream flow, for the purposes of this calculation pumping only occurred when the Skagit River was above the instream flow. The same constraints were applied to a project on Site 2 to calculate the minimum volume required to increase the storage to 7 ac-ft (Table 10).

Mitigation Volume

The mitigation volume provided from the project varies annually based on the number of days mitigation is required. The project will provide mitigation for the days when the Skagit River is below the instream flow, which occurred between 38 and 190 days during the period of 2000 – 2012 (Tables 9 and 10). The volumes for Site 1 shown in Table 9 are calculated assuming mitigation for 253 dwellings (equal to the 64 homes already built in the basin since 2001, and a 50-year development projection of 189 new homes). The volumes for Site 2 shown in Table 9 are calculated assuming mitigation for 84 dwellings (equal to the 64 homes already built in the

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basin since 2001, 20 new homes). Each dwelling assumed a mitigation rate of 175 gallons per day (gpd).

Streamflow Enhancement Volume

The streamflow enhancement volume for Site 1 (Table 9) is calculated based on a daily rate of 0.003 cfs for the months of July, August, September, and October. The enhancement flow represents a 6% increase over the typical flows in Fisher Creek during that time period (~0.5 cfs). The enhancement volume represents an average of 35% of the discharge from the project for the years 2000 - 2012.

The streamflow enhancement volume for Site 2 (Table 10) is calculated based on a daily rate of 0.007 cfs for the months of July, August, September, and October. The enhancement flow represents a 1% increase over the typical flows in Fisher Creek during that time period (~0.5 cfs). The enhancement volume represents an average of 28% of the discharge from the project for the years 2000 - 2012.

The streamflow enhancement volume could also be optimized to utilize more water if available on a given year. For example, in the water balance calculation for Site 1 in 2004, the minimum storage volume was 20.1 ac-ft (Table 9). In theory, streamflow enhancement releases could be adjusted year-to-year based on water levels in the project to achieve even greater flows to Starbird Creek than are presented in Tables 9 and 10.

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Table 9
Operational Summary for the Project – Site 1

Calendar Year	WWHM Everett Precip in inches	Maximum Storage in Acre-Feet	Minimum Storage in Acre-Feet	Secondary Water Volume in Acre-Feet	Mitigation Volume in Acre-Feet	Number of Mitigation Days	Streamflow Enhancement Volume in Acre-Feet	Percent of Enhancement	PRISM PRECIP
2000	36.6	35.0	15.3	21.9	15.8	116	7.8	33%	37.4
2001	44.1	35.0	5.8	31.2	25.8	190	7.8	23%	42.9
2002	37.2	35.0	3.7	22.6	13.9	102	7.8	36%	35.3
2003	39.2	35.0	5.2	26.3	12.6	93	7.8	38%	43.5
2004	40.4	35.0	24.5	26.2	5.2	38	7.8	60%	47.7
2005	41.9	35.0	0.2	12.6	21.3	157	7.8	27%	42.6
2006	52.5	35.0	5.0	23.3	17.5	129	7.8	31%	49.4
2007	43.7	35.0	13.3	21.5	10.1	74	7.8	44%	44.9
2008	43.0	35.0	15.4	23.1	16.7	123	7.8	32%	43.8
2009	43.8	35.0	9.9	23.9	19.2	141	7.8	29%	41.4
2010	49.6	35.0	21.6	20.6	15.9	117	7.8	33%	45.0
2011	46.1	35.0	10.2	20.4	14.9	110	7.8	34%	48.3
2012	53.3	35.0	6.8	18.7	7.3	54	7.8	52%	55.8
Average	**44.0**	**35.0**	**10.5**	**22.5**	**15.1**	**111**	**7.8**	**36%**	**44.5**

Notes:
Precipitation data used is from WWHM Everett, multiplied by a factor of 1.1.
Annual PRISM Precipitation data for Site 1 included for comparison.
Precipitation data for 7/27/2011 - December 31, 2012 from Everett Global Historical Climate Network (GHCN) weather station (data from NCDC: http://gis.ncdc.noaa.gov/map/viewer/#app=cdo&cfg=cdo&theme=daily&layers=111&node=gis).
No Runoff Data used as input from October 1, 2009 - December 31, 2012 (no data available from WWHM).
Precipitation total from July 27-September 17, 2011: 0.18 inches (1 day of precipitation [August 23] in 53-day period).
Precipitation total from July 23-September 8 2011: 0.23 inches (2 days of precipitation [August 18 and 21] in 48-day period).

