Hydrogeologic Study of the Lower Dosewallips/Brinnon Area

Prepared for:
WRIA 16 Planning Unit

**Funding Source: WRIA 16 Base Grant,
Department of Ecology Grant #G9900020**

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Acronym List

afy	acre-feet per year
bgs	below ground surface
cfs	cubic feet per second
DEM	digital elevation model
DNR	Washington State Department of Natural Resources
DOH	Washington State Department of Health
Ecology	Washington State Department of Ecology
^{o}F	degrees Fahrenheit
ft/ft	feet per feet (hydraulic gradient)
gpm	gallons per minute
LiDAR	light detection and ranging
mg/l	milligrams per liter
mybp	million years before present
RM	river mile
SWL	static water level
µS/cm	microsiemens per centimeter
USGS	U.S. Geological Survey
WRIA	Water Resources Inventory Area
WRTS	Water Rights Tracking System

Executive Summary

This report presents a Phase II Level II Study of the hydrogeology of the Lower Dosewallips/Brinnon Area under the Watershed Planning Act. The Dosewallips River basin is located in southern Jefferson County, within the Skokomish-Dosewallips Watershed Planning area. The purpose of the study is to develop the hydrogeologic framework for the lower Dosewallips River basin, in and around the community of Brinnon. The study provides a baseline of existing surface water/groundwater interaction within the basin as a basis for evaluating future water resource management decisions, including additional water supply development. The Brinnon area is considered in need of further assessment with respect to hydraulic continuity of groundwater and surface water due to the current degree of land development, anticipated growth, and pending water rights applications.

The scope of work for this project included:

- Defining principal aquifers and aquitards through compilation and review of existing hydrogeologic data;
- Evaluation of groundwater flow within the principal aquifers through sounding of selected wells and wellhead elevation survey by Jefferson County; and,
- Analysis of groundwater/surface water interaction.

Field methods for evaluating groundwater/surface water interaction included extensive monitoring of gaining and losing reaches of the river using seepage runs, mini-piezometers, temperature and specific conductance measurements and naturally occurring geochemical tracers.

The principal aquifers in the lower Dosewallips/Brinnon area occur in unconsolidated deposits and in basalt bedrock. Coarse-grained Recent Alluvium and older glacial deposits comprise the unconsolidated aquifer. The unconsolidated aquifer deposits generally exhibit weakly confined or unconfined conditions, depending on the presence/absence of fine-grained deposits. An aquitard comprised of glacial lake deposits, glacial till and local fine-grained alluvium results in local confinement of the unconsolidated aquifer. The water-bearing nature of the basalt bedrock aquifer (Crescent Formation) is variable and appears primarily associated with secondary fracture permeability. Water within the basalt aquifer is typically confined.

Recharge to the unconsolidated aquifer occurs as a result of direct infiltration of precipitation including mountain front recharge and, in the Brinnon Flats area, of losses from the Dosewallips River. Groundwater flows into the Brinnon Flats area from the upland areas and from the Dosewallips River subflow. Discharge of groundwater occurs into a spring creek that flows through Whitney Gardens and by direct discharge to tidal sloughs and Hood Canal. Discharge from wells also occurs, although pumping withdrawals are expected to be a relatively small component of the total discharge.

In the upland terrace areas, the data suggest a downward groundwater flow gradient exists between the unconsolidated aquifer and the underlying basalt aquifer. Above river mile 1 (RM-1), groundwater flow in the unconsolidated aquifer discharges into the Dosewallips River. Local losses from the river to the alluvial aquifer occur, but this groundwater is discharged back into the river at the bedrock constrictions.

Groundwater in the basalt aquifer flows from the upland areas toward the Dosewallips River. The relative head difference between the unconsolidated aquifer and the basalt aquifer in the lowland area is unknown, but is expected to be relatively small.

The Dosewallips River was subdivided into three reaches for study of groundwater/surface water interaction. The downstream reach (Reach 1) is defined by a bedrock constriction at RM-1 and by Hood Canal on the downstream end. The upstream end of Reach 2 is defined by a bedrock constriction at about RM-3.2 and the downstream end by the bedrock constriction at RM-1. Reach 3 begins at the mouth of a bedrock canyon near the National Forest boundary and ends at the upper end of Reach 2.

The Dosewallips River exhibits neutral to gaining behavior downstream of the National Forest boundary and upstream of RM-1 (Reaches 2 and 3). Below RM-1, the river loses water to the groundwater flow system. Analysis of vertical gradients indicates losses from the river to the groundwater system reach a maximum in June when the river is high from spring runoff and groundwater levels have dropped in response to diminished precipitation. Groundwater discharge into the river was observed at RM-1 and also likely occurs at the bedrock constriction at about RM-3.2. The discharge of groundwater to surface water is greatest during winter months when groundwater levels reach a seasonal maximum as a result of heavy winter precipitation.

Water within the unconsolidated aquifer is typically calcium-bicarbonate type. Two wells sampled in the Brinnon Flats area exhibited near-identical chemical characteristics to Dosewallips River surface water, consistent with Dosewallips River losses providing recharge to the unconsolidated aquifer. Isotope data and continuous water level measurements indicate that recharge in the Brinnon Flats area also includes a precipitation component.

The following recommendations for future work are made to:

- Improve definition of the seawater/freshwater interface by mapping chloride distribution in wells;
- Improve understanding of storage limitations in the basalt aquifer by aquifer testing of basalt wells in order to provide decision-making information for future groundwater development; and
- Develop a water balance for use in conjunction with the above recommendations to define safe yield of the aquifer.

Field work for this project would not have been possible without the assistance of many residents of Brinnon and the Dosewallips River valley. We thank them for allowing access to their property and wells.

1 Introduction

This section reviews the project background to the study, presents an overview of the scope of work, and discusses the general characteristics of the study area.

1.1 Background

This report presents a Phase II Level II study of the hydrogeology of the Lower Dosewallips/Brinnon Area under the Watershed Planning Act. The study was initiated by the Water Resources Inventory Area 16 (WRIA 16) Planning Unit to develop the hydrogeologic framework for the lower Dosewallips River basin, in and around the community of Brinnon, with particular emphasis on the groundwater/surface water interaction. The study findings provide a baseline to assess potential impacts of future water resources development.

The Planning Unit contracted with Aspect Consulting to begin work on this project in October, 2003. The study was initiated based on recommendations from the Level I technical assessment of the Skokomish-Dosewallips Basin (WRIA 16) (Golder Associates, 2003). The community of Brinnon, along with several other areas in the WRIA 16 watershed, was considered in need of further assessment with respect to hydraulic continuity due to the current degree of land development, anticipated growth, and pending water rights applications on file with Washington State Department of Ecology (Ecology).

1.2 Overview of Dosewallips Basin

The Dosewallips River basin is located in southern Jefferson County, within the Skokomish-Dosewallips Wastershed Planning Area. The locations of the WRIA 16 Planning Area and the Dosewallips Subbasin are shown in Figure 1.1. The Dosewallips River originates in the Olympic Mountains and is the largest river entering northern Hood Canal. The drainage area is approximately 83,825 acres (130.9 square miles) (Golder Associates, 2003). The river originates in sandstones and siltstones at its highest elevations. Basalts of the Crescent Formation underlie the mid-portion of the basin, and glacial deposits and Recent Alluvium underlie the lower section. Slopes are relatively gentle in the glacial valley bottoms and steepen toward the western headwaters (Figure 1.2).

Brinnon is located on the north side of the lower Dosewallips River near its confluence with the Hood Canal, on a broad alluvial plain referred to as Brinnon Flats. Dosewallips State Park occupies the low-lying area on the south side of the lower Dosewallips River. The Dosewallips River delta is second largest in the Hood Canal, after the Skokomish. On the north side of the river mouth, a large estuarine marsh is drained by several blind, tidal sloughs (Correa, 2003). Several diked areas are present within the estuarine marsh, and tidal flow into these areas in controlled in places by tide gates (WDFW/Point No Point Treaty Tribes, April 2000). A map of the Dosewallips River basin is shown in

Figure 1.2. An aerial photo montage of the lower Dosewallips River basin is shown in Figure 1.3.

There are approximately 28.3 miles of mainstem river and 104.5 miles of tributaries. Approximately 47,231 acres (56 percent) of the drainage lie within Olympic National Park and 22,028 acres (26 percent) fall within Olympic National Forest (Golder Associates, 2003). The remaining 17 percent is divided among forestlands, rural residential development, park, and commercial uses. Highest elevation in the basin is Mount Deception at 7,788 feet.

The average annual discharge at the former U.S. Geological Survey (USGS) gaging station at RM-7 is 446 cubic feet per second (cfs) for the period 1930 to 1951. The runoff pattern is bimodal, with peak runoff occurring as the result of winter rains in the period from November through February and again as a result of spring snow melt in May and June. A mean annual hydrograph for the period of 1930 to 1951 is presented in Figure 1.4. The WRIA 16 Planning Unit is currently collecting streamflow data at the Highway 101 Bridge for the purposes of instream flow recommendations.

The river valley below RM-3 was a forested floodplain with active side channels until the late 1800s, when the area was converted to a channelized stream with predominantly pasture floodplain (WDFW/Point No Point Treaty Tribes, April 2000). The middle and lower watersheds were intensively logged beginning in the late 1800s. Wetland and tidal slough infilling occurred during the development of the Town of Brinnon and construction of Highway 101. This infilling severed the connection between tide channels and the river. Two major distributary channels that were apparently connected to the river higher in the delta were cutoff by these activities (WDFW/Point No Point Treaty Tribes, April 2000).

The upper Dosewallips drainage basin is comprised of the West Fork of the Dosewallips, Silt Creek, and Dosewallips Subbasins. West Fork of the Dosewallips is the largest of these subbasins with an area of about 20 square miles. Areas of Silt Creek and Dosewallips (above the Silt Creek confluence) subbasins are approximately 14 and 16 square miles, respectively. Each of the subbasins has glaciers on the mountain divides. The largest of the glaciers is Eel Glacier, which is located on Mount Anderson, at the headwaters of Silt Creek.

A few small lakes are present within the Dosewallips basin. Lakes on lower tributaries include Jupiter Lakes and Lake Constance. At higher elevations several small tarn lakes created by alpine glacial scour are present.

Rocky Brook is the largest tributary on the lower Dosewallips with an area of about 8.8 square miles. A penstock and electrical generating facility are present near the base of Rocky Brook. Its unknown if these facilities are still active.

The year 2000 population of the Dosewallips drainage was 589 and is projected to increase to 675 by 2010, assuming continuance of the 1.4 percent growth rate that occurred between 1990 and 2000 (Golder Associates, 2003). Year 2000 groundwater use was estimated at 76 acre-feet total, 67 acre-feet served by public water systems and 9 acre-feet served by exempt wells. Water use is expected to increase to 88 acre-feet per year (afy) by 2010. The Town of Brinnon has no community water system. A groundwater sourced public water system in the Lazy C area is operated by Jefferson County PUD No. 1. Several smaller community water systems supplied by wells also exist. These include Dosewallips State Park, Jefferson County Fire District, Brinnon School District, and Brinnon Water Company. A permitted water right to divert 50 cfs of water from the Dosewallips has been maintained by the City of Port Townsend since 1956, but has never been acted upon (WDFW/Point No Point Treaty Tribes, April 2000). Minimum flow criteria were developed by Ecology in 1985, but were not implemented. There is currently an administrative closure to surface water withdrawals for the period from July to October; however, no instream flows have been set by rule making (WDFW/Point No Point Treaty Tribes, April, 2000; Golder Associates, 2003). The WRIA 16 Planning Unit is working under Watershed Planning Act (ESHB 2514/RCW 90.82) to develop recommended instream flows by Fall 2005, including collection of instream flow data for a 1-year period beginning in June 2004 (Ecology, January 2004).

Several claims, permits or certificates for small diversions (<1 cfs) from the lower Dosewallips River for irrigation or domestic use were identified in Ecology’s Water Rights Tracking System (WRTS) database. A certificate of right for 5 cfs for fish propagation purposes was issued to U.S. Department of Fish and Wildlife in 1958.

1.3 Purpose and Scope

The Planning Units objectives in this study were to:

- Develop a hydrogeologic framework of the Brinnon Area including defining groundwater flow; and,
- Better understand the groundwater/surface water interaction along the lower reaches of the Dosewallips River.

A scope of work was developed to meet these objectives consistent with the Planning Unit funding. The scope consisted of the following tasks:

- **Compilation and review of existing hydrogeologic data** (compilation of well log information from public agencies and published reports).
- **Hydrostratigraphic analysis** (defining principal aquifers and aquitards).
- **Development of Groundwater Elevation Contour Maps** (sounding of selected wells, wellhead elevation survey by Jefferson County, and generation of groundwater flow maps).
- **Groundwater/Surface Water Interaction Analysis** (extensive monitoring of gaining and losing reaches of the river using mini-piezometers, temperature and specific conductance measurements, seepage runs, and naturally occurring geochemical tracers).
- **Report Preparation.**

2 Geologic Conditions and Basin Glaciation

Geologic units comprise the framework through which groundwater flows. The geologic history and distribution of geologic units are described below.

2.1 Previous Investigation and Data Sources

The principal data source for geologic conditions in the Brinnon area is geologic mapping by Carson (1976) compiled on the Seattle 1:100,000 quadrangle. Geologic mapping of eastern Jefferson County, including the Brinnon area, also is published by Ecology (Grimstad and Carson, 1981) and in a master's thesis from the University of Washington (Frisken, 1965). The upper portion of the Dosewallips River basin is presented in Washington State Department of Natural Resources (DNR) 1:100,000 geologic map of the Mount Olympus Quadrangle (Gerstel and Lingley, 2003). Spicer (1986) inventoried and evaluated changes in modern alpine glacial size.

2.2 Geologic Units

The lower Dosewallips River Basin is covered by a considerable thickness of sediment, including glacial deposits and Recent Alluvium. Beneath those unconsolidated sediments and underlying the middle reaches of the Dosewallips River are basalts of the Crescent Formation. Tertiary (1.8 to 65 million years before present [mybp]) silt and sandstones underlie tributaries in the higher reaches of the river within Olympic National Park. The principal geologic units in the study area, from youngest to oldest are:

- Recent Alluvium
- Recessional Glacial Outwash
- Vashon Till
- Vashon Glaciolacustrine Deposits
- Vashon Advance Outwash
- Crescent Formation (basalt)

The distribution of these units at the surface is shown on the geologic map in Figure 2.1 (from DNR 1:100,000 scale map). Greater detail of mapped geologic conditions is available in Carson (1976), particularly for exposures along steep hill slopes.

With respect to groundwater flow in the study area, the most important geologic units are Vashon Glacial/Recent Alluvial deposits and the Crescent Formation. The Recent Alluivum and glacial deposits form a shallow aquifer collectively referred to as the unconsolidated aquifer. Water-bearing basalts of the Crescent Formation form a second aquifer in the project area referred to as the basalt aquifer. Characterization of these units as aquifers and aquitards is further discussed in Section 3.

2.2.1 *Crescent Formation*

The **Crescent Formation** is a basalt of marine origin. The upper Crescent Formation is flow dominated and consists predominantly of columnar to randomly jointed basalt. The lower member of the Crescent Formation is comprised of pillows to massive flows and flow breccias (Gertsel and Lingley, 2003; Haug, 1998). The upper Crescent Formation outcrops a short distance upstream of Wilson Creek and the pillow dominated, lower member outcrops downstream of this point and is exposed in the study area. The Crescent Formation was uplifted and folded into a broad antiform (a convex upward fold of rocks) during formation of the Olympic Mountains. The basalt is, therefore, fractured with moderately to steeply dipping beds.

In the study area, the Crescent Formation basalts underlie the glacial deposits and are exposed on the hill slopes of the Dosewallips River valley. The Dosewallips has incised through two basalt promontories segmenting the lower river into three distinct reaches. Moving downstream, the upper reach (referred to as Reach 3 in this report), is defined at the upstream end by a bedrock canyon near the National Forest boundary and at the downstream end by a bedrock constriction just downstream of the confluence with Rocky Brook. The downstream end of the middle reach (Reach 2) is defined by a bedrock constriction at about RM-1. The lower reach extends from the bedrock constriction at RM-1 to the Hood Canal. These reaches are further discussed in Section 4 and are presented in Figure 4.1.

A contour map showing the elevation of top of basalt in the study area is shown in Figure 2.2. The map was developed by extrapolating between known basalt elevations identified on well logs, and minimum basalt depth obtained from wells completed in the unconsolidated deposits. Well logs are summarized in Table A-1 in Appendix A. The map indicates that bedrock is at or below sea level from the coast to about 2 miles upstream, with the lowest elevation bedrock surface along the river channel. Two wells (136 and 137) encountered bedrock at about elevation -60 feet (NAVD 88) near the coast. A small ancestral bedrock channel is indicated on the upland by well 106. The glacial deposits appear to form a thin veneer over bedrock in the upland areas. Highest glacial deposits in the project vicinity are at about elevation 1,360 feet. The greatest depth to bedrock (about 226 feet below ground surface [bgs] in well 126, above the gravel pit) occurs at the upland terrace on the north margin of Brinnon Flats.

2.2.2 *Glacial Deposits*

Unconsolidated glacial deposits overlying the Crescent Formation in the study area were deposited predominantly during the Fraser Glaciation about 15,000 years before present. The Fraser Glaciation was one of five glacial advances ranging from 2 million to 10,000 years before present.

Pre-Fraser Glacial Deposits

Other than two isolated outcrops in the upland areas, no pre-Fraser deposits have been mapped in the area. Frisken (1965) speculated that cemented sand and gravel encountered at the base of the State Park's well (well 4) may be pre-Fraser deposits.

Alpine Glacial Deposits

Two distinct stades (substages of a glaciation) occurred during the Fraser Glaciation that affected the project area. The Evans Creek Stade occurred during the initial cooling associated with the Fraser Glaciation. During this cooler period (about 20,000 to 16,000 years ago), continental glaciers advanced southward from British Columbia and in the alpine regions of western Washington. A radial system of large alpine valley glaciers developed in the interior of the Olympic Mountains (Spicer ,1986). Alpine glacial deposits have been mapped as far downstream as the National Forest boundary (about RM-6). Although not identified in the study area, they could be present in the subsurface in the upper project area.

Continental Glacial Deposits

A minor warming event occurred after the Evans Creek Stade, and the alpine glaciers retreated upvalley. Following retreat of the alpine glaciers, the continental glacier continued to advance during the Vashon Stade of the Fraser Glaciation. At the onset of the Vashon Stade, an arm of the ice sheet advanced southward, blocking off the Strait of Juan de Fuca, forming a large pro-glacial (i.e., in front of the glacier) lake. The continental glacial advance eventually blocked drainages of the Olympic Mountain valleys including the Dosewallips River. Fine-grained sediment settled into the proglacial lake. The continental glaciers reached their maximum southerly limit about 15,000 years ago (Booth, 1986). At the maximum glacial extent, the Olympic Mountains were bounded by the continental Cordilleran ice sheet with the Puget ice lobe to the east and the Juan de Fuca ice lobe to the north. Glacial ice covered the area to about elevation 3,000 feet (Grimstad and Carson, 1981).

As the Puget lobe advanced southward, sediments were deposited by glacial meltwater (on top of the lacustrine silts), creating an outwash plain in front of the advancing ice. This unit is referred to as **Vashon Advance Outwash.** The unit tends to be finer grained in the lower sections and coarsens upward as the glacier advanced south and deposition occurred closer to the glacial snout by higher energy streams proximal to the glacier. The Vashon Advance Outwash is a regionally important aquifer. An exposure of Advance Outwash has been mapped between RM-3 and RM-4 and its presence is inferred in the subsurface based on well log descriptions and mapped exposures.