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Table 10
Operational Summary for the Project – Site 2

Calendar Year	WWHM Everett Precip in inches	Maximum Storage in Acre-Feet	Minimum Storage in Acre-Feet	Secondary Water Volume in Acre-Feet	Mitigation Volume in Acre-Feet	Number of Mitigation Days	Streamflow Enhancement Volume in Acre-Feet	Percent of Enhancement	PRISM PRECIP
2000	36.6	7.2	3.4	2.3	5.2	116	1.7	25%	37.4
2001	44.1	7.2	2.6	2.4	8.6	190	1.7	17%	42.9
2002	37.2	7.2	0.7	2.3	4.6	102	1.7	27%	35.3
2003	39.2	7.2	1.5	3.3	4.2	93	1.7	29%	43.5
2004	40.4	7.2	5.3	2.9	1.7	38	1.7	50%	47.7
2005	41.9	7.2	0.1	1.2	7.1	157	1.7	19%	42.6
2006	52.5	7.2	0.7	2.2	5.8	129	1.7	23%	49.4
2007	43.7	7.2	2.9	2.1	3.3	74	1.7	34%	44.9
2008	43.0	7.2	3.0	2.4	5.5	123	1.7	24%	43.8
2009	43.8	7.2	2.3	2.9	6.4	141	1.7	21%	41.4
2010	49.6	7.2	3.7	5.2	5.3	117	1.7	24%	45.0
2011	46.1	7.2	2.6	3.4	5.0	110	1.7	26%	48.3
2012	53.3	7.2	2.4	4.3	2.4	54	1.7	41%	55.8
Average	**44.0**	**7.2**	**2.4**	**2.8**	**5.0**	**111**	**1.7**	**28%**	**44.5**

Notes:
Precipitation Data Used is from WWHM Everett, multiplied by a factor of 1.1.
Annual PRISM Precipitation data for Site 1 included for comparison.
Precipitation data for 7/27/2011 - December 31. 2012 from Everett Global Historical Climate Network (GHCN) weather station (data from NCDC: http://gis.ncdc.noaa.gov/map/viewer/#app=cdo&cfg=cdo&theme=daily&layers=111&node=gis).
No Runoff Data used as input from October 1, 2009 - December 31, 2012 (no data available from WWHM).
Precipitation total from July 27-September 17, 2011: 0.18 inches (1 day of precipitation [August 23] in 53 day period).
Precipitation total from July 23-September 8 2011: 0.23 inches (2 days of precipitation [August 18 and 21] in 48-day period).

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5.0 COST ESTIMATE

A preliminary cost estimate for the projects is currently being developed. The estimate will include preliminary costs associated with property acquisition, planning, construction, operation and maintenance, and monitoring for the project.

6.0 UNCERTAINTIES

The primary uncertainty related to the conceptual design of the project includes the year-to-year variability in precipitation that controls the primary water inputs to the project. The feasibility for a secondary water source to provide additional input to the project during below-average precipitation years will be evaluated during the planning and full design of the project. Water release schemes to maximize the potential streamflow enhancement water will also be evaluated during the planning and full design of the project.

Additional uncertainties are related to the site surface water and ground water system including seasonal fluctuations in water levels, and the horizontal and vertical variability in soil properties across the site (e.g., hydraulic conductivity, porosity, and gradient). Water level data will continue to be collected as the project moves forward to establish seasonal fluctuations. Additional data on the soil properties may also be collected as necessary to support the full design of the project.

7.0 PRELIMINARY MONITORING AND MAINTENANCE REQUIREMENTS

Monitoring and maintenance requirements for the project will be determined once the project is fully designed. The final design documents will include details on these requirements.

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8.0 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,
ASSOCIATED EARTH SCIENCES, INC.
Everett, Washington

Jay W. Chennault, L.G., L.Hg.
Senior Hydrogeologist

Charles S. Lindsay, L.G., L.E.G., L.Hg.
Senior Principal Geologist/Hydrogeologist