During the Vashon period, the Hood Canal was a north-south trending glacial trough along the west side of the Puget ice lobe (Haug, 1998). As the Puget ice lobe advanced into the Hood Canal, ice entered the many drainages of the east Olympic Mountains including the Dosewallips River valley, impounding stream flow behind the ice-choked, lower river valleys. Relatively fine-grained **Glaciolacustrine Deposits** comprised predominantly of silts and clays were deposited in the low-energy lake environment in these drainages. Good exposures of glaciolacustrine unit are seen on the undercut river bank across from the Lazy C development where they are mantled by recessional outwash. Frisken (1965) suggests two advances of the valley glacier into the Dosewallips drainage occurred. The maximum upvalley ice advance is marked by end moraines deposited about 5.4 miles upvalley.

Vashon Till was deposited beneath the ice as continental glaciers advanced. Glacial lodgement till is an unsorted to poorly-sorted soil mixture composed of clay- to bouldersize particles that were deposited at the base of the glacier. Compaction by the weight of the overlying ice resulted in a concrete-like texture and appearance. Glacial till overlies the advance outwash and mantles the bedrock in the upland areas. Glacial till is present overlying the lacustrine deposits in the steep slope rising up from the floodplain, in Section 34 above RM-1. The till is mantled by recessional outwash over much of this area.

Retreat of the glacial ice resulted in deposition of **Recessional Outwash**. Recessional Outwash typically consists of well-sorted sands and gravels deposited in meltwater channels, deltas and depositional environments. Where higher energy streams enter lakes, a rapid decline in energy results in deposition of the suspended load and deltas form. A large delta complex comprised of stratified sand and gravel is comprises a terrace the north side of the Dosewallips River drainage near Highway 101 (Grimstad and Carson, 1981). A small remnant of the terrace also is present upstream in the southeast portion of Section 28 below RM-3. The terrace likely extended across the lower valley prior to erosion by the Dosewallips River (Frisken, 1965).

The lake in the Hood Canal trough drained during the breakup of the continental ice sheet resulting in erosion of glacial deposits within the stream valley. Downcutting occurred, which superimposed the rivers onto the basalts of the Crescent Formation (Frisken, 1965) and resulted in the bedrock constrictions observed at RM-1 and RM-3.

Post-Pleistocene Glaciation

Alpine glaciers wasted away during post-glacial time, and all but the largest glaciers on Mount Olympus and Mount Anderson may have disappeared completely about 8,000 to 4,000 years before present (Spicer, 1986). Temperatures during this time were estimated to be about 2 degrees C above present temperatures. This period was followed by a gradual cooling. The period from 1450 to 1800s is referred to as the “Little Ice Age,” which resulted in glacial advances (Mayewski and Bender, 1995). Dating of glacial moraines on Mount Olympus suggest that the Olympic alpine glaciers reached their maximum post-Pleistocene (within the past 10,000 years) extent in the early 1800s (Spicer, 1986).

The Dosewallips River channel transported and deposited sediment locally derived from the Olympic Mountains. These Recent Alluvial deposits consist predominantly of coarse bedload materials deposited in the Dosewallips River channel. Floodplain deposits formed terraces about 5 to 10 feet above the current river. The floodplain terraces narrow where the river incises through bedrock restrictions. The Recent Alluvium is comprised almost entirely of locally derived clasts. Clasts from northern provenances (i.e., transported by continental glaciation) were not identified in the Recent Alluvium (Frisken, 1965). A large delta has built out into the Hood Canal from the Dosewallips River. Within the study area, Recent Alluvial deposits have been identified predominantly within the lower portions of the stream valley, below about RM-4.

The upper portions of the Dosewallips drainage have been subdivided into the following subbasins: West Fork of the Dosewallips River, Silt Creek, and the Dosewallips River (Figure 1.2). Each of these subbasins supports alpine glaciers, which in turn, feed streamflow into the Dosewallips River. Silt Creek is the most heavily glaciated of the three subbasins. Nine glaciers have been identified in the Silt Creek drainage ranging in size from 0.008 to 0.43 square mile (Spicer, 1986). Of these glaciers, the Eel Glacier is the largest. Other glaciers, including Hanging Glacier, are all relatively smaller, with areas less than 0.07 square mile size. Eight glaciers have been identified in the West Fork of Dosewallips ranging in size from 0.004 to 0.05 square mile. Twelve glaciers have been identified in the Dosewallips subbasin ranging in size from 0.0004 square mile to the Mystery Glacier at 0.06 square mile. These glaciers include valley glaciers, mountain glaciers, and perennial ice patches (Spicer, 1986).

Spicer (1986) examined the glacial variations in the Dosewallips River drainage for the period 1890 to 1982 using a combination of historical ground photos and aerial photography. Overall glacier recession characterized this period. Greatest losses of ice mass occurred in the 1930s and 1940s, with a corresponding rise in the mean glacial altitude. From 1939 to 1982, the area of the Eel Glacier was reduced by 17 percent with an overall reduction of 40 percent since its Neoglacial maximum. The Mystery Glacier was reduced by about 19 percent from 1939 to 1982, with 31 percent reduction since its maximum extent. Based on studies of other glaciers in the Cascade region, the glaciated area of the Dosewallips River basin has continued to shrink since Spicer's work in 1986.

2.3 Effects of Glacier Size on Streamflow

Glaciers act as a reservoir for water, storing it as snow and ice, and internally. Glaciers that are increasing in size will "bank" water that may otherwise be available for runoff. Glaciers that decrease in size over a winter will augment stream flows with glacial melt water (Fountain and Tangborn, 1985).

Glaciers delay peak runoff through melting of snow and ice. Factors that encourage snowmelt (solar radiation, cloud cover and snow-ice albedo) peak in late July and August. As such, glaciers tend to supplement stream flow during periods when runoff from non-glacial basins is at its lowest. Qualitative inspection of the glacial cover in the Dosewallips basin indicates a relatively small amount of the total basin area has glacial cover. The total contribution to runoff from a glacial basin is proportional to the glaciated area (Fountain and Tangborn, 1985). The relatively small glaciated area of the Dosewallips basin would therefore be expected to have a small contribution to the total basin runoff. However, because the peak glacial runoff occurs during low summer flows, the glacial contribution may be significant component of low flows.

Further glacial retreat would diminish glacial runoff and consequently lower the summer flows. Gaging of the glaciated subbasin tributaries and quantification of changes in glacial mass balance would be necessary to quantify the contribution of glacial melt water to low flows on the Dosewallips River and to project the impacts of diminished flows as a result of further glacial retreat.

3 Hydrogeology

An aquifer is a water-bearing unit comprised of some combination or part of geologic formations that can yield significant quantities of water to wells and springs. In the lower Dosewallips-Brinnon area, the primary aquifers are:

- the unconsolidated aquifer comprised predominantly of Recent Alluvial deposits and of glacially deposited sand and gravel layers; and,
- the basalt aquifer comprised of the Crescent Formation.

The principal constraints on groundwater development in the region relate to the relatively low yield potential of the basalts and hydraulic continuity with the Dosewallips River in the unconsolidated aquifer. The potential for hydraulic continuity between the basalt aquifer and the Dosewallips River exists, but insufficient data were available to define this relationship. Seawater intrusion may also constrain groundwater development in the region, although limited data exists on the occurrence of saline water in the project area.

3.1 Well Information

There is little published information on groundwater conditions in the lower Dosewallips-Brinnon area. Grimstad and Carson (1981) discuss groundwater conditions in east Jefferson County. Well information was compiled from several sources in this study. Well logs on file with Ecology for the study area were compiled. Washington State Department of Health (DOH) listings of Group A and B water systems in the project area were obtained. Jefferson County's electronic well database and wells in the project area from the USGS well database were also obtained.

Well construction details and aquifer completion zones are summarized in Appendix A, Table A-1. Also included are wells that were identified during the course of our field work, but which had not been identified by any of the previous sources. Comprehensive, field identification and verification of wells in the project area was not performed. Each well was assigned a unique, consecutive identification number for this study.

A total of 146 wells were identified in the project area from the data sources. Of these wells, eight were identified as sources for Group A systems and seven were identified as Group B systems. The largest annual groundwater right (either claim or certificate) identified in the study area (as of 2002) was Washington State Parks and Recreation Commission with an instantaneous withdrawal rate of 60 gallons per minute (gpm) and an annual rate of 36 acre-feet.

3.2 Hydrostratigraphic Units

A hydrostatigraphic unit is a geologic formation, part of a formation, or a group of formations with similar hydrologic characteristics such as porosity and permeability that can be characterized as an aquifer or non-water bearing confining layer.

Three hydrostratigraphic units are of importance in the hydrogeologic conceptual model for the lower Dosewallips/Brinnon area. These include:

- Coarse-grained, unconsolidated glacial and alluvial deposits, which form the unconsolidated aquifer;
- Fine-grained glacial till, glaciolacustrine deposits, and alluvial deposits, which act as an aquitard; and,
- The basalt, which acts as both an aquifer as an aquitard.

Of the 146 wells identified in Table A-1, 67 are completed in unconsolidated deposits and 66 are completed in the basalt aquifer. For the balance, the completion cannot be determined with existing information. Figure 3.1 shows well locations and identifies the aquifer in which the well was completed. Wells completed in basalt predominate in areas away from the river floodplain, although at least two wells (136 and 137) located in the lowland area near the coast penetrate through the unconsolidated aquifer and are completed within the basalt. Each of these wells encountered salty water in the unconsolidated aquifer before being completed in the basalt.

Five hydrostratigraphic cross sections were developed through the study area. The locations of the cross section lines are shown in Figure 3.2 and the cross sections are presented in Figures 3.3 through 3.7. The geologic interpretation of the soil descriptions as shown on the well logs is incorporated into the sections based on mapped surficial geology and assuming a relatively continuous stratigraphic sequence. As additional age dating and descriptions of geologic materials are developed in the Dosewallips area, these geologic assignments may change.

The major hydrostratigraphic units are depicted with similar color to assist in differentiating aquifers and aquitards. The unconsolidated aquifer consists predominantly of glacial outwash sands and gravels and Recent Alluvium. Where the permeable Recent Alluvium and permeable glacial deposits are in direct contact with one another, water moves freely between them. These coarse-grained geologic units are considered collectively as a hydrostratigraphic unit and are shown in a yellowish color in the cross sections. Where these units are saturated, they comprise the unconsolidated aquifer.

The glacial till, lacustrine deposits, and the fine-grained material within the Recent Alluvium act as an aquitard that retard groundwater flow. Where the aquitard overlies the unconsolidated aquifer, they may result in local confinement of the unconsolidated aquifer. The existing well log control suggests the fine-grained unit is continuous in the upper reaches of the study area (Section A-A', Figure 3.3), but shows lateral discontinuity in the lower reaches of the study area. The fine-grained units are shown in green on the cross sections.

Basalt wells are typically confined, and bear water from fracture zones and faults. Unlike the Columbia River basalts of eastern Washington where water-bearing flow tops may be traced over large distances, the greater structural complexity of the basalts in the Olympic Mountains makes correlating water-producing zones difficult. No apparent pattern to depth of yield from basalts could be identified with existing data. Several basalt wells have large intervals on the order of 100 feet or more open to the aquifer, indicating that only limited yield is obtained from fracture zones throughout the well depth. Well 61

(Lazy C well 4) was drilled to a depth of 440 feet and a small water-bearing zone from 302 to 305 feet was identified on the well log. This well was reportedly not used due to lack of production (Graham, 2003). Groundwater producing zones in the basalt are typically described as “fractured basalt” on driller’s logs, suggesting that water is predominantly derived from fracture zones as opposed to flow tops, where sedimentary interbeds would also be expected to be present and indicated on well logs.

3.3 Aquifer Hydraulic Properties

3.3.1 Specific Capacity

Specific capacity is a simple, empirical measure of well productivity that is computed by dividing the pumping rate in gpm by the water level drawdown below static level in feet (ft). Specific capacities are a function of both the aquifer and the well construction. Because drawdown commonly continues to increase slowly over time, specific capacity is most meaningful if the duration of pumping is specified. For wells of similar construction, specific capacity provides a measure of aquifer transmissivity. Transmissivity is a measure of the capacity of an aquifer to transmit water horizontally. Transmissivity is most accurately defined by pumping tests, but can also be estimated from specific capacity. Other than driller’s tests that provide limited drawdown data in the pumping well, no pump tests were identified for any wells in the study area. Specific capacities were calculated based on information provided on driller’s logs and are listed in Table A-1. Figure 3.8 is a map depiction of these data for the unconsolidated and basalt aquifers.

Specific capacities of the wells completed in basalt aquifer are considerably lower than the specific capacities of the wells completed in the unconsolidated aquifer. Most wells completed in the basalt aquifer have specific capacities of 0.5 gpm/ft of drawdown or less. In the unconsolidated aquifer, specific capacities are typically greater than 1. Nine wells of 34 shown on Figure 3.8 have specific capacities of 10 or greater. The highest specific capacities are found in wells in the Brinnon Flats area and are completed in the unconsolidated aquifer.

3.3.2 Static Water Level and Aquifer Storage

Static water level is measured as the depth to water in a well before pumping. Static water elevations, or heads, define the potentiometric surface of the aquifer. If the level to which water rises in the well is above the top of the aquifer, the aquifer is “confined” or “artesian”. If the water level is free to fluctuate within the aquifer zone and is not constrained by the stratigraphic top of the aquifer, it is an “unconfined” aquifer. The unconsolidated aquifer appears unconfined in the Recent Alluvial deposits close to the Dosewallips River and semi-confined or confined where it occurs beneath the lacustrine/till unit. The basalt aquifer is typically confined and one well (well 65) near the confluence with Rocky Brook was flowing at ground surface.

Static water level depths at the time of drilling are normally reported on driller’s logs. During this investigation, static water level measurements were made on 17 wells on March 18, 2004 and again on June 12, 2004 by Aspect Consulting and Jefferson County personnel. These wells plus 12 mini-piezometers were surveyed using survey grade GPS equipment by Jefferson County. In addition, as part of the surface water/groundwater interaction investigation, well 9 was instrumented with a pressure transducer. This well showed tidal fluctuations on the order of 1 foot that are discussed in Section 4.2. Static water level data are reported on Table A-1.

Storage coefficient is a dimensionless measure of the relationship between aquifer yield and drawdown. For equivalent quantities of groundwater withdrawn, drawdown of the potentiometric surface will be much greater in a confined (artesian) aquifer than in an unconfined (water table) aquifer. The pore space is drained in the unconfined case, whereas a confined aquifer yields water by elastic expansion of the aquifer skeleton and of the water as pressure is reduced. Storage coefficients are typically on the order of 10^{-5} for confined aquifers, 10^{-3} for semiconfined aquifers and 10^{-1} for unconfined aquifers. Storage coefficients are most reliably calculated from multi-well pumping tests where drawdown was monitored in an observation well. No multi-well pumping test data were available in the study area. Storage coefficients for the unconsolidated aquifer may be expected to be in the range of 10^{-1} to 10^{-3} and in areas with locally greater confinement could be expected to be around 10^{-4}. Storage coefficient in the basalt aquifer is expected to be low, on the order of 10^{-5}. Total storage at any given location within the basalt aquifer could be limited by poor interconnection of fractures.

3.4 Groundwater Flow

Based primarily on the June 12, 2004 static water level measurements and to a lesser degree on driller's reports, a potentiometric surface map was generated for the unconsolidated aquifer relative to mean sea level (Figure 3.9). Ground surface elevation control for the wells used in computing groundwater elevation are presented in Table A-1.

Groundwater in the unconsolidated aquifer in the Brinnon Flats area is recharged by subsurface flow from the upland areas and from stream losses in the lower Dosewallips River below RM-1. Direct runoff from upland areas provides recharge where it infiltrates into the unconsolidated material (referred to as mountain front recharge).

Below the bedrock constriction near RM-1, surface water from the Dosewallips River loses water to groundwater. The interaction of surface water and groundwater along the lower Dosewallips is presented in detail in Section 4. The unconsolidated aquifer discharges to a small spring creek that runs through Whitney Gardens. Examination of the aerial photographs (Figure 1.3) suggests this channel is a remnant of a former distributary channel. Discharge also likely occurs directly into the Hood Canal and into tidal sloughs through high-permeability alluvium and outwash. Limited aquifer discharge also occurs through wells completed within the aquifer. Upstream of RM-1, groundwater upwells and discharges into the Dosewallips River upstream of the bedrock constriction at RM-1 (refer to Section 4.2).

A groundwater elevation map of the basalt aquifer in the Brinnon area was constructed using average groundwater elevations relative to mean seal level (NGVD29) (Figure 3.10). The basalt aquifer flows from the upland areas toward the Brinnon Flats area. The basalt aquifer generally exhibits lower heads than the unconsolidated aquifer in the terraces on the north side of the river, suggesting downward movement of groundwater from the unconsolidated aquifer to the basalt aquifer. In places, for example well 100, the hydraulic connection between these units is limited and water within the unconsolidated formation perches on the bedrock. Two wells (wells 129 and 126) located near the edge of the terrace area do not indicate saturation of the overlying unconsolidated sediment.

Recharge to the basalt aquifer occurs through direct precipitation onto basalt exposures in upland areas and, in the unconsolidated terrace areas, through downward discharge of the unconsolidated aquifer. Available well data generally show an increasing depth to water with increasing well depth, indicating a downward vertical gradient within the basalts for basalt wells in the upland areas. Groundwater development in the Brinnon Flats area has been nearly exclusively from the unconsolidated aquifer, due to its shallow occurrence and limited expense of development.

Because of the absence of basalt wells in the Brinnon Flats area, the interaction between the unconsolidated aquifer and basalt aquifer cannot be characterized with certainty; however, two wells (136 and 137) were completed in basalt after penetrating saline water in the unconsolidated aquifer. Presuming that the water quality of the basalt aquifer in these wells is suitable for domestic use (e.g., has not been impacted by seawater) then a confined high head condition in the basalt aquifer can be inferred that limits seawater intrusion in this area.

Heads within the basalt aquifer are variable, indicating limited interconnection within the aquifer. The groundwater elevations presented in Figure 3.10 reflect the general pattern of head within the basalt aquifer. Because of the many local variations in head, the groundwater elevations were not contoured. Nearby wells completed in short distance of one another showed marked variations in head (see for example wells 85 and 86, cross section B-B', Figure 3.4).

3.5 Naturally-Occurring Geochemical Tracers

Naturally-occurring dissolved constituents and isotopes in water can serve as a means for tracking water movement through a watershed (Winter and others, 1998). Major ions and a stable oxygen isotope (18O) and hydrogen isotope (Deuterium or 2H) were analyzed from the Dosewallips River and selected wells in order to evaluate groundwater flow paths and mixing of recharge sources (Dosewallips River and direct precipitation). Water samples were collected on March 18, 2004 at each of the transects on the Dosewallips River and at three wells completed in the unconsolidated aquifer (134/135, 9, and 89) and two wells completed in the basalt aquifer (91 and 144). Streamflow at the time of collection was estimated at about 430 cfs. Major ion results are summarized in Table 3.1 along with specific conductance and pH measurements made during the sampling event.