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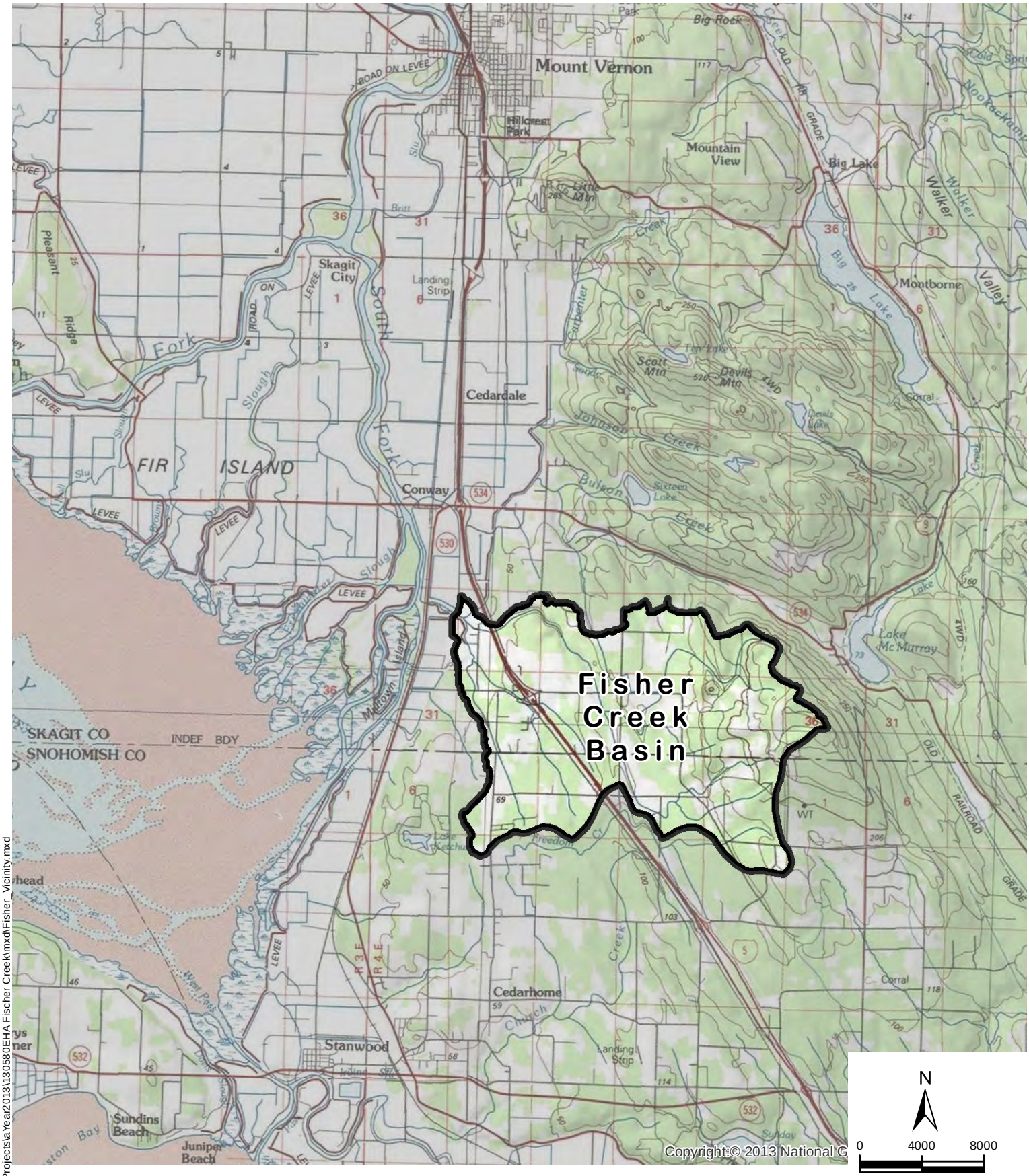

REFERENCE: USGS, SKAGIT CO.

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VICINITY

FISHER CREEK BASIN
SKAGIT AND SNOHOMISH CO., WASHINGTON

FIGURE 1

DATE 6/14

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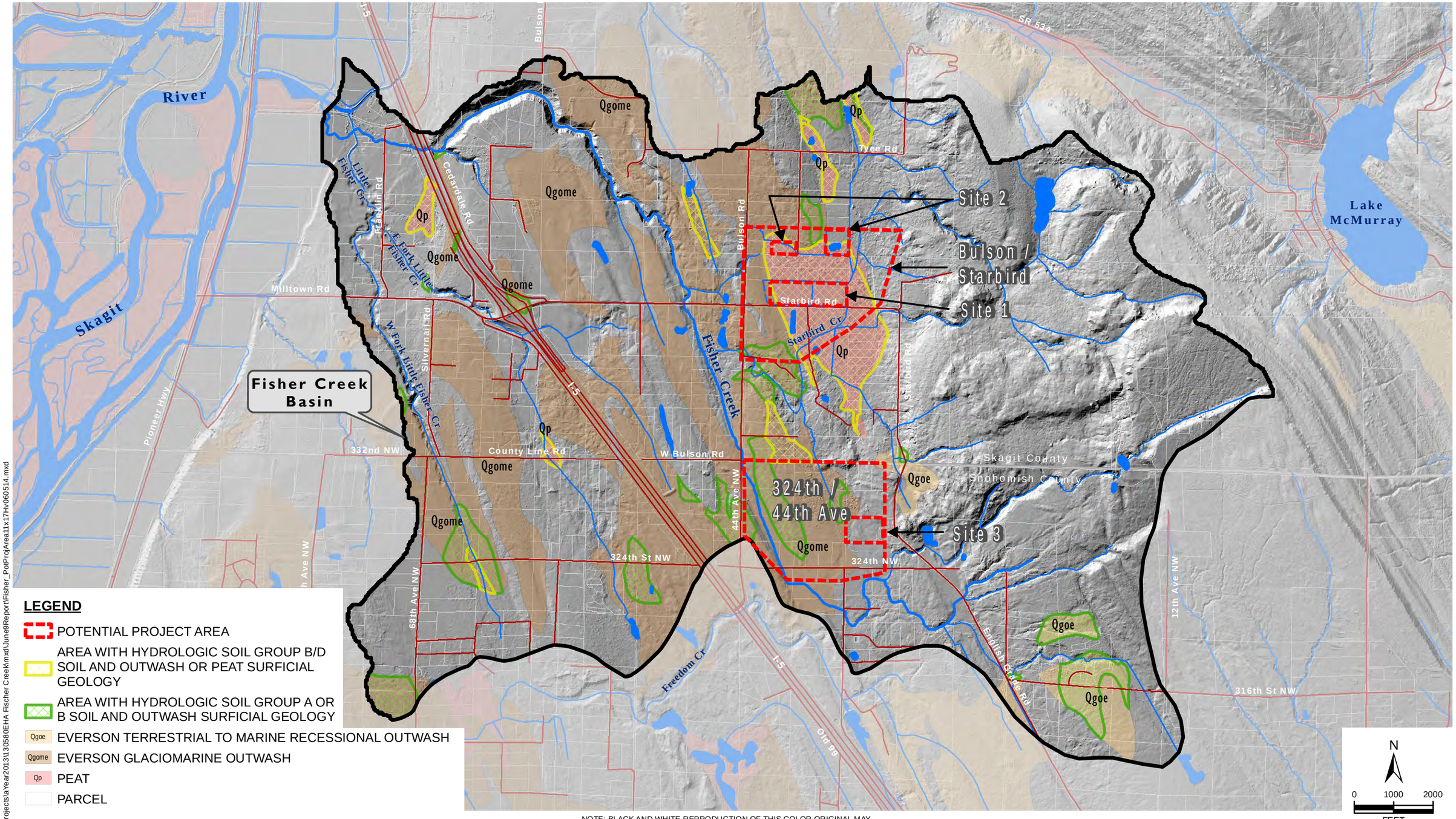