3.5.1 Major Ions

Figure 3.11 presents a ternary plot of the major cations and anions. Ternary plots provide a method for displaying the chemical data from multiple sample points on a single graph. In the lower left hand corner of the diagram, the major cations are plotted. Anions are plotted in the lower right trilinear plot. For each cation and anion, a line is extended up to the diamond shaped graph, and the intersection of the two points, representative of the hydrochemical facies as defined by major ion concentrations, is plotted as single point. These diagrams are useful for showing mixing of water from two different sources. A water mixture will plot along a straight line, to the extent that the water chemistry has not been affected by ion exchange or other processes within the aquifer such as precipitation or dilution of salts.

No significant difference was noted in the geochemical fingerprint for the four samples collected from the Dosewallips River. The Jefferson County Fire District wells (combined sampled from the water tank supplied by wells 134 and 135) and well 9 show a near-identical chemical fingerprint to the Dosewallips River water, indicating that recharge occurs predominantly from the river to the aquifer in the Brinnon Flats area. The Dosewallips River and wells 134/135 and 9 are calcium-bicarbonate type water. These data are further discussed in Section 4.2 in relation to surface water/groundwater interaction.

Wells 144 and 89 show similar chemical signatures. Both are located in an upland area with completion intervals well above sea level. Well 89 is completed at a depth of 40 feet (elevation 141 feet) in the unconsolidated aquifer and well 144 is completed at a depth of 258 feet (elevation 47 feet) in the basalt aquifer. Both are calcium-bicarbonate type water, with greater magnesium than the samples from the Dosewallips River. Magnesium is slightly greater in the unconsolidated well (89) than the basalt well (144). Specific conductance was greater in well 144 (171 microsiemens per centimeter [µS/cm]) compared to well 89 (92 µS/cm). The data from these two wells suggest that the chemical signature from the unconsolidated aquifer and the basalt aquifer are similar in the upland area, but with the basalt aquifer having higher concentrations of total dissolved solids.

Well 91 is also completed in basalt (open interval from elevation -163 to -263 feet), but exhibits calcium-magnesium chloride type water. No data was available on the pumping water level in this well. Concentrations of all dissolved constituents were greater in well 91 than any of the other wells tested. The chloride concentrations in this well (61 milligrams per liter [mg/l]) is elevated compared to other wells sampled and could be either a result of seawater intrusion or representative of the geochemical condition of the basalt aquifer. Additional investigations would need to be performed to differentiate chloride sources in well 91.

3.5.2 Isotopes

Naturally-occurring isotopes provide data that can assist in differentiating recharge sources. Isotopes are variations of elements that differ in atomic weight due to additional neutrons. Common isotopes used in hydrologic investigations are deuterium (^{2}H, hydrogen with one additional neutron) and heavy oxygen (^{18}O – oxygen with two additional neutrons). During the hydrologic cycle, water will evaporate, condense and fall as precipitation. Heavy oxygen and deuterium undergo fractionation during evaporation; that is, lighter isotopes are preferentially removed, leaving the residual water relatively enriched in heavier isotopes (Mazor, 1991). Similarly, snow melt may also become relatively enriched in heavier isotopes

Heaviest isotopes condense more readily and would be expected to be preferentially removed by precipitation events on the west side of the Olympic Mountains. As storm fronts progress over the Olympic Mountains, moisture becomes enriched in lighter isotopes and precipitation falling on the summit of the Olympic Mountains would be expected to be enriched in lighter isotopes. This pattern is often not observed on the leeward side of mountains (Kendall and others, 2004).

Water sampled from the same five wells and four surface water stations was analyzed for deuterium and heavy oxygen. Results of the analyses are plotted in Figure 3.12. The ratio of deuterium and heavy oxygen to their respective light isotopes were measured and expressed relative to standard mean ocean water (SMOW). An increase in the ratios of ^{18}O /O and ^{2}H/H ratios are indicated by less negative values. Negative values on Figure 3.12 indicate the heavy to light isotope ratio is less than SMOW. Also shown in Figure 3.12 is a local meteoric water line for Victoria, British Columbia derived from data obtained from the Global Network of Isotopes in Precipitation (GNIP database, accessible at http://isohis.iaea.org). The local meteoric water line for Victoria provides reference values for deuterium and heavy oxygen based on precipitation samples collected from 1975 to 1980 and has been used in other regional studies.

The Dosewallips River samples have the lightest isotopic composition. The orographic effect previously described is consistent with the light isotopic composition identified in the Dosewallips River. Wells 9 and 134/135 are enriched in heavier isotopes relative to Dosewallips River water, which suggests a portion of recharge derived from direct precipitation. These data are discussed in Section 4.2. The heaviest isotopic composition was measured in the upland wells 89 and 144. These wells are completed above the level of the Dosewallips River and are considered to be indicative of the isotopic signature of water derived directly from precipitation. Well 91 is intermediate in isotopic composition between precipitation dominated wells (144 and 89) and the Dosewallips River dominated wells (9 and 134/135).

As expected, river water exhibits relatively lighter isotopic composition due to the orographic effect. Surface water is not the sole source of groundwater recharge in the Brinnon Flats area. Incident precipitation contributes to groundwater recharge, which correspondingly exhibits heavier isotopic fractionation.

4 Interaction Between the Lower Dosewallips River and Groundwater

4.1 Methods of Investigation

An analysis of the interaction between the Dosewallips River and the shallow alluvial/glacial aquifer system was made. The objective of the analysis was to estimate river reaches that gain water from groundwater inflow and reaches that lose surface water through the river bed to the shallow aquifer system. Hydraulic, thermal, and naturally-occurring geochemical tracers were used to delineate the spatial and temporal variability in seepage along the lower reaches of the Dosewallips River. These methods are discussed in the subsections below. Seepage measurements provide an overall estimate of gains or losses along a given reach, while mini-piezometer data provide location-specific data. Collectively, all these techniques offer multiple lines of evidence for evaluating groundwater/surface water interaction. Sections 4.2 through 4.5 provide an interpretation of these data for each reach of the river. Detailed field methodology is presented in Appendix B.

Mixing of river water and groundwater is important to the ecological functions of rivers (Woesner, 2000). The zone where mixing occurs is referred to as the hyporheic zone. The hyporheic zone performs a critical function in the transport and exchange of nutrients to a river system. Details on the function of the hyporheic zone and its relationship to fish habitat were prepared by MCS Environmental, Inc. as part of this study and are presented in Appendix C.

4.1.1 Seepage Runs

The amount of groundwater gained or lost to the stream was estimated using seepage measurements for three reaches of the stream. The reaches were delineated based on bedrock constrictions, which subdivided the river into the three reaches shown in Figure 4.1. A flow measurement was made using the area velocity technique at upstream and downstream transects for each reach. The difference between the upstream and downstream measurement after accounting for tributary inflow and diversions is the estimated groundwater gain/loss along the reach. Seepage measurements were made on October 9 and 10, 2003 and again prior to snow melt on February 27, 2004 and March 4, 2004. Results of the seepage runs are presented in Table 4.1 and on Figure 4.1 and are discussed in detail in Sections 4.2, 4.3, and 4.4.

Stage measurements were recorded relative to a reference point on the Highway 101 Bridge at the beginning, middle and end of the day of seepage measurements. Flow at Transect A was also re-measured at the end of each day. Seepage measurements were corrected for changes in flow during the day, by assuming a linear change in river stage between measurements and adjusting flow for the upstream and downstream transects for a given reach to the same time. This correction was small as the time between upstream and downstream transects was relatively short. Because the measurements were made after the irrigation season, irrigation diversions were assumed to be zero. Tributary inflow was estimated by direct measurement or by estimating inflow based on basin area (Appendix B). During the October 9 and 10, 2003 seepage runs, the only tributary identified with flow was Rocky Brook. The late winter measurements were split between 2 days, as the highest transects were not wadeable on February 27, 2004. Tributary inflow was based on extrapolating runoff from the Rocky Brook drainage to the ungaged basin areas. As such, the groundwater seepage estimates for late February are noted as estimated on Table 4.1. Details of flow measurement methodology are presented in Appendix B.

4.1.2 Mini-Piezometers

Mini-piezometers are small diameter (3/4- or 1.25-inch diameter), hollow steel probes that were driven into the subsurface to provide a head (or water level) measurement corresponding to the depth of the open interval. A portion of the tip (0.8 foot) was perforated to allow water within the aquifer to flow freely into the mini-piezometer. A total of 19 mini-piezometers were installed in a total of six clusters. Clusters 1, 2, and 3 were located in Reach 1, Clusters 4 and 5 in Reach 2, and Cluster 6 near the intersection of Reaches 2 and 3. Typical installation depths for the mini-piezometers ranged from 4 to 6 feet bgs. The construction details for the mini-piezometers are presented in Table 4.2 and the mini-piezometer locations are presented in Figure 4.2.

The mini-piezometers were monitored on a monthly basis from November 2003 through August 2004. Data collected at the mini-piezometers included temperature, specific conductance, and the relative head between the mini-piezometer and the river level. A manometer board was used to measure the relative difference between groundwater levels in the mini-piezometer and surface water levels. Detailed field methodology for installation and monitoring of the mini-piezometers is presented in Appendix B.

The relative water level difference between the surface water and groundwater indicates the direction of water flow. If the surface water level is higher than groundwater level, the stream is in a losing condition. Conversely, if the groundwater level measured in the mini-piezometer is higher than the surface water level, then the stream is gaining water from the groundwater system. An unsaturated zone may exist between the groundwater and surface water, indicating a stream that is “disconnected” from the groundwater system (Winter and others, 1998). These interactions of surface water and groundwater are presented in Figure 4.3.

Mini-piezometers were installed both directly in the flowing stream and adjacent to it. Those placed out of the channel were installed to either ensure that a monitoring point would be in place if a significant runoff event destroyed a mini-piezometer in the flowing channel, or to obtain lateral profile of water levels perpendicular to the river.

The relative groundwater/surface water gradient was computed by taking the difference between the surface water level and groundwater level (*dh*) and dividing it by the separation distance between the bottom of the stream channel and the middle of perforated interval in the piezometer (*dl*). Figure 4.4 presents the calculation methodology, which also discussed in detail in Appendix B.

Continuous groundwater temperature measurements were made using Tidbit temperature sensors and dataloggers at six locations. River temperature was measured at three locations (Clusters 2, 4 and 5) and air temperature was measured outside the well house at well 17 at Dosewallips State Park. Groundwater temperatures were monitored at P-11, P-12, P-14, P-16, P-18, P-19 and well 9. The mini-piezometer (P-18), located at Cluster 5 between the river and the Lazy C wells, was instrumented with a pressure/temperature transducer. Well 9 (located near a residence on the northeast side of the intersection of the Dosewallips River and Highway 101) was similarly instrumented (Table 4.1). A stilling well and pressure/temperature transducer were installed into the river along the riprap bank at the Lazy C community in order to monitor river stage. Water level data collected at P-18, well 9, and the Dosewallips River is presented in Figure 4.5 with precipitation measured at Quilcene.

Cross sectional profiles were developed at four locations along the stream to illustrate surface and groundwater level changes between the March and June, 2004 water level measurements. The profiles were developed using water level measurements in the mini-piezometers and nearby supply wells. Profiles were developed through Clusters 1, 2, 4 and 5 (Figures 4.6a through 4.6d).

4.1.3 Temperature Methods

For a losing stream condition, the groundwater temperature and river water temperature would track in a similar manner. Specific conductance would also be expected to be similar for a losing condition. For a gaining stream condition, the groundwater temperature will be largely independent of surface water temperature. Groundwater temperature will be relatively constant, reflecting broad seasonal changes in temperature, whereas surface water temperature will be dependent on short-term air temperature fluctuations. Gaining reaches will typically exhibit groundwater temperature conditions that are warmer in the winter and cooler in the summer. Specific conductance may exhibit considerable differences from river specific conductance for a gaining condition (Simonds and Sinclair, 2002). Data collected at the mini-piezometers are presented in Tables 4.3 and 4.4 and temperature data are presented in Figure 4.7. Results are discussed by reach in Sections 4.2 through 4.4.

4.2 Reach 1

Reach 1 extends from RM-0 to about RM-1. The downstream end of this reach occurs on the delta on the east side of Highway 101, near where the river enters the Hood Canal. A bedrock constriction at RM-1 marks the upstream extent of the reach. River gradient along this reach is estimated at 0.0046 feet per feet (ft/ft). Gravel bars are present throughout the reach and in places are vegetated with small alder. River bank sides are typically less than 10 feet. The floodplain is relatively broad on the north side of the river in the Brinnon Flats area and is limited in extent on the south side of the channel where Dosewallips State Park is located. A riprap bank extends for about 200 yards along the north side of the river, just upstream from the old Highway 101 Bridge location. No tributaries or diversion from the Dosewallips River were identified in this reach of the river during our October 2003 reconnaissance. A side channel that receives groundwater inflow is present along the south side of the river. A creek informally referred to as “State Park Creek” drains a small valley on the south side of the Dosewallips State Park.

All data along this reach indicate that a losing condition exists downstream of the bedrock constriction at RM-1. Seepage losses computed for Reach 1 were consistently losing during each of the three seepage measurement dates (Table 4.1). Losses ranged from a low of 13 cfs on October 10, 2003 to a high of 30 cfs on February 27, 2004. The seepage losses generally showed an increase in loss with increased river flow. These losses ranged from 5 to 14 percent of the total flow and are slightly greater than those reported by Simonds and Sinclair (2002) for the Dungeness River in the Sequim vicinity, which ranged from 1 to 8 percent of flow. A portion of the February 2004 stream flow loss was likely partially offset by shallow groundwater inflow entering the stream via the steep bank on the south side of the river.

The mini-piezometers also indicated a downward vertical gradient from the streambed to the aquifer. At mini-piezometer Cluster 1 located near the Highway 101 Bridge, a consistent surface to groundwater gradient was identified, with gradient increasing during the lower groundwater levels (Figure 4.2, Table 4.4). At P-1, a maximum vertical gradient of 0.42 ft/ft was measured in June, 2004. The gradient declined between the June and August measurements, in response to declining river stage. Temperature and specific conductance differences between surface and groundwater were relatively small, ranging from 0.2 to -1.6 degrees (^{o}F) and -1.4 to 1.5 µS/cm, respectively at P-18. These results are consistent with surface water to groundwater losses.

Cluster 2, located at RM-0.4 also exhibited a losing condition, although gradients were very small, and for the period December through May, near neutral conditions (neither gaining nor losing) were identified. Further upstream at Cluster 3, the largest downward vertical gradients for the study were identified, with June measurements at mini-piezometer P-15 approaching a unit gradient. At P-3, also located in Cluster 3, the mini-piezometer was dry in early November and again in May through August. Apparently, the groundwater mound beneath the river channel had dissipated during the drier months and the river became locally detached from the groundwater system. The maximum and minimum temperature differences between groundwater and surface water were very close at piezometer P-15 and support the theory of surface to groundwater flow (Table 4.4).

The continuous water level monitoring data at well number 9, located near Cluster 1, indicates this well responds predominantly to precipitation events (Figure 4.5). The blue line in Figure 4.5 presents the Dosewallips River stage measured at the Lazy C riprap bank. Well 9 water level data is shown with the red line and the black line represents the moving average. Tidal influence of the well is indicated by the typical 1-foot diurnal variations in water level shown in the red line. A longer term monthly tidal trend is superimposed on the diurnal water level trends in well 9. During the winter periods of precipitation dominated runoff, both the groundwater level and river stage rise in response to precipitation events. As river levels rise in response to snow melt, the response in groundwater changes at well 9 is small or greatly attenuated. During the late June to August recession in river flows, the monthly tidal effects dominate water levels in well 9, masking the water level decline.

Continuous temperature measurements made at Clusters 1 (P-19, RM-0.2) and 3 (P-14, RM-0.75) track surface water temperature changes very closely and are consistent with losing conditions at each of these locations (Figure 4.7). However, the temperature response at well 9 appears characteristic of a gaining condition, but the large distance (about 500 feet) and travel time likely attenuate the temperature signal. Furthermore, the well casing at P-9 could act as a heat sink, effectively attenuating temperature changes.

Water level profiles through Cluster 1 and wells 9 and 6 indicate the head at well 9 was consistently lower than the river level, consistent with a losing condition (Figure 4.6a). Similarly the profile at Cluster 2 (RM-0.4), indicates a similar head loss from the river to wells 132 and 134 located on Brinnon Flats (Figure 4.6b).

Major ion data provides further support for the losing condition along Reach 1. Water samples collected from wells 9 and 134 and the river samples are calcium bicarbonate type water and plot in a near-identical position on the ternary plot (Figure 3.11). Specific conductances measured at wells 9 and 134 of 87 and 85 µS/cm, respectively, were slightly less than specific conductance measured in the river water (ranging from 98 to 101 µS/cm), suggesting dilution from direct precipitation recharge or from lower conductivity Dosewallips River water (Table 3.1). The minimum specific conductance in the Dosewallips River measured in this investigation was approximately 77 µS/cm measured in June, 2004, during spring melt. As such, spring runoff could also contribute lower specific conductance water to the aquifer, and with mixing lead to the lower conductance values measured in wells 9 and 134.

The isotope data indicate that water becomes increasingly enriched in heavier isotopes with increasing distance from the river and are consistent with a component of recharge being derived from direct precipitation (Figure 3.12). Direct recharge from precipitation that undergoes fractionation due to evaporation would result in an enrichment in heavier isotopes. Consideration of the isotope data collectively with the major ion data suggests a chemical fingerprint dominated by river water, with dilution of the dissolved solids and, hence specific conductance, by direct precipitation and spring melt water. Other than diluting the dissolved ion concentration, recharge from direct precipitation appears to have no identifiable effect on the chemical signature for these two wells.

4.3 Reach 2

Reach 2 spans from a downstream bedrock constriction at RM-1 to a second bedrock constriction at about RM-3.2. A steep right bank is present along the south side of the river on this reach extending up to the Mount Jupiter ridge line. The valley reaches a maximum width of the about 1,500 feet along this reach. The Lazy C development is located on the north side of the river at about RM-2. Gravel bars are present within the channel and as point bars. Upstream of Lazy C the steam channel is relatively straight and there does not appear to be any significant gravel bars.

Seepage runs along Reach 2 indicated slight gains to near neutral (neither gaining nor losing) conditions. A gain of 15 cfs was indicated by the October 9 seepage runs and a near neutral condition was indicated for the October 10 measurements (Table 4.1). A slight gain, within the measurement error, was noted for the February measurements.

The mini-piezometers were located above the bedrock constriction at RM-1 (Cluster 4) and along the river bank bordering the Lazy C development (Cluster 5, approximately RM-1.9). Mini-piezometer data at Lazy C indicate that losing conditions exist along portions of this reach near Lazy C; however, significant groundwater discharge occurs upstream of the bedrock constriction at the lower end of the reach (Cluster 4). The mini-piezometer data at Cluster 4 showed a consistent gaining pattern. Average gradient at this location measured at P-10 was 0.23 foot. Temperature difference between groundwater and surface water varied from -10 to 9 ^{o}F. This relatively large difference is consistent with a gaining condition.

Water level profile developed from the mini-piezometer transect upstream of the bedrock construction at RM-1 was consistent with the gaining condition, with the groundwater gradient sloping consistently toward the river for both the March and June measurement dates (Figure 4.6c). The gradient showed a general decrease during the low water period from March through June. The gradient increase during the August measurement is attributed to a drop in river level that outpaced declines in groundwater levels. Continuous temperature data further support gaining conditions at this location. Groundwater temperatures exceed the surface water temperatures for the period from November through mid-April. The relationship reverses from mid-April through August. Moreover, the groundwater temperatures are relatively constant and exhibit little diurnal to monthly fluctuations as observed for Dosewallips River.