LEGEND

- POTENTIAL PROJECT AREA
- AREA WITH HYDROLOGIC SOIL GROUP B/D SOIL AND OUTWASH OR PEAT SURFICIAL GEOLOGY
- AREA WITH HYDROLOGIC SOIL GROUP A OR B SOIL AND OUTWASH SURFICIAL GEOLOGY
- Qgoe EVERSON TERRESTRIAL TO MARINE RECESSIONAL OUTWASH
- Qgome EVERSON GLACIOMARINE OUTWASH
- Qp PEAT
- PARCEL

N

0 1000 2000 FEET

REFERENCE: PSLC, SKAGIT AND SNOHOMISH CO., NRCS, USGS REPORT 2009-5270

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POTENTIAL PROJECT AREAS

FISHER CREEK BASIN

SNOHOMISH AND SKAGIT COUNTIES, WASHINGTON

FIGURE 2

DATE 6/14

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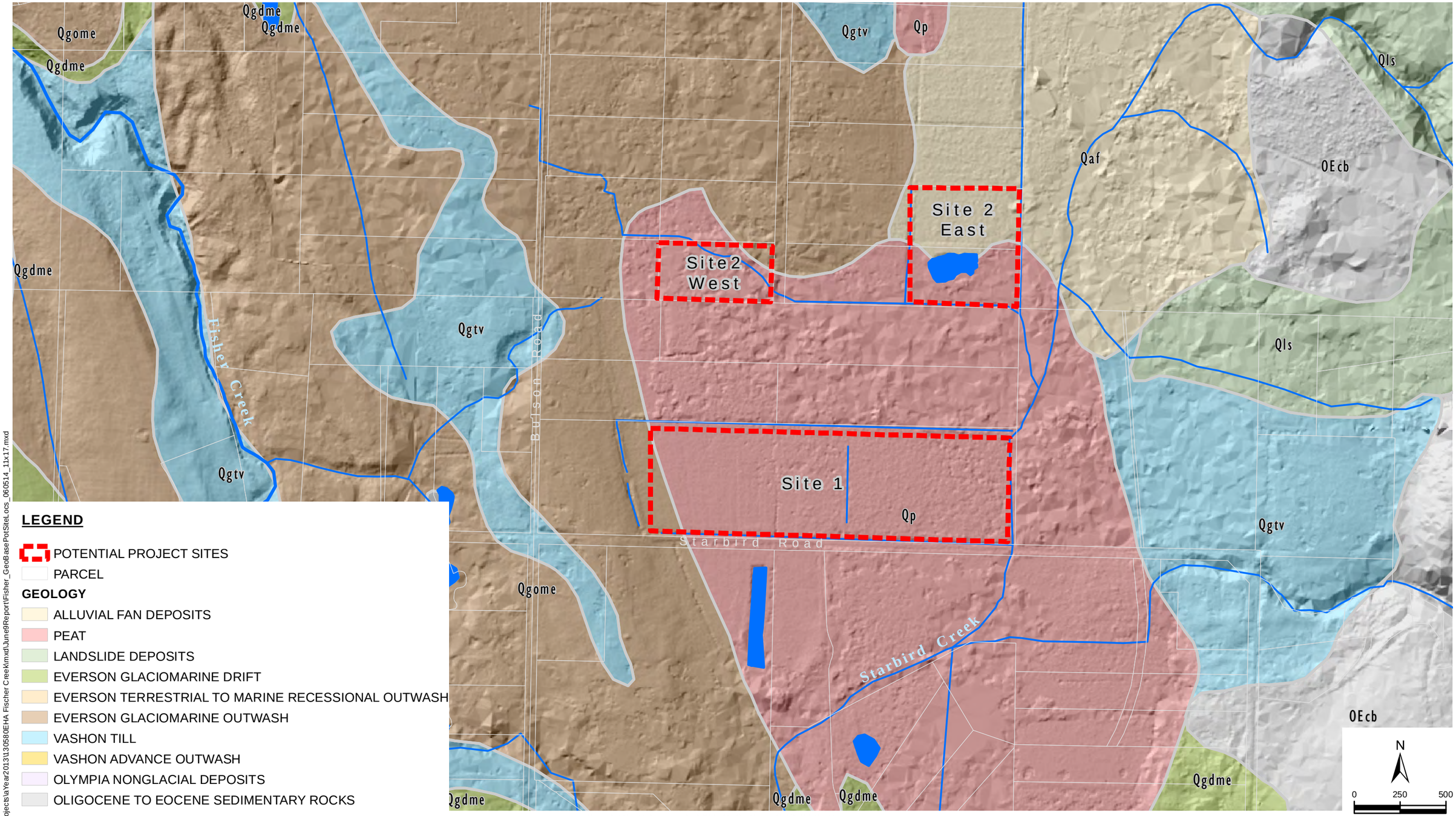

LEGEND

POTENTIAL PROJECT SITES

PARCEL

GEOLOGY

ALLUVIAL FAN DEPOSITS

PEAT

LANDSLIDE DEPOSITS

EVERSON GLACIOMARINE DRIFT

EVERSON TERRESTRIAL TO MARINE RECESSIONAL OUTWASH

EVERSON GLACIOMARINE OUTWASH

VASHON TILL

VASHON ADVANCE OUTWASH

OLYMPIA NONGLACIAL DEPOSITS

OLIGOCENE TO EOCENE SEDIMENTARY ROCKS

REFERENCE: BING, SKAGIT CO., USGS REPORT 2009-5270

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GEOLOGIC MAP OF POTENTIAL PROJECT SITES

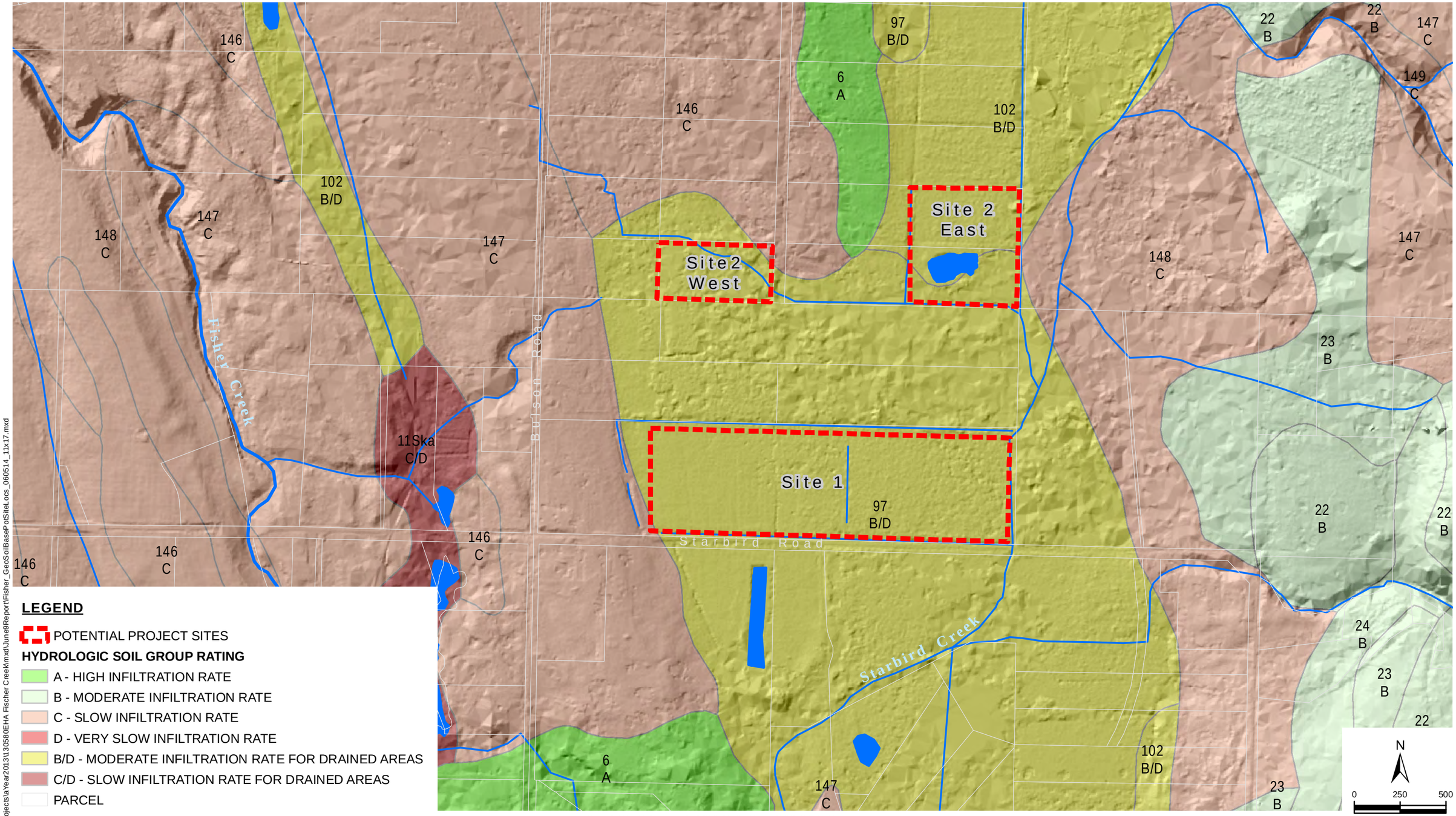
FISHER CREEK BASIN

SNOHOMISH AND SKAGIT COUNTIES, WASHINGTON

FIGURE 3

DATE 6/14

PROJ. NO. EH130580A