Mini-piezometers at Lazy C generally indicated a loss of groundwater to surface water. The piezometers were located around the point bar where the Lazy C community is located. Gradients ranged from a neutral condition in late December, 2004 to a maximum of -0.44 ft/ft in June, 2004 (Table 4.2). Continuous water level measurements at piezometer P-18 are consistent with a losing condition (Figure 4.5). Changes in water levels in P-18 track consistently with river level changes. A losing condition in the Lazy C vicinity is further illustrated by the water level profiles through piezometer P-18 and the Lazy C wells (study well numbers 92 and 93). Mini-piezometer P-18 was located between the Lazy C wells and the river. Static water levels were lower in the Lazy C wells than in mini-piezometer P-18 (Figure 4.6). Continuous temperature data measured at P-18 is also consistent with a losing condition throughout the study period (Figure 4.7). The temperature measured at P-18 closely tracks the average river temperature, indicating a strong influence from river water.

4.4 Reach 3

Reach 3 extends from the boundary with the National Forest land downstream to the bedrock constriction at RM-3.2. The river exits an incised bedrock canyon just above Transect D at the National Forest boundary. Numerous steep gradient tributaries enter the Dosewallips River along this reach, particularly from the south. Rocky Brook dominates the drainage along the north side of the river and enters just below Transect C. Several pastures are present on the north side of the river. The south side is bounded by a steep hill slope. Several braided channels are present above the confluence with Rocky Brook.

Similar to Reach 2, this reach has shown neutral to gaining conditions. Seepage runs indicate a 14 cfs gain or about 8 percent of river flow during the October 9, 2003 measurements. The groundwater gain expressed as cfs/mile was consistent between Reaches 2 and 3 at 5.6 cfs/mile for the October 9 measurements. Neutral or near neutral conditions were identified in Reach 3 during the October 10 and early March measurements, also similar to Reach 2.

One mini-piezometer cluster was installed upstream of Rocky Brook. Near neutral conditions prevailed at this location. A slight gain of groundwater to surface water was noted from late November through March and a slight loss of surface water to groundwater was noted from May through August. The continuous temperature data at this station do not corroborate the hydraulic data, likely as a result of the near neutral condition. The groundwater temperature data tracks with surface water temperature data through late May, suggesting that surface water flows to groundwater for this period.

4.5 Summary of Losing/Gaining Conditions

A summary of losing and gaining conditions indicated by the hydraulic data from the mini-piezometers is shown in Figure 4.8 (after Simonds and Sinclair, 2002). Although the mini-piezometers are representative only of the specific location where they were installed, consideration of vertical gradients, the geomorphic setting, and seepage measurements permits generalizations regarding the gaining and losing characteristics of the lower Dosewallips River.

Beginning upstream, Reaches 3 and 2 are neutral to slightly gaining. Local surface water to groundwater losses in the upper portions of these reaches are returned to the river upstream of bedrock constrictions where groundwater discharges into the river. Groundwater likely moves in a parallel-flow manner within the valley alluvium due to the higher permeability of alluvium compared to the surrounding uplands. Parallel flow reaches are indicated where groundwater head and surface water head are equal (Woesner, 2000). These conditions are indicated by the near neutral conditions observed at Cluster 6 and seasonally at Cluster 2.

Hydraulic gradients at local losing sections increase through June, corresponding to high river flows from snow melt and declining groundwater levels as seasonal precipitation diminishes. In later summer following snow melt, river stage decline exceeds groundwater level decline and the downward vertical hydraulic gradient diminishes slightly. At the local gaining areas above the bedrock constrictions, the smallest upward gradient occurs in June when the difference between river levels and groundwater levels is the smallest. The vertical gradient is greatest in late summer when river levels are low and in early winter when groundwater levels are high as a result of winter precipitation.

The Dosewallips River appears to be a losing stream throughout Reach 1. The change in vertical gradients follows that discussed above. Losses in the lower reach may occur preferentially through former distributary channels. A former distributary channel, extending from the Dosewallips River downstream of the bedrock constriction at RM-1 and merging with the existing spring fed creek at Whitney Gardens is indicated by the vegetative pattern shown in Figure 1.3.

5 Conclusions and Recommendations

5.1 Conclusions

5.1.1 Principal Aquifers

The principal aquifers in the lower Dosewallips-Brinnon area occur in the unconsolidated deposits and the underlying basalt bedrock. The unconsolidated deposits are comprised of relatively high permeability Recent Alluvium and older glacial deposits. The unconsolidated aquifer generally exhibits unconfined to semi-confined conditions. An aquitard comprised of glaciolacustrine deposits, glacial till, and local fine-grained alluvium, where present, results in local confinement of the unconsolidated aquifer.

The water-bearing nature of the basalt aquifer, occurring in the Crescent Formation, is variable and associated primarily with secondary fracture permeability. Water within the basalt aquifer is typically confined.

5.1.2 Groundwater Flow

Recharge to the unconsolidated aquifer occurs as a result of direct infiltration of precipitation and, in the Brinnon Flats area, from losses from the Dosewallips River. Groundwater flows from the upland areas and from the Dosewallips River into the Brinnon Flats area. Discharge occurs into a spring creek that flows through Whitney Gardens and by direct saltwater discharge. Discharge from wells also occurs, although pumping withdrawals are expected to be a relatively small component of the total discharge. In the upland areas, a downward groundwater flow gradient exists between the unconsolidated aquifer and the underlying basalt aquifer. Above RM-1, groundwater flow in the unconsolidated aquifer has a slight net discharge to the Dosewallips River, although locally the river loses water to the alluvial aquifer.

Groundwater in the basalt aquifer flows from the upland areas toward the Dosewallips River. The relative head difference between the unconsolidated aquifer and the basalt aquifer in the lowland area is unknown but is expected to be fairly small.

5.1.3 Surface Water/Groundwater Interaction

The Dosewallips River exhibits neutral to gaining behavior downstream of the National Forest boundary and upstream of RM-1. Below RM-1 the river loses water to the groundwater flow system. Downward vertical gradients between the river and groundwater reach a maximum in June when the river is high from spring runoff and the groundwater levels are dropping in response to diminished precipitation. Groundwater discharge into the river was observed above the bedrock constriction at RM-1 and also likely occurs at the bedrock constriction near RM-3.2. The upward gradient is greatest during winter months when groundwater levels reach a maximum as a result of heavy winter precipitation.

5.1.4 Water Types and Natural Geochemical Tracers

Water in the Dosewallips River and in the unconsolidated aquifer is typically calcium bicarbonate type. Samples collected at the upstream and downstream end of each reach had nearly identical chemical characteristics, indicating limited groundwater inflow consistent with the size of seepage gains observed. The two wells sampled in the Brinnon Flats area exhibited chemical characteristics nearly identical to the Dosewallips River surface water. The Dosewallips River water was relatively enriched in lighter isotopes. This finding is consistent with other studies that have shown the orographic effect to result in precipitation with an isotopically lighter composition. Groundwater exhibited an increase in heavy isotopes with increasing distance from the river. That pattern indicates that a greater portion of groundwater recharge was derived from direct precipitation.

Of the two basalt wells sampled, one exhibited calcium bicarbonate water (well 144) and the other exhibited calcium-magnesium chloride type water (well 91). This well is completed below sea level about 1 mile inland from the Hood Canal. The source of chloride in this well is uncertain but may be related to either upconing of seawater or geochemical conditions within the basalt aquifer.

5.2 Recommendations

1. Better definition of the seawater/freshwater mixing zone should be obtained by mapping chloride distribution in wells in the unconsolidated and basalt aquifers. This mapping will provide data to support decision making that will minimize seawater intrusion into the aquifer during future groundwater development in the area.
2. Aquifer testing of the basalts should be performed in order to evaluate the storage of the aquifer and its ability to sustain long term pumping.
3. A water balance should be developed and used, in conjunction with results from Recommendations 1 and 2, in order to define the safe yield of the aquifer.

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Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of WRIA 16 Planning Unit for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

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Table 3.1
Laboratory Results and Field Parameters of Water Samples
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Sample Information				Field Parameters		Cations				Anions				
Sample Location	**Sample ID**	**Date**	**Time**	**Conductivity (uS/cm)**	**pH**	**Calcium (mg/l)**	**Magnesium (mg/l)**	**Sodium (mg/l)**	**Potassium (mg/l)**	**Chloride (mg/l)**	**Sulfate (mg/l)**	**Bicarbonate (mg/l)**	**Carbonate (mg/l)**	**Hydroxide (mg/l)**
River (Transect D)	#1 Transect 4	3/18/2004	16:00	100.00	7.25	18.60	1.63	2.21	2.28	0.71	7.72	44.60	ND[2]	ND[2]
River (Transect C)	#2 Transect 3	3/18/2004	8:25	101.00	7.14	18.70	1.68	2.20	2.47	0.71	7.72	46.80	ND[2]	ND[2]
River (Transect B)	#4 Transect 2	3/18/2004	18:50	97.50	7.20	17.60	1.67	2.17	3.04	0.83	7.28	43.20	ND[2]	ND[2]
River (Transect A)	#5 Transect 1	3/18/2004	8:00	99.00	6.93	18.00	1.76	2.47	2.97	0.82	7.34	43.80	ND[2]	ND[2]
#91 (PUD)	#6 PUD	3/18/2004	11:15	NA	NA	28.10	2.71	29.70	2.42	62.70	8.98	30.80	8.80	ND[2]
#89 (Haley)	#7 Haley	3/18/2004	17:00	92.00	NA	10.30	4.08	4.79	ND[1]	1.18	1.33	50.00	ND[2]	ND[2]
#134/135 (JCFD #4)	#8 Fire	3/18/2004	11:50	85.00	6.87	14.20	1.66	2.07	ND[1]	0.83	5.59	38.40	ND[2]	ND[2]
#9 (WSPRC #3)	#9 Well 9	3/18/2004	11:00	87.00	7.10	14.70	1.55	1.95	ND[1]	0.87	5.96	37.80	ND[2]	ND[2]
#144 (Hockett)	#10 Hockett	3/18/2004	16:00	171.00	6.78	25.00	5.16	7.29	ND[1]	1.02	1.49	98.00	ND[2]	ND[2]
Rocky Brook	NA	3/18/2004	16:15	57.00	7.25	NA	NA	NA	NA	NA	NA	NA	NA	NA
Seawater [3]	NA	NA	NA	NA	NA	421.28	1322.25	11029.00	408.98	19833.75	2777.75	145.55	NA	NA

Notes:
NA = Not Applicable
ND[1] = Not Detected; Detection Limit is 2.0 mg/l
ND[2] = Not Detected; Detection Limit is 5.0 mg/l
[3] Seawater composition from Drever, 1982; based on a seawater density of 1025 kg/m^3.

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Table 4.1
Seepage and River Flow
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Reach ID			**Reach 3**	**Reach 2**	**Reach 1**
Length of reach (miles)			2.5	2.65	0.75
Basin area (acres)			2,870	9,423	967
Date	**Maximum flow**[1]	**Units**	**Groundwater Gain/Loss**		
10/9/03	212 cfs	(cfs)	14.1	14.9	-28.8
		(cfs/mile)	5.6	5.6	-38.5
		(gain or loss)	Gain	Gain	Loss
		(%)	8%	8%	-14%
10/10/03	158 cfs	(cfs)	-5.2	0.5	-12.9
		(cfs/mile)	-2.1	0.2	-17.2
		(gain or loss)	Neutral	Neutral	Loss
		(%)	-3%	0%	-8%
2/27/04[2]	564 cfs	(cfs)	-0.5	10.7	-30.3
		(cfs/mile)	-0.2	4.0	-40.4
		(gain or loss)	Neutral	Gain	Loss
		(%)	0%	2%	-5%

1. Measured at Transect B.
2. Values are estimated for Reaches 2 and 3 (Appendix B).

Table 4.2
Construction and Installation Details of Mini-Piezometers Installed Along the Lower Dosewallips River

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Mini-Piezometer Number	River Mile	Northing (WA State Plane 83)	Easting (WA State Plane 83)	Installation Date	Piezometer length L (feet)	Installation depth (feet)	Depth to center of perforations (feet)	Piezometer Diameter and Instrumentation
P-1	0.23	258747.00	1131695.60	10/31/03	7.0	5.6	5.0	1/2" Piezometer
P-2	0.41	259207	1130866	10/31/03	7.0	4.7	4.1	1/2" Piezometer
P-3	0.75	259768.00	1129416.00	10/31/03	7.0	5.2	4.6	1/2" Piezometer
P-4	1.11	261656	1128588	10/31/03	7.0	5.1	4.5	1/2" Piezometer
P-5	1.04	261438.50	1129024.58	10/31/03	14.0	10.2	9.6	1/2" Piezometer
P-6	1.98	262826	1125137	11/4/03	7.0	5.9	5.3	1/2" Piezometer
P-7	1.85	262758.27	1125780.90	11/4/03	7.0	5.6	5.0	1/2" Piezometer
P-8	3.45	268656	1120917	11/4/03	7.0	4.9	4.3	1/2" Piezometer
P-9	0.41	259135	1130899	11/25/03	7.0	4.6	4.0	1/2" Piezometer
P-10	1.04	261335.00	1128853.40	11/25/03	7.0	4.2	3.6	1/2" Piezometer
P-11	1.04	261373.40	1128920.50	11/25/03	6.9	4.3	3.7	1-1/4" Piezometer w/ temp logger
P-12	1.04	261400.60	1128974.50	11/25/03	7.0	4.5	3.9	1-1/4" Piezometer w/ temp logger
P-13	0.41	259135.00	1130833.00	12/22/03	7.0	4.7	4.1	1/2" Piezometer
P-14	0.74	259803.00	1129444.00	12/30/03	7.0	5.3	4.7	1-1/4" Piezometer w/ temp logger
P-15	0.74	259762.80	1129412.00	12/30/03	7.0	4.5	3.9	1/2" Piezometer
P-16	3.45	268672	1120933	12/30/03	7.0	5.4	4.8	1-1/4" Piezometer w/ temp logger
P-17	1.76	263145	1126065	1/20/04	na	na	na	In-river stilling well w/ level/temp transducer
P-18	1.95	262722.90	1125339.80	1/20/04	10.1	7.3	6.7	1-1/4" Piezometer w/ level/temp transducer
P-19	0.23	258756.00	1131708.48	1/20/04	6.9	5.4	4.8	1-1/4" Piezometer w/ temp logger

Notes:

1. Depth is below riverbed or groundsurface and is calculated using initial stickup. "na" = not applicable.

Table 4.3
Data Collected at Mini-Piezometer Locations
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Mini-Piezometer[1]	Date	Time[2,5]	Temperature (°F)			Specific Conductance (µS/cm @ 25 °C)			Manometer Reading[3,4,5] (inches H_2O)			dh (feet)	Stickup[5] (feet)	SWL[6] (feet)	dl[7] (feet)	Gradient Direction	Vertical Hydraulic Gradient[4,5] (ft/ft)	Submerged[8]
			River	Groundwater	Difference	River	Groundwater	Difference	River	Piezometer	Difference							
Cluster 1																		
P-1	10/31/03	8:40	39.9						1.9	-5.5	-7.4	-0.62	1.39	--	4.99	SW to GW	-0.12	Y (assumed)
	11/4/03	8:25	37.9	38.7	-0.7	116.2	114.7	1.5	7.1	-2.3	-9.4	-0.78	--	--	5.07	SW to GW	-0.15	Y (assumed)
	11/25/03	9:20	40.1	40.6	-0.5	104.5	104.0	0.5	9.3	-1.8	-11.1	-0.93	--	1.00	**5.14**	SW to GW	-0.18	Y
	12/22/03	13:30	41.4	41.2	0.2	104.4	104.1	0.3	10.9	2.6	-8.3	-0.69	1.16	0.84	5.22	SW to GW	-0.13	Y
	1/22/04	10:05	41.0	41.0	0.0	101.5	100.8	0.7	4.6	-4.8	-9.4	-0.78	--	0.95	**5.25**	SW to GW	-0.15	Y
	3/1/04	9:15	42.8	43.0	-0.2	99.9	99.7	0.2	9.6	0.1	-9.5	-0.79	1.10	1.05	5.28	SW to GW	-0.15	Y
	4/8/04	9:50	43.2	44.1	-0.9	100.1	100.2	-0.1	11.6	1.0	-10.6	-0.88	1.02	--	5.36	SW to GW	-0.16	Y
	5/11/04	8:55	45.0	45.5	-0.5	91.0	90.9	0.1	16.0	2.6	-13.4	-1.12	1.10	1.10	5.28	SW to GW	-0.21	Y
	6/12/04	11:30	46.6	48.2	-1.6	77.2	77.1	0.1	13.4	-13.4	-26.8	-2.23	--	2.22	**5.28**	SW to GW	-0.42	Y
	8/3/04	9:35	57.0	58.3	-1.3	101.8	103.2	-1.4	16.0	0.9	-15.1	-1.25	1.10	2.02	5.28	SW to GW	-0.24	Y
P-19	1/20/04	17:00	42.3	42.3	0.0	97.5	94.9	2.6					1.5	5.14				N
	1/22/04	9:22	32.0										--	5.32				N
	3/1/04	9:30	42.8	43.7	-0.9	99.9	134.9	-35.0	14.6	3.3	-11.3	-0.94	1.5	5.44	1.75	SW to GW	-0.54	N
	4/8/04	10:30	43.2	47.1	-4.0	100.1	129.3	-29.2	7.5	-5.1	-12.6	-1.05	1.5	5.41	1.89	SW to GW	-0.55	N
	5/11/04	**9:20**											--	5.46				N
	6/12/04	11:15											1.5	6.54				N
	8/3/04	9:55											1.5	6.35				N
Cluster 2																		
P-13	12/22/03	16:00	41.5	41.5	-0.1	105.6	106.9	-1.3	10.1	10.1	0.0	0.00	2.30	1.66	4.10	Neutral	0.000	Y
	1/22/04	10:40	41.4	42.6	-1.3	101.5	101.7	-0.2	8.5	8.3	-0.2	-0.02	2.45	1.85	3.95	SW to GW	-0.004	Y
	3/1/04	10:07	43.2	43.7	-0.5	100.1	100.2	-0.1	5.2	5.1	-0.1	-0.01	2.43	2.00	3.97	SW to GW	-0.002	Y
	4/8/04	10:55	44.6	45.9	-1.3	99.9	99.1	0.8	4.3	3.9	-0.4	-0.03	2.45		3.95	SW to GW	-0.007	Y
	5/11/04	9:50	45.1	46.0	-0.9	91.0	90.9	0.1	6.6	5.3	-1.3	-0.11	2.45	2.64	3.95	SW to GW	-0.027	Y
	6/12/04	12:20	46.9	48.7	-1.8	77.5	77.3	0.2	15.9	8.4	-7.5	-0.63	2.45	2.04	3.95	SW to GW	-0.158	Y
	8/3/04	10:45	56.8	59.4	-2.5	101.4	102.1	-0.7	10.7	4.0	-6.7	-0.56	2.45	3.32	3.64	SW to GW	-0.153	N
P-9	11/25/03	11:15	40.6	40.8	-0.2	104.7	102.1		8.8	9.6	0.8	0.07	2.45	1.72	3.95	GW to SW	0.02	Y
	12/22/03	14:30	River channel moved. P-9 is bent and in deep water.										**3.50**					Y
	8/3/04	10:45	Probe found on bank and removed.															
P-2	10/31/03	11:00							2.0	3.3	1.3	0.10	2.35	--	4.05	GW to SW	0.03	Y
	11/4/03	10:54	39.4	44.8	-5.4	116.4	110.0	6.4	11.1	8.6	-2.5	-0.21	--	--	4.33	SW to GW	-0.05	Y (assumed)
	11/25/03	10:25	40.6	42.4	-1.8	103.8	91.2	12.6	6.6	7.5	0.9	0.08	0.30	1.85	4.48	GW to SW	0.02	N
	12/22/03	14:30																