LEGEND

POTENTIAL PROJECT SITES

HYDROLOGIC SOIL GROUP RATING

- A - HIGH INFILTRATION RATE
- B - MODERATE INFILTRATION RATE
- C - SLOW INFILTRATION RATE
- D - VERY SLOW INFILTRATION RATE
- B/D - MODERATE INFILTRATION RATE FOR DRAINED AREAS
- C/D - SLOW INFILTRATION RATE FOR DRAINED AREAS
- PARCEL

REFERENCE: BING, SKAGIT CO., USGS REPORT 2009-5270

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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SOILS MAP OF POTENTIAL PROJECT SITES

FISHER CREEK BASIN

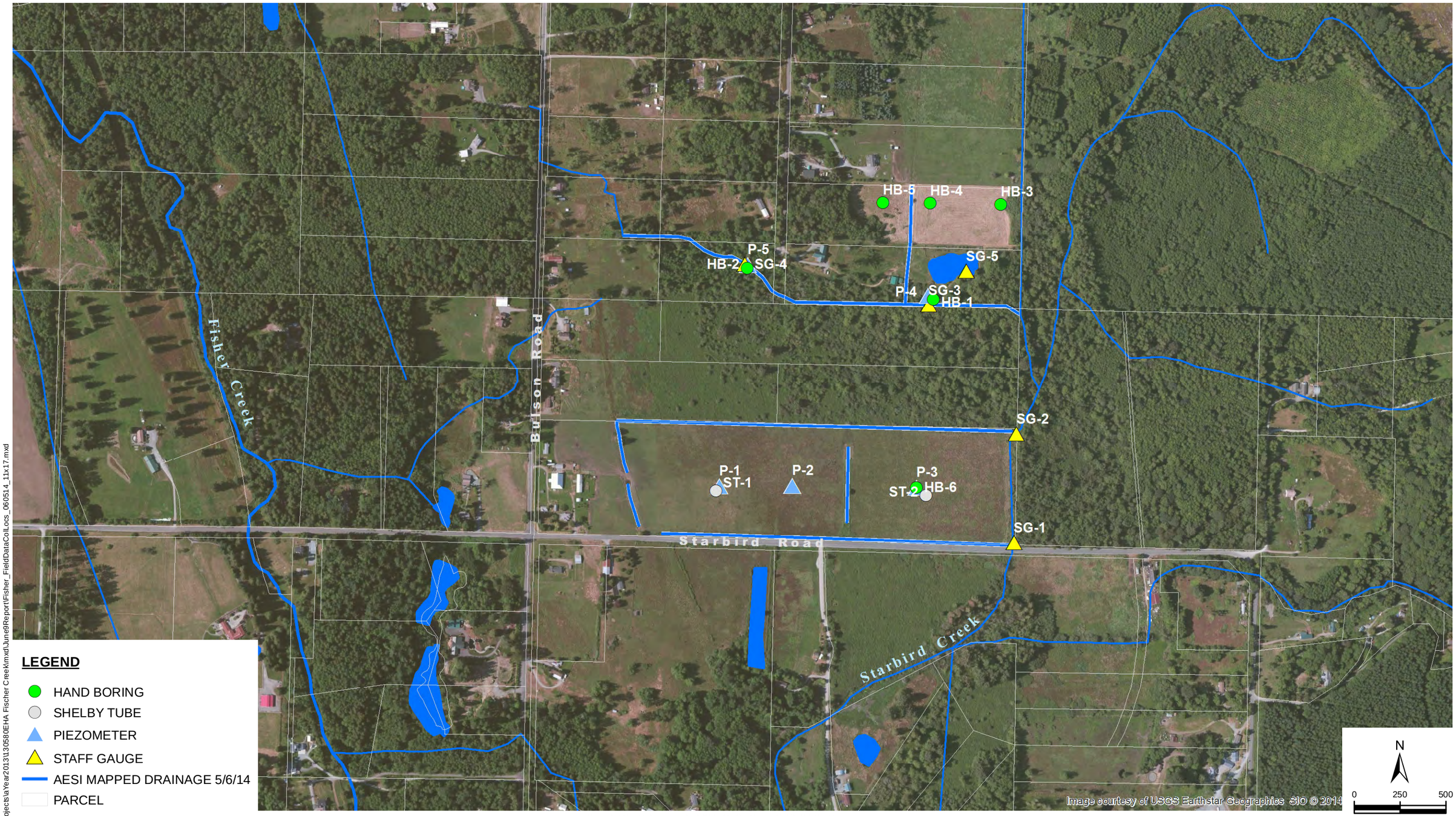
SNOHOMISH AND SKAGIT COUNTIES, WASHINGTON