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Table 4.3
Data Collected at Mini-Piezometer Locations
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Mini-Piezometer[1]	Date	Time[2,5]	Temperature (°F)			Specific Conductance (µS/cm @ 25 °C)			Manometer Reading[3,4,5] (inches H_2O)			dh (feet)	Stickup[5] (feet)	SWL[6] (feet)	dl[7] (feet)	Gradient Direction	Vertical Hydraulic Gradient[4,5] (ft/ft)	Submerged[8]
			River	Groundwater	Difference	River	Groundwater	Difference	River	Piezometer	Difference							
Cluster 3																		
P-15	12/30/03	11:00	37.8	37.8	0.0	106.4	106.8	-0.4	14.0	0.0	-14.0	-1.17	2.49	2.68	3.91	SW to GW	-0.30	Y
	1/22/04	12:15	41.5	41.4	0.2	101.6	100.2	1.4	9.4	-9.7	-19.1	-1.59	2.85	3.29	3.55	SW to GW	-0.45	Y
	2/27/04	11:40	43.2	43.0	0.2	94.3	94.0	0.3	16.6	-5.6	-22.2	-1.85	3.10	3.40	3.30	SW to GW	-0.56	Y
	4/8/04	11:50	44.8	44.6	0.2	99.9	100.0	-0.1	12.7	-15.5	-28.2	-2.35	3.10	--	3.30	SW to GW	-0.71	Y
	5/11/04	10:20	45.1	46.2	-1.1	91.1	89.6	1.5		< -40	< -40	< -3.33	3.00	6.26	3.40	GW to SW	< -0.98	Y
	6/12/04	12:50	46.8			77.9							3.00	Dry	3.40	Dry		Y
	8/3/04	12:15	57.2	57.9	-0.7	100.0	99.7	0.3	Pump dry.	< -36	< -36.0	< -3.00	--	6.30	3.40	GW to SW	< -0.88	Y
P-3	10/31/03	13:00	42.1	43.9	-1.8				44.0	0.0	-44.0	-3.67	1.80	--	4.60	SW to GW	-0.80	Y (assumed)
	11/4/03	10:15	38.8			116.3							--	Dry		Dry		
	11/25/03	12:00	40.8	40.6	0.2	103.8	95.1	8.7	11.3	-4.4	-15.7	-1.31	1.75	4.11	3.60	SW to GW	-0.36	N
	12/30/03	11:00	37.8	37.6	0.2	106.4	106.0	0.4	15.6	0.1	-15.5	-1.29	1.85	4.10	3.59	SW to GW	-0.36	N
	1/22/04	12:00	41.5	41.0	0.5	101.6	100.2	1.4	12.8	-8.4	-21.2	-1.77	1.90	4.70	4.50	SW to GW	-0.39	Y
	2/27/04	11:22	43.2	43.2	0.0	94.3	94.6	-0.3	15.7	-7.4	-23.1	-1.93	1.84	4.82	3.51	SW to GW	-0.55	N
	4/8/04	11:50	44.8	44.8	0.0	99.9	100.1	-0.2	12.3	-16.3	-28.6	-2.38	2.00	--	4.40	SW to GW	-0.54	Y (assumed)
	5/11/04	**10:40**									Dry		1.90	6.80		Dry		N
	6/12/04	12:50												Dry		Dry		N
	8/3/04	11:30												Dry		Dry		N
P-14	12/30/03	**12:00**											1.70	5.11				N
	1/22/04	11:35											1.70	5.46				N
	2/27/04	11:22											1.70	5.50				N
	4/8/04	11:22											1.65	5.87				N
	5/11/04	10:45											1.70	Dry		Dry		N
	6/12/04	13:00												Dry		Dry		N
	8/3/04	11:35												Dry		Dry		N

Table 4.3
Data Collected at Mini-Piezometer Locations
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Mini-Piezometer[1]	Date	Time[2,5]	Temperature (°F)			Specific Conductance (µS/cm @ 25 °C)			Manometer Reading[3,4,5] (inches H_2O)			dh (feet)	Stickup[5] (feet)	SWL[6] (feet)	dl[7] (feet)	Gradient Direction	Vertical Hydraulic Gradient[4,5] (ft/ft)	Submerged[8]
			River	Groundwater	Difference	River	Groundwater	Difference	River	Piezometer	Difference							
Cluster 4																		
P-4	10/31/03	15:00	In direct contact with the river.						-1.9	-1.8	0.1	0.01	1.95	--	4.45	GW to SW	0.002	Y (assumed)
	11/4/03	17:03	39.0	47.3	-8.3	116.4	101.8	14.6	13.0	13.0	0.0	0.00	--	--	4.45	GW to SW	0.000	Y (assumed)
	12/22/03		Abandoned due to direct contact with river.															
P-10	11/25/03	15:15	41.9	47.7	-5.8	104.0	106.0	-2.0	4.3	15.1	10.8	0.90	2.82	1.83	3.58	GW to SW	**0.25**	Y
	12/30/03	13:15	39.9			104.4							2.60	2.01	3.80			Y
	1/22/04	14:15	43.0	45.0	-2.0	100.0	94.8	5.2	5.7	16.8	11.1	0.93	2.55	1.92	3.85	GW to SW	**0.24**	Y
	3/1/04	11:04	44.1	44.1	0.0	98.6	94.6	4.0	2.6	14.0	11.4	0.95	2.53	2.03	3.87	GW to SW	**0.25**	Y
	4/8/04	15:05	48.7	46.4	2.3	98.6	96.0	2.6	5.3	15.9	10.6	0.88	**2.60**	--	3.80	GW to SW	**0.23**	Y
	5/11/04	11:37	46.6	47.1	-0.5	91.4	94.4	-3.0	1.4	11.6	10.3	0.85	2.65	1.87	3.75	GW to SW	**0.23**	Y
	6/12/04	15:45	47.3	48.9	-1.6	79.8	89.9	-10.1	1	10.9	9.6	0.80	--	1.8	**3.78**	GW to SW	**0.21**	Y
	8/3/04	13:15	58.3	51.4	6.8	96.9	93.3	3.6	3	13.9	10.5	0.875	2.6	2.49	3.80	GW to SW	**0.23**	Y (assumed)
P-11	11/25/03	15:45	41.9	50.9	-9.0	104.0	103.1	0.9	2.0	13.1	11.1	0.93	2.62	2.25	3.14	GW to SW	0.30	N
	12/30/03	13:45	39.9	49.1	-9.2	104.4	95.6	8.8	-5.4	6.5	11.9	0.99	2.30	2.37	2.95	GW to SW	0.34	N
	1/22/04	14:45	43.0	48.9	-5.9	100.0	88.3	11.7	-3.5	8.4	11.9	0.99	2.25	2.32	3.00	GW to SW	0.33	N
	3/1/04	11:30	44.1	46.6	-2.5	98.6	89.9	8.7	-3.5	8.7	12.2	1.02	2.26	2.44	2.85	GW to SW	0.36	N
	4/8/04	15:35	48.7	46.9	1.8	98.6	92.6	6.0	0.1	11.2	11.1	0.93	2.25	2.40	2.99	GW to SW	0.31	N
	5/11/04	12:20	46.6	45.9	0.7	91.4	93.7	-2.3	4.2	14.5	10.3	0.86	2.45	2.35	3.10	GW to SW	0.28	N
	6/12/04	16:30	47.3	46.4	0.9	79.8	93.3	-13.5	4.2	13.8	9.6	0.8	2.5	2.29	3.22	GW to SW	0.25	N
	8/3/04	14:00	58.3	52.0	6.3	96.9	95.7	1.2	-2.9	9.4	12.3	1.025	2.5	2.82	2.47	GW to SW	0.42	N
P-12	11/25/03	16:15	41.9	49.1	-7.2	104.0	107.0	-3.0	-0.5	13.1	13.6	1.13	2.47	2.20	3.07	GW to SW	0.37	N
	12/30/03	14:15	39.9	50.4	-10.4	104.4	93.3	11.1	1.9	17.9	16.0	1.33	2.25	2.26	2.81	GW to SW	0.48	N
	1/22/04	15:15	43.0	49.6	-6.7	100.0	86.6	13.4	-0.4	14.2	14.6	1.22	--	2.22	2.96	GW to SW	0.41	N
	3/1/04	11:50	44.1	47.8	-3.8	98.6	86.8	11.8	-1.6	13.4	15.0	1.25	2.20	2.31	2.84	GW to SW	0.44	N
	4/8/04	15:53	48.7	48.2	0.5	98.6	89.0	9.6	2.7	16.4	13.7	1.14	2.20	2.33	2.93	GW to SW	0.39	N
	5/11/04	12:40	46.6	47.3	-0.7	91.4	93.0	-1.6	1.9	14.3	12.4	1.03	2.20	2.29	3.08	GW to SW	0.34	N
	6/12/04	16:45	47.3	46.9	0.4	79.8	96.4	-16.6	5.0	16.7	11.7	0.98	2.20	2.25	3.18	GW to SW	0.31	N
	8/3/04	14:30	58.3	49.3	9.0	96.9	96.1	0.8	1.4	17.6	16.2	1.35	2.30	2.63	2.42	GW to SW	0.56	N
P-5	11/4/03	16:27	41.9	49.5	-7.6	109.4	107.3	2.1	-6.9	15.2	22.0	1.83	--	4.69	3.18	GW to SW	0.58	N
	11/25/03	17:00	41.9	48.9	-7.0	104.0	109.1	-5.1	-10.0	7.6	17.6	1.47	--	--	3.50	GW to SW	0.42	Y (assumed)
	12/30/03	14:45											3.80	4.77				N
	1/22/04	15:45	43.0	48.9	-5.9	100.0	91.7	8.3	-3.8	14.3	18.1	1.51	--	4.76	3.43	GW to SW	0.44	N
	3/1/04	12:07	44.1	46.9	-2.9	98.6	86.4	12.2	-6.1	12.4	18.4	1.53	--	4.87	3.30	GW to SW	0.47	N
	4/8/04	16:20	48.7	48.6	0.2	98.6	89.7	8.9	-1.0	16.0	17.0	1.42	3.90	4.89	3.39	GW to SW	0.42	N
	5/11/04	13:00	46.6	49.1	-2.5	91.4	94.0	-2.6	-4.2	11.3	15.5	1.29	3.90	4.87	3.54	GW to SW	0.37	N
	6/12/04	17:00	47.3	48.9	-1.6	79.8	95.3	-15.5	0.1	14.8	14.7	1.225	3.90	4.84	3.64	GW to SW	0.34	N
	8/3/04	15:40	58.3	50.5	7.7	96.9	96.9	0.0	-5.6	13.3	18.9	1.575	--	5.24	2.89	GW to SW	0.55	N

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Table 4.3
Data Collected at Mini-Piezometer Locations
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Mini-Piezometer[1]	Date	Time[2,5]	Temperature (°F)			Specific Conductance (µS/cm @ 25 °C)			Manometer Reading[3,4,5] (inches H_2O)			dh (feet)	Stickup[5] (feet)	SWL[6] (feet)	dl[7] (feet)	Gradient Direction	Vertical Hydraulic Gradient[4,5] (ft/ft)	Submerged[8]
			River	Groundwater	Difference	River	Groundwater	Difference	River	Piezometer	Difference							
Cluster 5																		
P-6	11/4/03		Insufficient production for making measurements.										1.1	--				
P-7	11/4/03	12:52	38.8	39.2	-0.4	117.0	114.6	2.4	5.6	-0.1	-5.6	-0.47	--	--	4.83	SW to GW	-0.10	Y (assumed)
	11/25/03	15:50	40.6	41.2	-0.5	104.5	102.8	1.7	1.9	0.2	-1.7	-0.14	1.45	1.71	4.83	SW to GW	-0.03	N
	12/22/03	10:30	40.5	40.6	-0.2	104.4	104.0	0.4	0.6	0.5	-0.1	-0.01	3.50	1.62	2.90	SW to GW	0.00	Y
	1/22/04	16:30	42.4	41.4	1.1	102.5	101.4	1.1	1.7	-0.8	-2.5	-0.21	4.10	--	2.30	SW to GW	-0.09	Y
	3/1/04	14:45	44.6	43.5	1.1	101.0	100.7	0.3	0.0	-3.1	-3.1	-0.26	4.40	2.01	2.00	SW to GW	-0.13	Y
	4/8/04	14:25	46.9	44.2	2.7	99.8	100.0	-0.2	10.3	5.9	-4.4	-0.37	4.40	--	2.00	SW to GW	-0.18	Y
	5/11/04	15:05	48.4	45.9	2.5	91.0	91.7	-0.7	5.1	-1.9	-7.0	-0.58	4.45	2.07	1.95	SW to GW	-0.30	Y
	6/12/04	14:55	46.2	48.6	-2.3	78.6	78.1	0.5	14.7	4.3	-10.4	-0.87	4.45	2.27	1.95	SW to GW	-0.44	Y
	8/3/04	16:10	58.5	58.6	-0.2	101.6	100.1	1.5	5.3	-3.2	-8.5	-0.71	2.25	3.05	4.15	SW to GW	-0.17	Y
Cluster 6																		
P-8	11/4/03	15:10	38.7	48.2	-9.5	118.8	115.9	2.9	6.5	5.1	-1.4	-0.12	2.14	--	4.20	SW to GW	-0.03	Y (assumed)
	11/25/03	12:45	40.5	49.1	-8.6	107.5	106.6	0.9	8.4	8.7	0.3	0.03	--	2.17	**4.20**	GW to SW	0.01	Y
	12/30/03	16:00	38.8	44.6	-5.8	113.4	62.8	50.6	10.4	10.9	0.5	0.04	2.27	2.41	3.95	GW to SW	0.01	N
	1/22/04	12:50	41.9	42.6	-0.7	105.8	61.9	43.9	5.6	6.3	0.7	0.06	2.40	2.24	4.00	GW to SW	0.01	Y
	3/1/04	15:50	44.1	42.6	1.4	107.2	51.2	56.0	4.1	5.4	1.3	0.11	2.30	2.36	3.93	GW to SW	0.03	N
	4/8/04	13:00	45.5	45.5	0.0	101.5	77.0	24.5	11.0	11.2	0.2	0.02	2.40	--	4.00	GW to SW	0.00	Y
	5/11/04	15:50	48.0	46.9	1.1	91.6	89.1	2.5	-4.2	-4.5	-0.3	-0.03	2.40	2.16	4.00	SW to GW	-0.01	Y
	6/12/04	14:00	45.9	48.4	-2.5	78.5	80.3	-1.8	4.4	3.8	-0.6	-0.05	2.40	2.08	4.00	SW to GW	-0.01	Y
	8/3/04	18:58	56.8	54.1	2.7	101.8	97.6	4.2	8.6	7.8	-0.8	-0.07	2.27	2.88	3.59	SW to GW	-0.02	N
P-16	12/30/03	16:00											1.60	5.27				
	1/22/04	13:25		41.2	<--downhole reading.								1.60	5.12				
	3/1/04	16:05	44.1	42.4	1.6	107.2	49.4	57.8	-3.3	2.6	5.9	0.49	1.60	5.07	0.84	GW to SW	0.59	N
	4/8/04	13:00											1.60	5.22				N
	5/11/04	**16:15**											1.60	5.22				N
	6/12/04	13:55											1.60	5.14				
	8/3/04	18:54											1.60	16.01				

1. In each cluster, piezometers are ordered from the probe furthest into the channel to that most inland.
2. Times are reported in PST or PDST as recorded in the field.
3. Manometer measurements for P-5, P-12, P-11, and P-10 reference the river level in an eddy on the north bank against a bedrock constriction (Appendix B).
4. Head differences and vertical gradients are positive for a gaining location.
5. Values in bold font are estimates.
6. SWL data corrected for angle of piezometer (P-8).
7. For an in-river piezometer, dl = L - stickup was used; for an out-of-river piezometer, dl = L - SWL - dh was used. Bold font indicates use of an interpolated value for the stick-up.
8. Y (assumed) indicates piezometers at the edge of the river.

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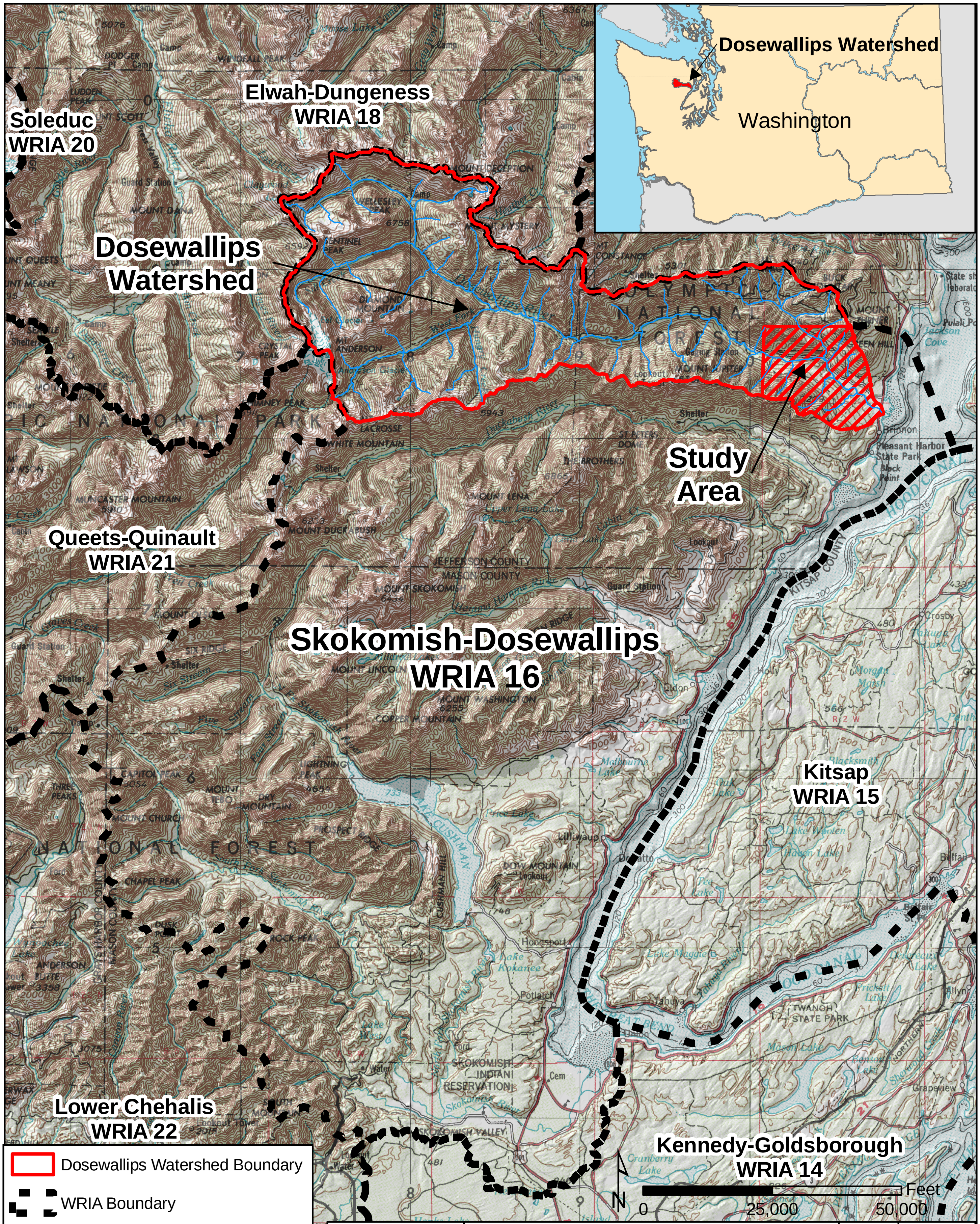
Table 4.4
Summary of Parameters for Instream Piezometers
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Cluster	In-River Mini-Piezometer	Temperature Difference (℉)			Conductivity Difference (µS/cm)			Vertical Hydraulic Gradient (ft/ft)			2003-2004 Conditions
		Min	Average	Max	Min	Average	Max	Min	Average	Max	
1	**P-1**	-1.62	**-0.62**	0.18	-1.40	**0.21**	1.50	-0.42	**-0.19**	-0.12	Losing.
2	**P-13**	-2.52	**-1.20**	-0.09	-1.30	**-0.17**	0.80	-0.16	**-0.05**	0.00	Neutral to losing.
3	**P-15**	-1.08	**-0.21**	0.18	-0.40	**0.50**	1.50	-0.71	**-0.50**	-0.30	Losing.
4	**P-10**	-5.76	**-0.10**	6.84	-10.10	**0.04**	5.20	0.21	**0.23**	0.25	Gaining.
5	**P-7**	-2.34	**0.42**	2.70	-0.70	**0.78**	2.40	-0.44	**-0.16**	0.00	Neutral to losing.
6	**P-8**	-9.54	**-2.44**	2.70	-1.80	**20.41**	56.00	-0.03	**0.00**	0.03	Neutral.