FIGURE 4

DATE 6/14

PROJ. NO. EH130580A

Document Path: H:\GIS_Projects\aYear2013\130580EHA Fischer Creek\mxd\June9Report\Fisher_GeoSoilBasePotSiteLocs_060514_11x17.mxd



LEGEND

- HAND BORING
- SHELBY TUBE
- PIEZOMETER
- STAFF GAUGE
- AESI MAPPED DRAINAGE 5/6/14
- PARCEL

REFERENCE: BING, SKAGIT CO., USGS REPORT 2009-5270

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

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FIELD DATA COLLECTION POINTS

FISHER CREEK BASIN

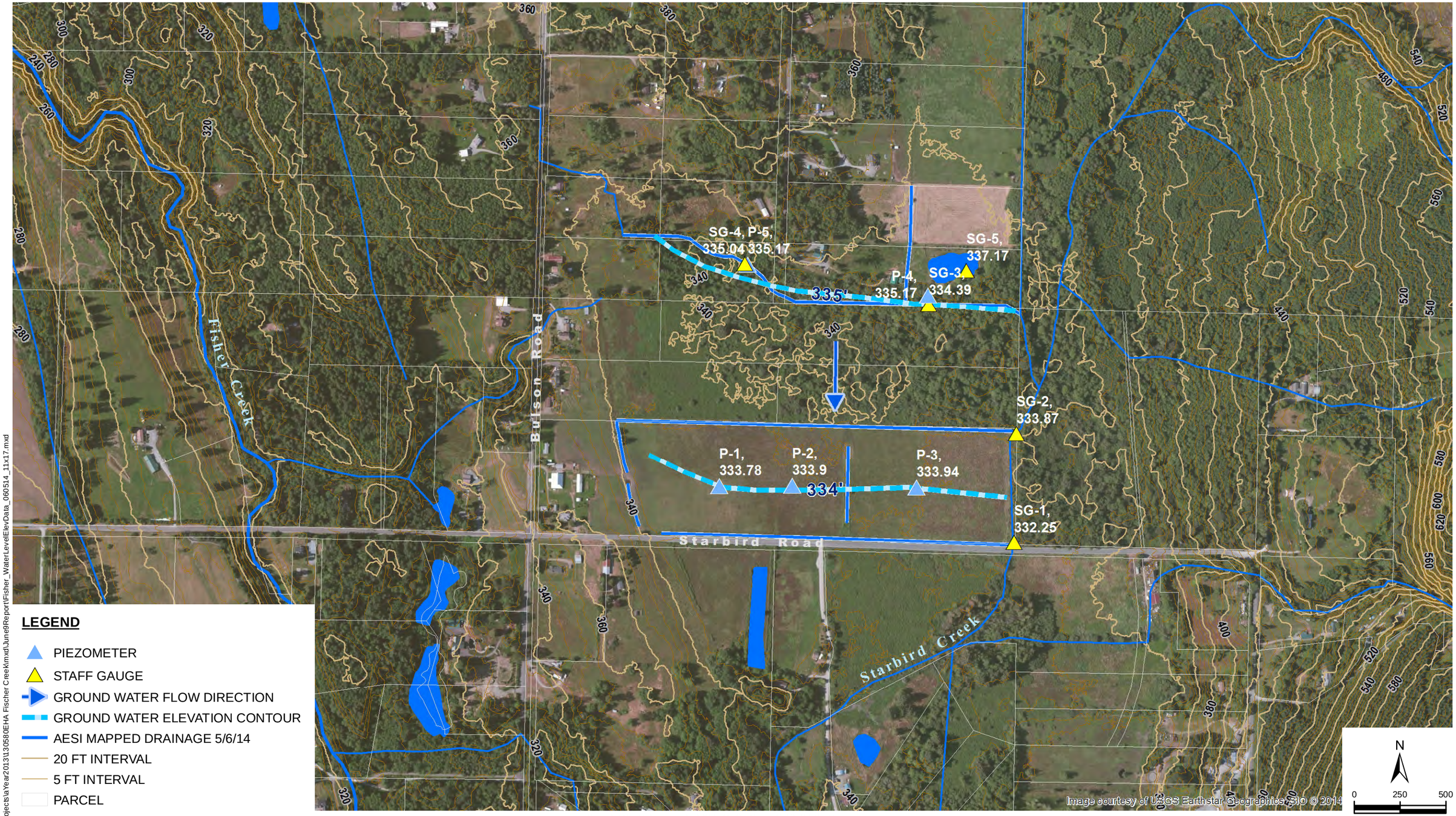
SNOHOMISH AND SKAGIT COUNTIES, WASHINGTON

FIGURE 5

DATE 6/14

PROJ. NO. EH130580A

Document Path: H:\GIS_Projects\aYear2013\130580EHA Fischer Creek\mxd\June9Report\Fisher_FieldDataCollLocs_060514_11x17.mxd



LEGEND

- PIEZOMETER
- STAFF GAUGE
- GROUND WATER FLOW DIRECTION
- GROUND WATER ELEVATION CONTOUR
- AESI MAPPED DRAINAGE 5/6/14
- 20 FT INTERVAL
- 5 FT INTERVAL
- PARCEL

REFERENCE: BING, SKAGIT CO., USGS REPORT 2009-5270

NOTE: BLACK AND WHITE REPRODUCTION OF THIS COLOR ORIGINAL MAY REDUCE ITS EFFECTIVENESS AND LEAD TO INCORRECT INTERPRETATION.

Document Path: H:\GIS_Projects\a\Year2013\130580EHA Fischer Creek\mxd\June9Report\Fisher_WaterLevelElevData_060514_11x17.mxd

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WATER LEVEL ELEVATION DATA - MAY 6, 2014

FISHER CREEK BASIN

SNOHOMISH AND SKAGIT COUNTIES, WASHINGTON

FIGURE 7

DATE 6/14

PROJ. NO. EH130580A

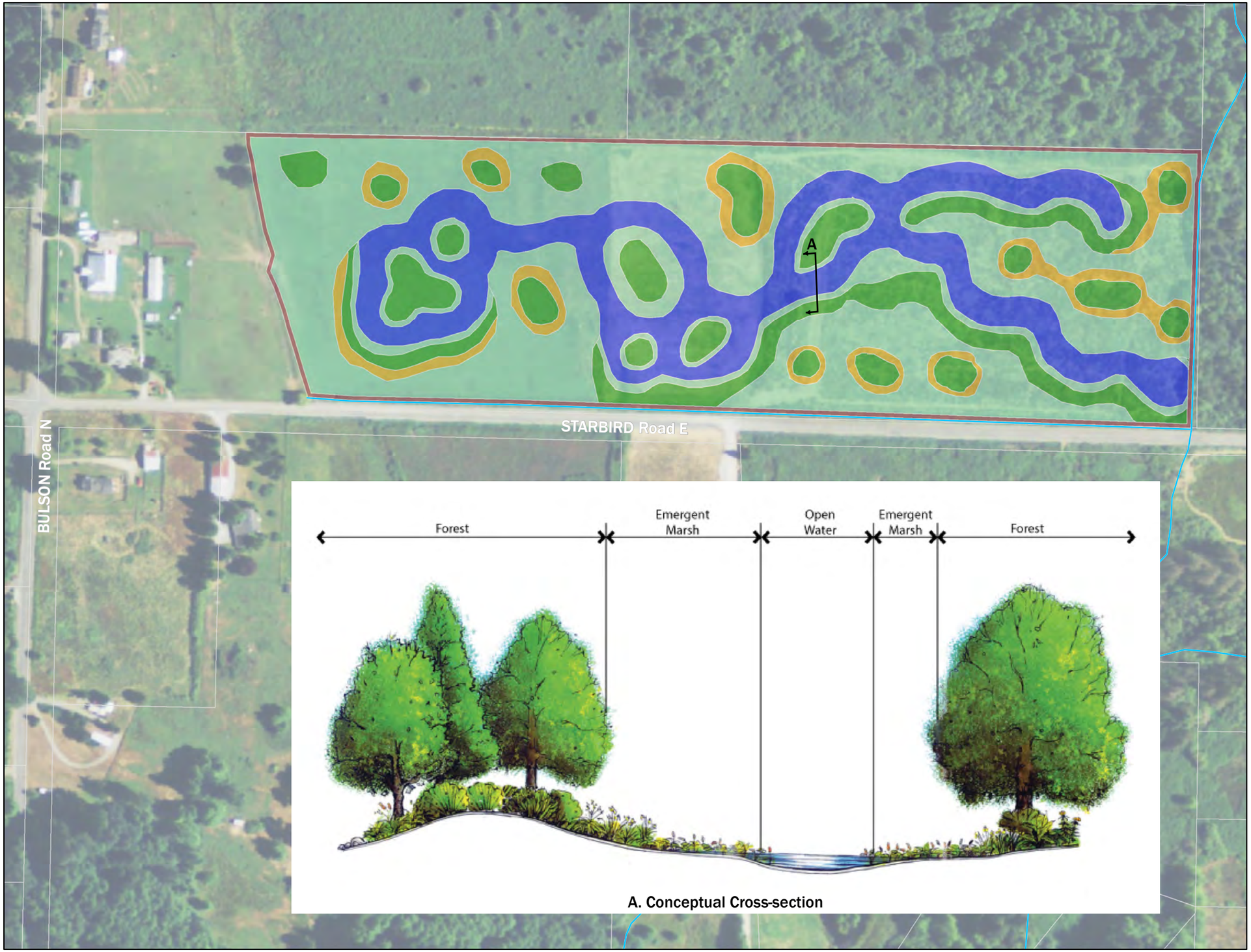

Figure 8.
Conceptual Plan for Site 1.

Legend

Proposed Habitats

- Emergent marsh
- Forest
- Forest perimeter berm
- Open water
- Scrub-shrub

- Creek
- Cross-section
- Parcel

N

0 112.5 225 450 ft

HERRERA

NAD 1983
Washington State Plane North FIPS 4601 Feet

USDA, Aerial (2013)

Produced By: GIS
Project: K:\Projects\Y2014\14-05841-000\Project\Hanika_prop_wetland_habitats.mxd (6/18/2014)