Positive differences indicate that parameter values in the river are higher than groundwater values.



🟥 Dosewallips Watershed Boundary

▬ ▬ WRIA Boundary

Note: Base map is USGS 1:250,000 scale
topographic map
(U.S. Geological Survey, 1958).
200 foot contour interval.

Aspectconsulting
IN-DEPTH PERSPECTIVE

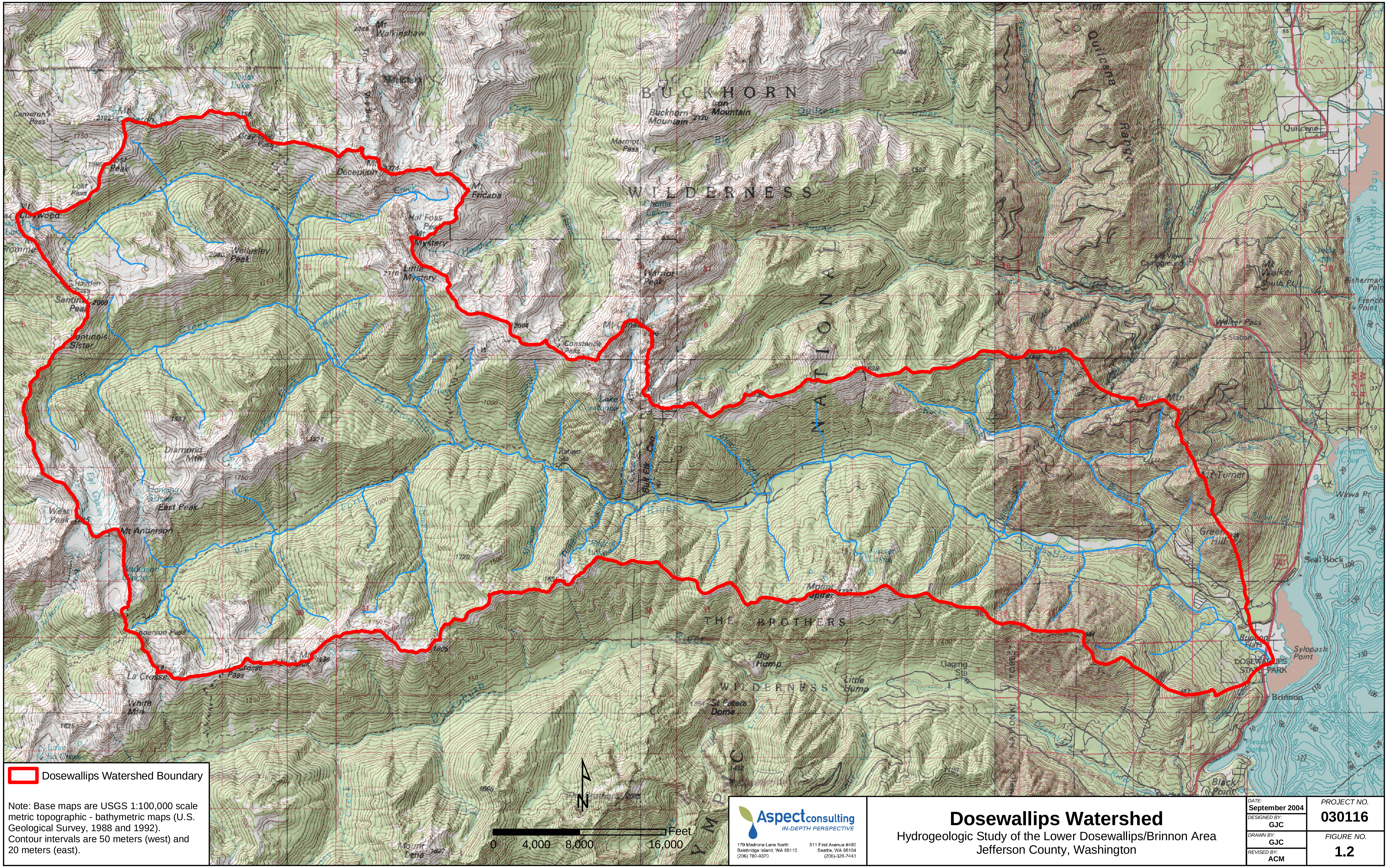
179 Madrone Lane North
Bainbridge Island WA 98110
(206) 780-9370

811 First Avenue #480
Seattle, WA 98104
(206)-328-7443

Project Location Map

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: September 2004	PROJECT NO. 030116
DESIGNED BY: GJC	
DRAWN BY: GJC	FIGURE NO. 1.1
REVISED BY: ACM	



Note: Base maps are USGS 1:100,000 scale metric topographic - bathymetric maps (U.S. Geological Survey, 1988 and 1992).
Contour intervals are 50 meters (west) and 20 meters (east).

Aspect consulting
IN-DEPTH PERSPECTIVE

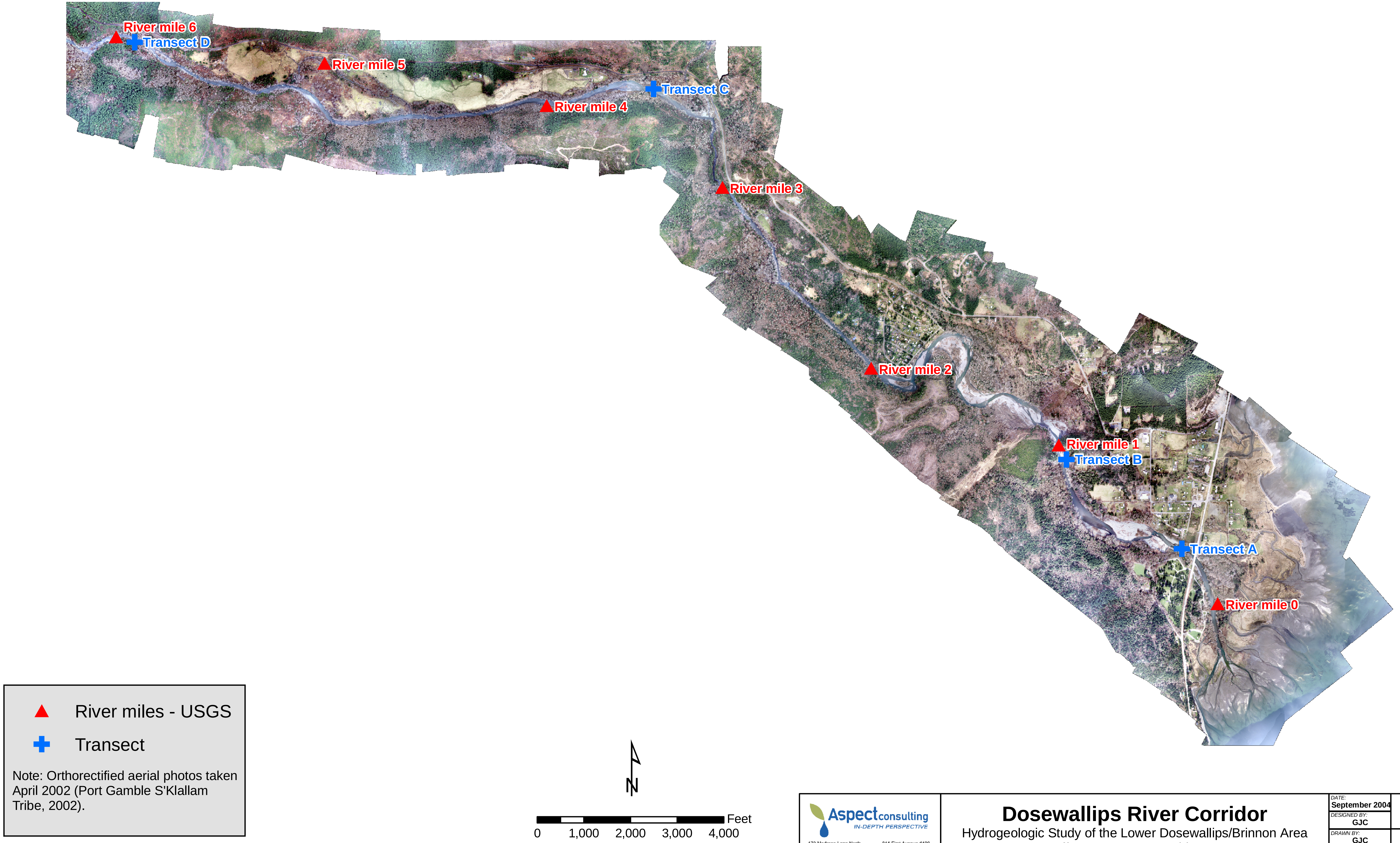
179 Madrone Lane North
Bainbridge Island, WA 98110
(206) 780-9370

811 First Avenue #480
Seattle, WA 98104
(206)-328-7443

Dosewallips Watershed

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: September 2004	PROJECT NO. 030116
DESIGNED BY: GJC	
DRAWN BY: GJC	FIGURE NO. 1.2
REVISED BY: ACM	



Note: Orthorectified aerial photos taken April 2002 (Port Gamble S'Klallam Tribe, 2002).

Aspect consulting
IN-DEPTH PERSPECTIVE

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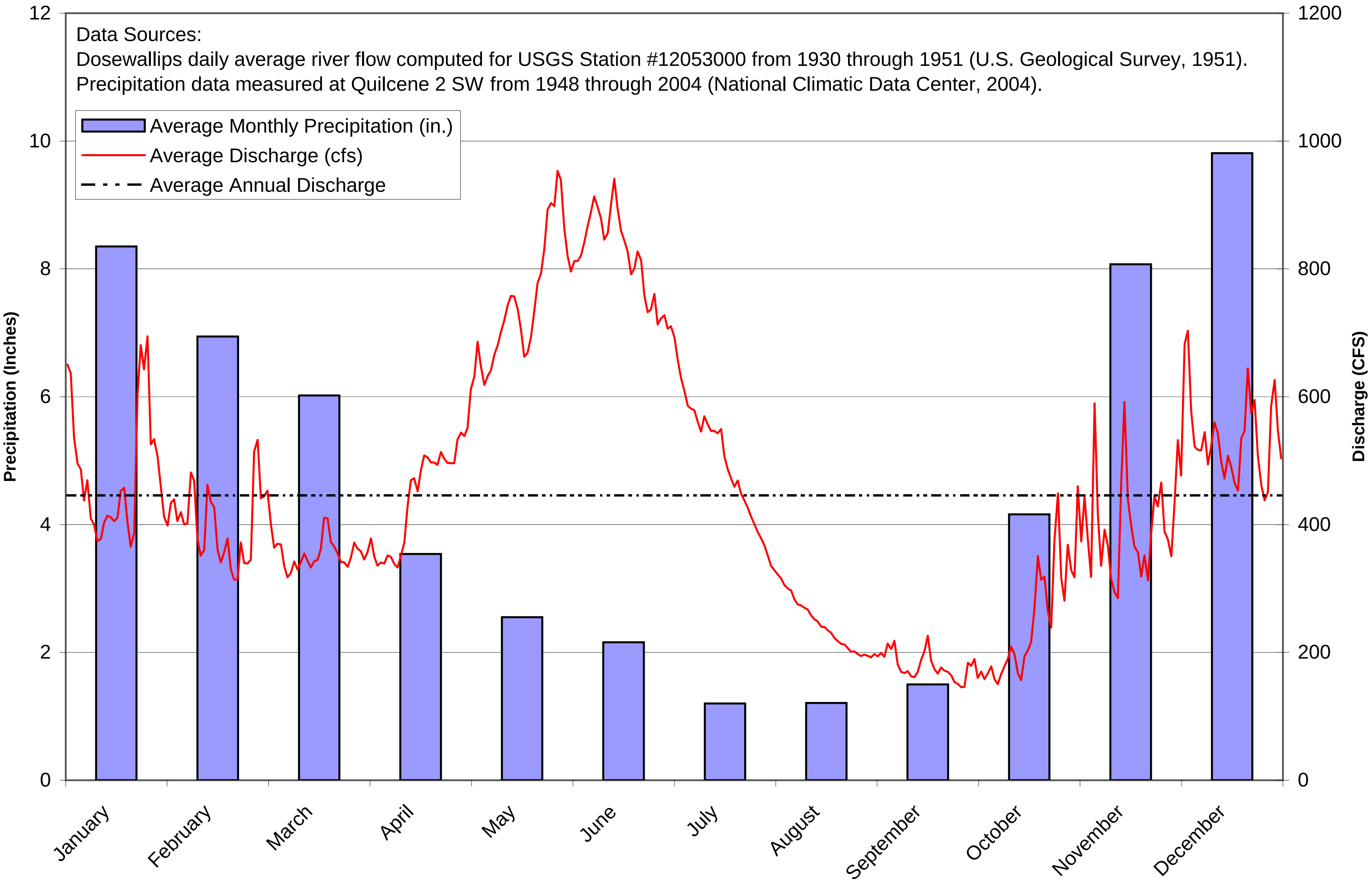
Dosewallips River Corridor

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: **September 2004**
DESIGNED BY: **GJC**
DRAWN BY: **GJC**
REVISED BY: **ACM**

PROJECT NO. **030116**
FIGURE NO. **1.3**



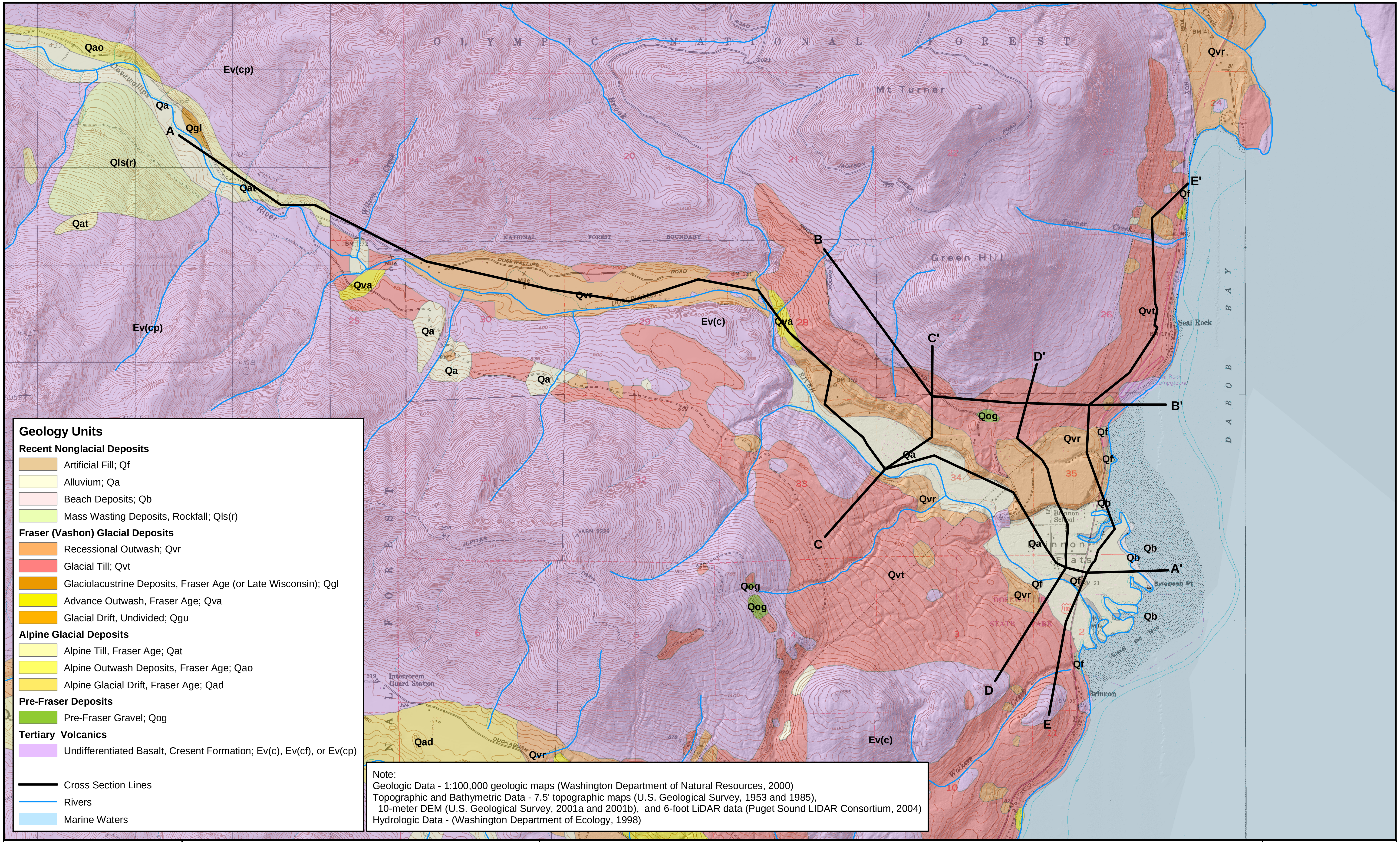
Average Daily Discharge and Average Monthly Precipitation for Historical Data

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Figure 1.4

Aspect consulting

W:\030116 WRIA 16\Final Report\Discharge Data 1910-1951 .xls



Geology Units

Recent Nonglacial Deposits

- ▨ Artificial Fill; Qf
- ▨ Alluvium; Qa
- ▨ Beach Deposits; Qb
- ▨ Mass Wasting Deposits, Rockfall; Qls(r)

Fraser (Vashon) Glacial Deposits

- ▨ Recessional Outwash; Qvr
- ▨ Glacial Till; Qvt
- ▨ Glaciolacustrine Deposits, Fraser Age (or Late Wisconsin); Qgl
- ▨ Advance Outwash, Fraser Age; Qva
- ▨ Glacial Drift, Undivided; Qgu

Alpine Glacial Deposits

- ▨ Alpine Till, Fraser Age; Qat
- ▨ Alpine Outwash Deposits, Fraser Age; Qao
- ▨ Alpine Glacial Drift, Fraser Age; Qad

Pre-Fraser Deposits

- ▨ Pre-Fraser Gravel; Qog

Tertiary Volcanics

- ▨ Undifferentiated Basalt, Cresent Formation; Ev(c), Ev(cf), or Ev(cp)

- — Cross Section Lines
- — Rivers
- ▨ Marine Waters

Note:
Geologic Data - 1:100,000 geologic maps (Washington Department of Natural Resources, 2000)
Topographic and Bathymetric Data - 7.5' topographic maps (U.S. Geological Survey, 1953 and 1985),
10-meter DEM (U.S. Geological Survey, 2001a and 2001b), and 6-foot LiDAR data (Puget Sound LIDAR Consortium, 2004)
Hydrologic Data - (Washington Department of Ecology, 1998)

Aspect consulting
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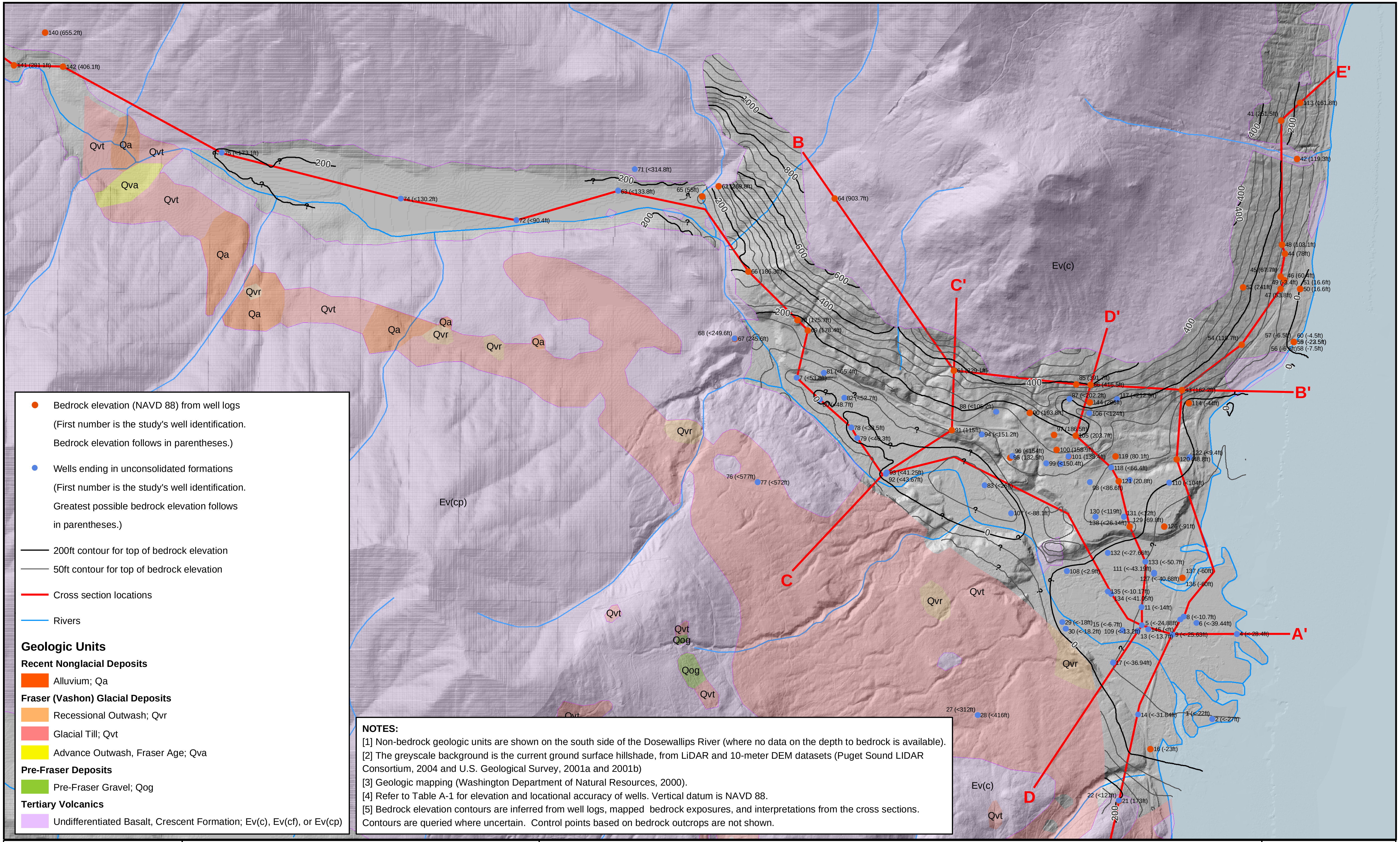
0 1,500 3,000 6,000 Feet

N

GEOLOGIC MAP

Hydrogeologic Study of the Lower Dosewallips / Brinnon Area
Jefferson County, WA

Figure 2.1



● Bedrock elevation (NAVD 88) from well logs
(First number is the study's well identification.
Bedrock elevation follows in parentheses.)

● Wells ending in unconsolidated formations
(First number is the study's well identification.
Greatest possible bedrock elevation follows
in parentheses.)

200ft contour for top of bedrock elevation

50ft contour for top of bedrock elevation

Cross section locations

Rivers

Geologic Units

Recent Nonglacial Deposits

🟧 Alluvium; Qa

Fraser (Vashon) Glacial Deposits

🟧 Recessional Outwash; Qvr

🟥 Glacial Till; Qvt

🟨 Advance Outwash, Fraser Age; Qva

Pre-Fraser Deposits

🟩 Pre-Fraser Gravel; Qog

Tertiary Volcanics

🟪 Undifferentiated Basalt, Crescent Formation; Ev(c), Ev(cf), or Ev(cp)

NOTES:

[1] Non-bedrock geologic units are shown on the south side of the Dosewallips River (where no data on the depth to bedrock is available).

[2] The greyscale background is the current ground surface hillshade, from LiDAR and 10-meter DEM datasets (Puget Sound LIDAR Consortium, 2004 and U.S. Geological Survey, 2001a and 2001b)

[3] Geologic mapping (Washington Department of Natural Resources, 2000).

[4] Refer to Table A-1 for elevation and locational accuracy of wells. Vertical datum is NAVD 88.

[5] Bedrock elevation contours are inferred from well logs, mapped bedrock exposures, and interpretations from the cross sections. Contours are queried where uncertain. Control points based on bedrock outcrops are not shown.

Aspectconsulting
IN-DEPTH PERSPECTIVE

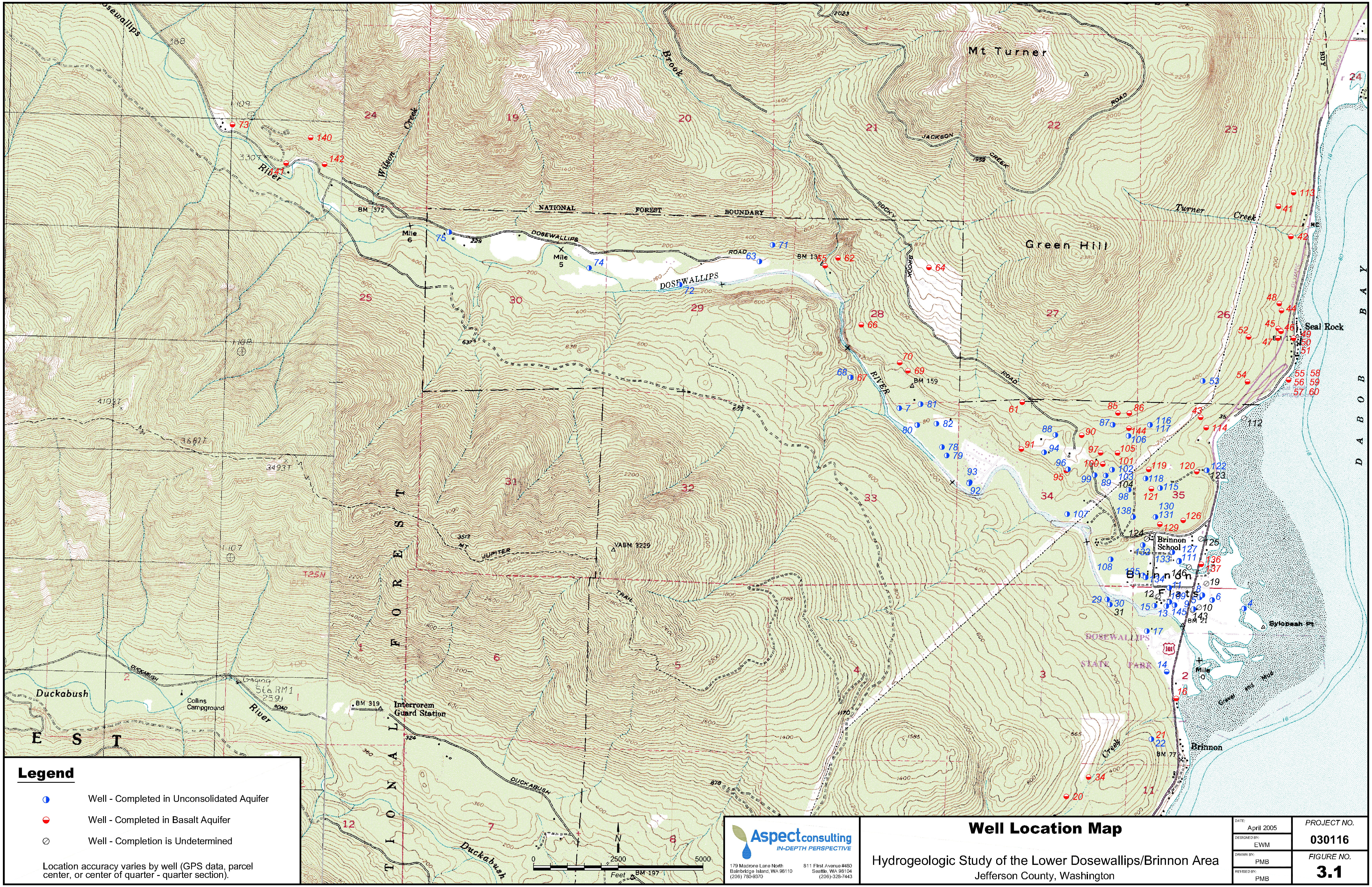
0 1,000 2,000 4,000 Feet

N

TOP OF BEDROCK ELEVATION CONTOUR MAP

Hydrogeologic Study of the Lower Dosewallips / Brinnon Area
Jefferson County, WA

Figure 2.2



Legend

◐ Well - Completed in Unconsolidated Aquifer

◒ Well - Completed in Basalt Aquifer

⊘ Well - Completion is Undetermined

Location accuracy varies by well (GPS data, parcel center, or center of quarter - quarter section).

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Well Location Map

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE:	April 2005
DESIGNED BY:	EWM
DRAWN BY:	PMB
REVISED BY:	PMB
PROJECT NO.	030116
FIGURE NO.	3.1

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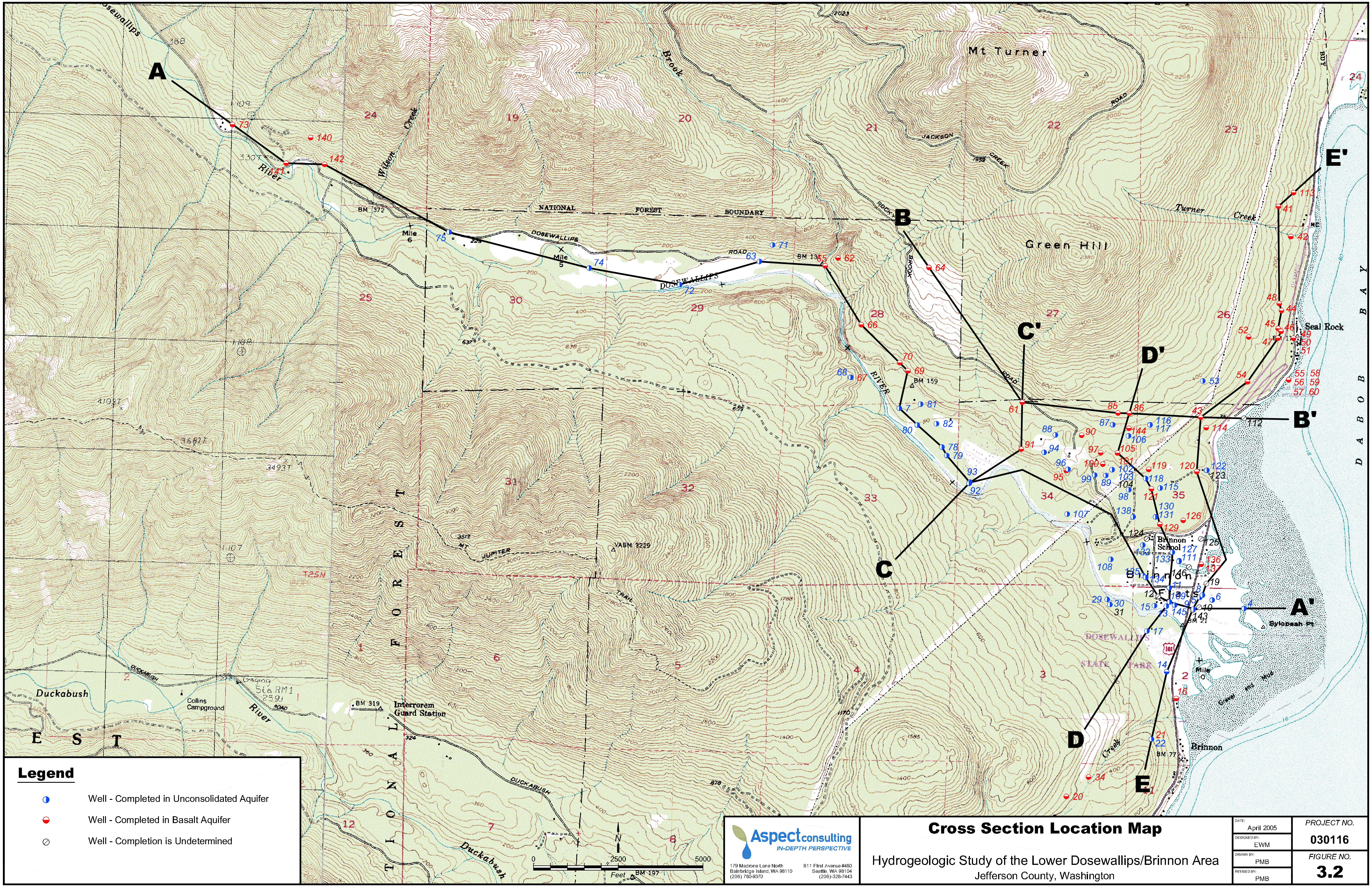

Legend

◐ Well - Completed in Unconsolidated Aquifer

◒ Well - Completed in Basalt Aquifer

⊘ Well - Completion is Undetermined

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Cross Section Location Map

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: April 2005	PROJECT NO. 030116
DESIGNED BY: EWM	
DRAWN BY: PMB	FIGURE NO. 3.2
REVISED BY: PMB	

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LEGEND

SYMBOLS	
———	Ground Surface
— — —	Geologic Unit Contact *(approximate)*
▤	Well Screen or Perforated Casing Interval
☐	Open Hole, Uncased
▽	Static Water Level Reported on Well Log and Point of Measurement
94 - 34F	Well No. - Section and Quarter-Quarter
Brown	Owner Name - Refer to Table A-1 for locational accuracy of wells

GEOLOGY	
Qal	= Recent Alluvium
Qvr	= Glacial Recessional Outwash
Qvt	= Glacial Till (Includes alpine till in west portion of A-A')
Qvt/Ql	= Undifferentiated Glacial Till/ Glaciolacustrine Deposits
Qva	= Glacial Advance Outwash
Tb	= Basalt (Crescent Formation)

REPORTED SOIL DESCRIPTIONS

f	= fine	*Cl*	= Clay	*abd*	= abundant
m	= medium	*Si*	= Silt	*cem*	= cemented
c	= coarse	*Sa*	= Sand	*int*	= interbeds
w/	= with	*Gr*	= Gravel	*lam*	= laminations
s	= some	*Bo*	= Boulders	*lay*	= layers
+	= and	*Co*	= Cobbles	*len*	= lenses
occ	= occasional	*Till*	= Glacial Till	*l*	= light
sc	= scattered	*Org*	= Organics	*ox*	= oxidized
li	= little	*Wd*	= Wood	*tr*	= trace
w/b	= water-bearing	*Ts*	= Topsoil	*volc*	= volcanics
frac	= fractured	*Ba*	= Basalt		
		Hp	= Hardpan		

Example: *f-c SiGr, s Sa, tr Co + Bo*

Fine to coarse Silty Gravel, some sand, trace cobbles and boulders

🟨	Unconsolidated Coarse Grained Deposits
🟩	Unconsolidated Fine Grained Deposits
🟥	Basalt

Elevation Datum NAVD 88

Aspect consulting
IN-DEPTH PERSPECTIVE

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Geologic Cross Section A-A'

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE:	April 2005
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DRAWN BY:	PMB
REVISED BY:	PMB
PROJECT NO.	030116
FIGURE NO.	3.3

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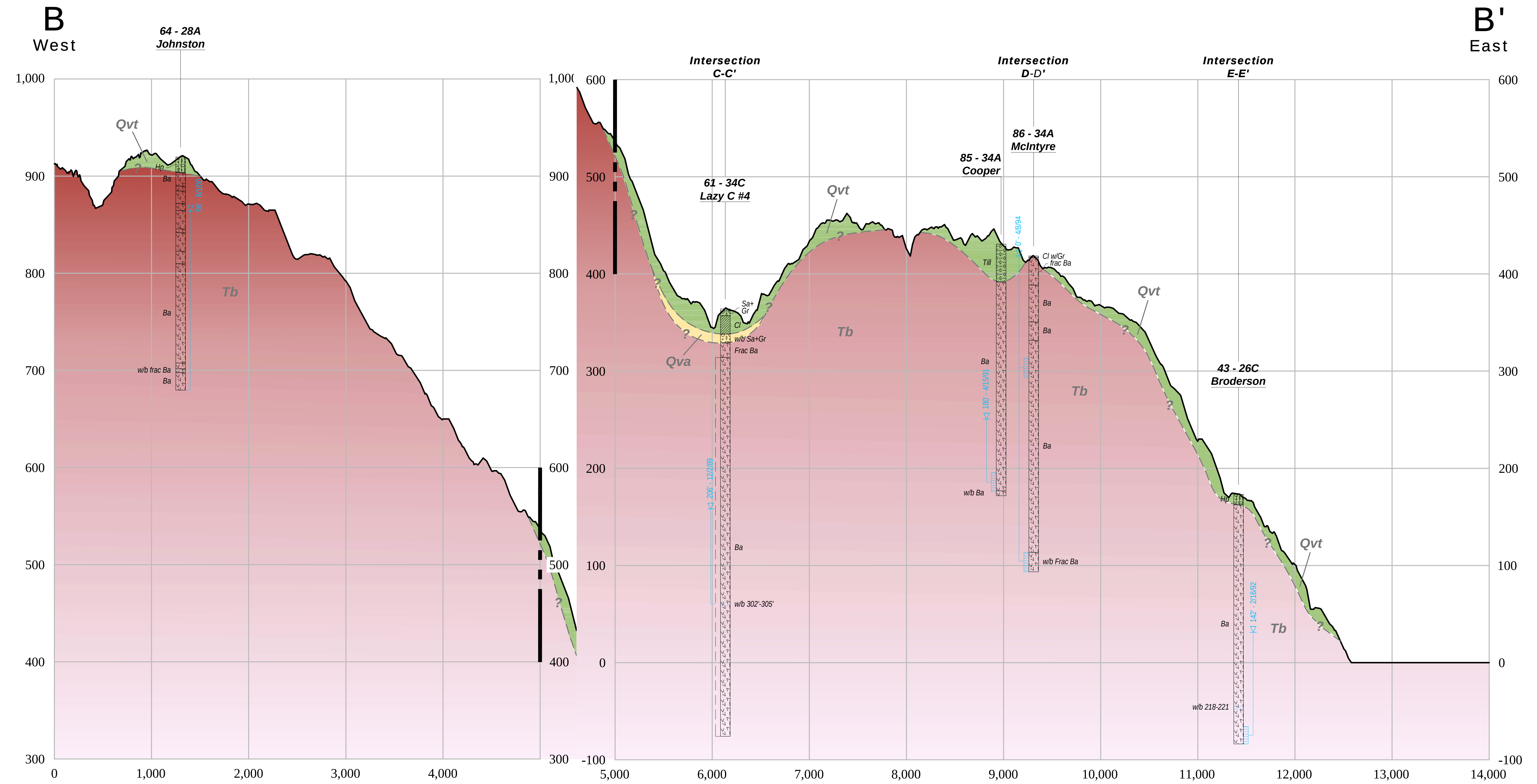

Elevation Datum NAVD 88

LEGEND

SYMBOLS

———	Ground Surface
— — —	Geologic Unit Contact *(approximate)*
▤	Well Screen or Perforated Casing Interval
⊏ ⊐	Open Hole, Uncased
▽	Static Water Level Reported on Well Log and Point of Measurement
94 - 34F **Brown**	Well No. - Section and Quarter-Quarter Owner Name - Refer to Table A-1 for locational accuracy of wells

GEOLOGY

Qal	= Recent Alluvium
Qvr	= Glacial Recessional Outwash
Qvt	= Glacial Till (Includes alpine till in west portion of A-A')
Qvt/Ql	= Undifferentiated Glacial Till/ Glaciolacustrine Deposits
Qva	= Glacial Advance Outwash
Tb	= Basalt (Crescent Formation)

REPORTED SOIL DESCRIPTIONS

f = fine
m = medium
c = coarse
w/ = with
s = some
\+ = and
occ = occasional
sc = scattered
li = little
w/b = water-bearing
frac = fractured

Cl = Clay
Si = Silt
Sa = Sand
Gr = Gravel
Bo = Boulders
Co = Cobbles
Till = Glacial Till
Org = Organics
Wd = Wood
Ts = Topsoil
Ba = Basalt
Hp = Hardpan

abd = abundant
cem = cemented
int = interbeds
lam = laminations
lay = layers
len = lenses
l = light
ox = oxidized
tr = trace
volc = volcanics

Example: *f-c SiGr, s Sa, tr Co + Bo*

Fine to coarse Silty Gravel, some sand, trace cobbles and boulders

🟨	Unconsolidated Coarse Grained Deposits
🟩	Unconsolidated Fine Grained Deposits
🟥	Basalt

Aspect consulting
IN-DEPTH PERSPECTIVE

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Geologic Cross Section B-B'

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: April 2005
DESIGNED BY: EWM
DRAWN BY: PMB
REVISED BY: PMB

PROJECT NO. 030116
FIGURE NO. 3.4

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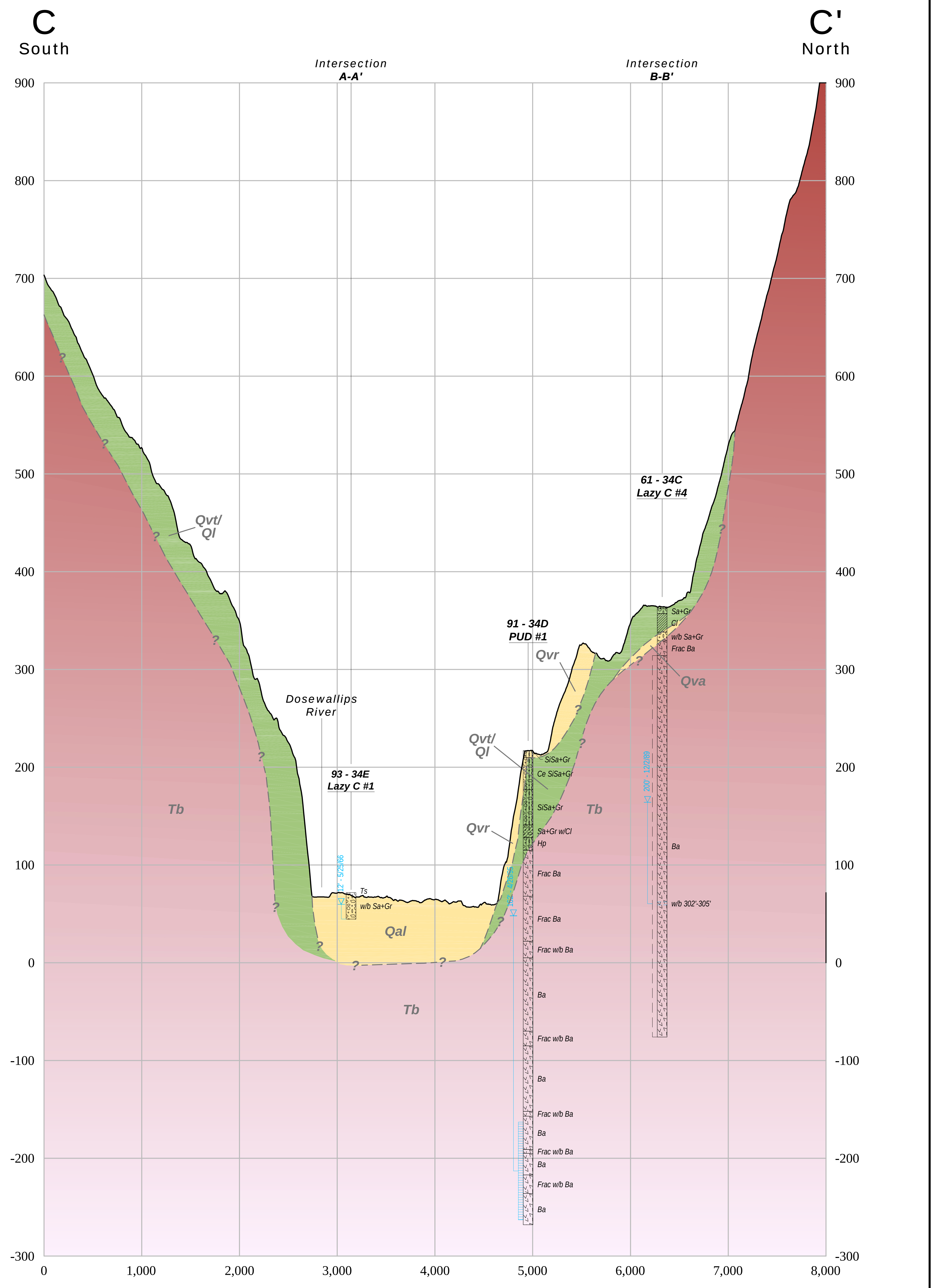

Elevation Datum NAVD 88

LEGEND

SYMBOLS

Ground Surface
Geologic Unit Contact *(approximate)*
Well Screen or Perforated Casing Interval
Open Hole, Uncased
Static Water Level Reported on Well Log and Point of Measurement.
94 - 34F Well No. - Section and Quarter-Quarter
Brown Owner Name - Refer to Table A-1 for locational accuracy of wells

GEOLOGY

Qal = Recent Alluvium
Qvr = Glacial Recessional Outwash
Qvt = Glacial Till (Includes alpine till in west portion of A-A')
Qvt/Ql = Undifferentiated Glacial Till/ Glaciolacustrine Deposits
Qva = Glacial Advance Outwash
Tb = Basalt (Crescent Formation)

REPORTED SOIL DESCRIPTIONS

f = fine
m = medium
c = coarse
w/ = with
s = some
\+ = and
occ = occasional
sc = scattered
li = little
w/b = water-bearing
frac = fractured

Cl = Clay
Si = Silt
Sa = Sand
Gr = Gravel
Bo = Boulders
Co = Cobbles
Till = Glacial Till
Org = Organics
Wd = Wood
Ts = Topsoil
Ba = Basalt
Hp = Hardpan

abd = abundant
cem = cemented
int = interbeds
lam = laminations
lay = layers
len = lenses
l = light
ox = oxidized
tr = trace
volc = volcanics

Example: *f-c SiGr, s Sa, tr Co + Bo*

Fine to coarse Silty Gravel, some sand, trace cobbles and boulders.

🟨 Unconsolidated Coarse Grained Deposits
🟩 Unconsolidated Fine Grained Deposits
🟥 Basalt

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IN-DEPTH PERSPECTIVE

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Geologic Cross Section C-C'

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area

Jefferson County, Washington

DATE: April 2005
DESIGNED BY: EWM
DRAWN BY: PMB
REVISED BY: PMB

PROJECT NO. 030116
FIGURE NO. 3.5

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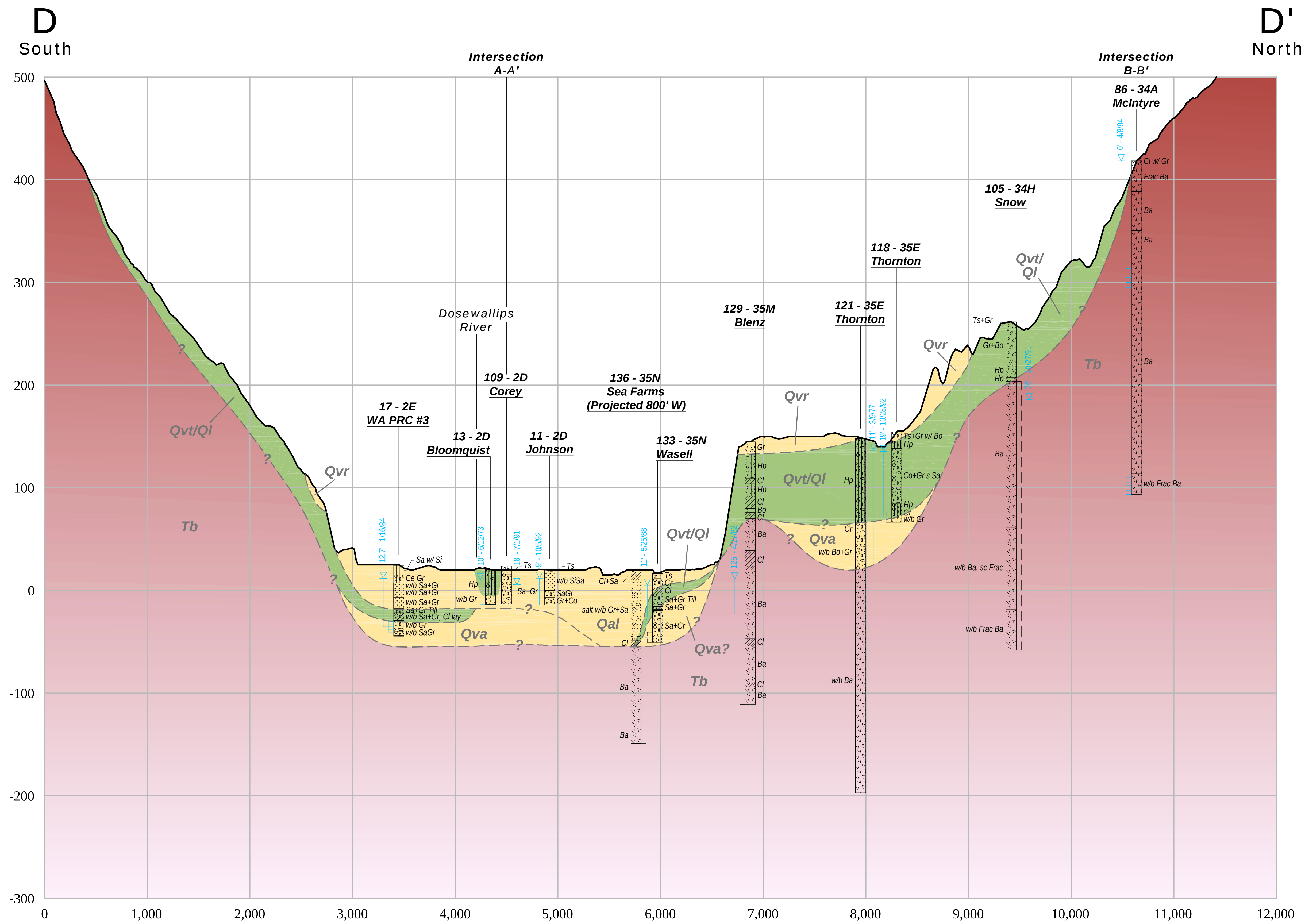

Elevation Datum NAVD 88

L E G E N D

SYMBOLS

—	Ground Surface
– – –	Geologic Unit Contact *(approximate)*
▤	Well Screen or Perforated Casing Interval
☐	Open Hole, Uncased
▽	Static Water Level Reported on Well Log and Point of Measurement
94 - 34F	Well No. - Section and Quarter-Quarter
Brown	Owner Name - Refer to Table A-1 for locational accuracy of wells

GEOLOGY

Qal	= Recent Alluvium
Qvr	= Glacial Recessional Outwash
Qvt	= Glacial Till (Includes alpine till in west portion of A-A')
Qvt/Ql	= Undifferentiated Glacial Till/ Glaciolacustrine Deposits
Qva	= Glacial Advance Outwash
Tb	= Basalt (Crescent Formation)

REPORTED SOIL DESCRIPTIONS

f = fine
m = medium
c = coarse
w/ = with
s = some
+ = and
occ = occasional
sc = scattered
li = little
w/b = water-bearing
frac = fractured

Cl = Clay
Si = Silt
Sa = Sand
Gr = Gravel
Bo = Boulders
Co = Cobbles
Till = Glacial Till
Org = Organics
Wd = Wood
Ts = Topsoil
Ba = Basalt
Hp = Hardpan

abd = abundant
cem = cemented
int = interbeds
lam = laminations
lay = layers
len = lenses
l = light
ox = oxidized
tr = trace
volc = volcanics

Example: *f-c SiGr, s Sa, tr Co + Bo*

Fine to coarse Silty Gravel, some sand, trace cobbles and boulders

🟨	Unconsolidated Coarse Grained Deposits
🟩	Unconsolidated Fine Grained Deposits
🟥	Basalt

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Geologic Cross Section D-D'

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE:	April 2005
DESIGNED BY:	EWM
DRAWN BY:	PMB
REVISED BY:	PMB
PROJECT NO.	030116
FIGURE NO.	3.6

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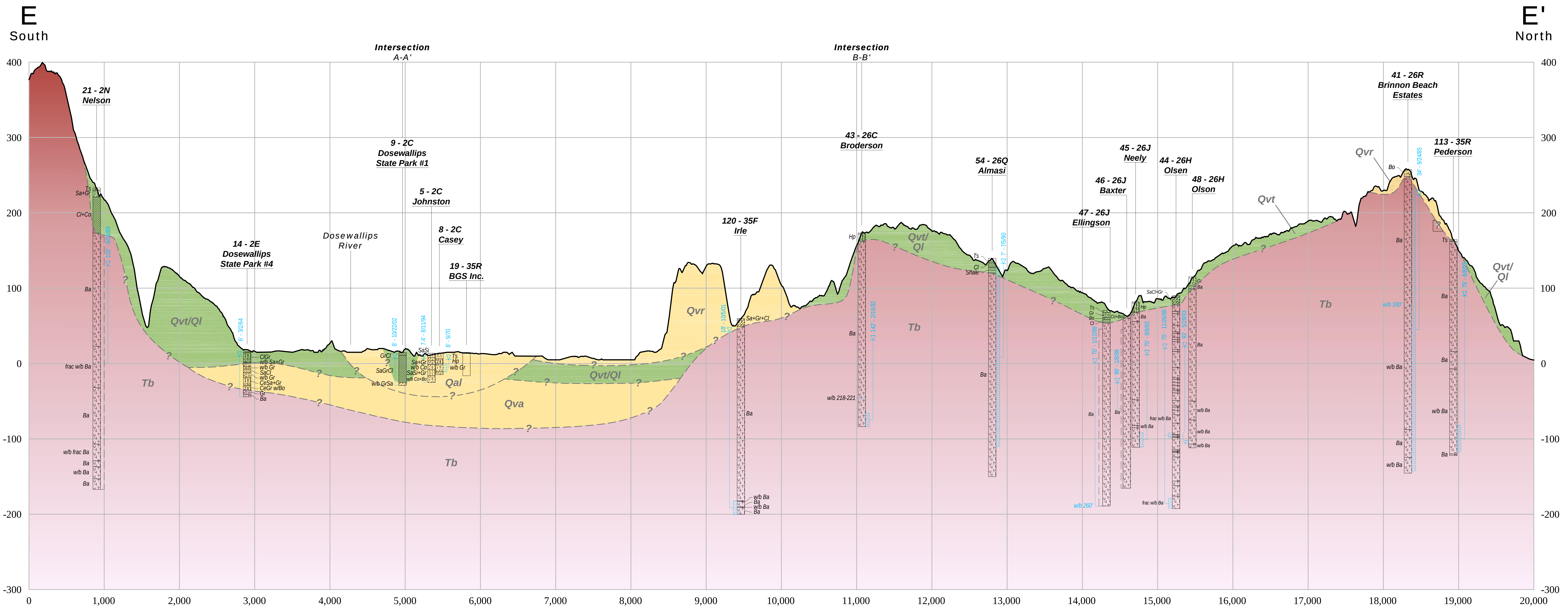

Elevation Datum NAVD 88

L E G E N D

SYMBOLS	
───	Ground Surface
— — —	Geologic Unit Contact *(approximate)*
▤	Well Screen or Perforated Casing Interval
☐	Open Hole, Uncased
▽	Static Water Level Reported on Well Log and Point of Measurement
94 - 34F	Well No. - Section and Quarter-Quarter
Brown	Owner Name - Refer to Table A-1 for locational accuracy of wells

GEOLOGY	
Qal	= Recent Alluvium
Qvr	= Glacial Recessional Outwash
Qvt	= Glacial Till (Includes alpine till in west portion of A-A')
Qvt/Ql	= Undifferentiated Glacial Till/ Glaciolacustrine Deposits
Qva	= Glacial Advance Outwash
Tb	= Basalt (Crescent Formation)

REPORTED SOIL DESCRIPTIONS

f	= fine	*Cl*	= Clay	*abd*	= abundant
m	= medium	*Si*	= Silt	*cem*	= cemented
c	= coarse	*Sa*	= Sand	*int*	= interbeds
w/	= with	*Gr*	= Gravel	*lam*	= laminations
s	= some	*Bo*	= Boulders	*lay*	= layers
+	= and	*Co*	= Cobbles	*len*	= lenses
occ	= occasional	*Till*	= Glacial Till	*l*	= light
sc	= scattered	*Org*	= Organics	*ox*	= oxidized
li	= little	*Wd*	= Wood	*tr*	= trace
w/b	= water-bearing	*Ts*	= Topsoil	*volc*	= volcanics
frac	= fractured	*Ba*	= Basalt		
		Hp	= Hardpan		

Example: *f-c SiGr, s Sa, tr Co + Bo*

Fine to coarse Silty Gravel, some sand, trace cobbles and boulders

🟨	Unconsolidated Coarse Grained Deposits
🟩	Unconsolidated Fine Grained Deposits
🟥	Basalt

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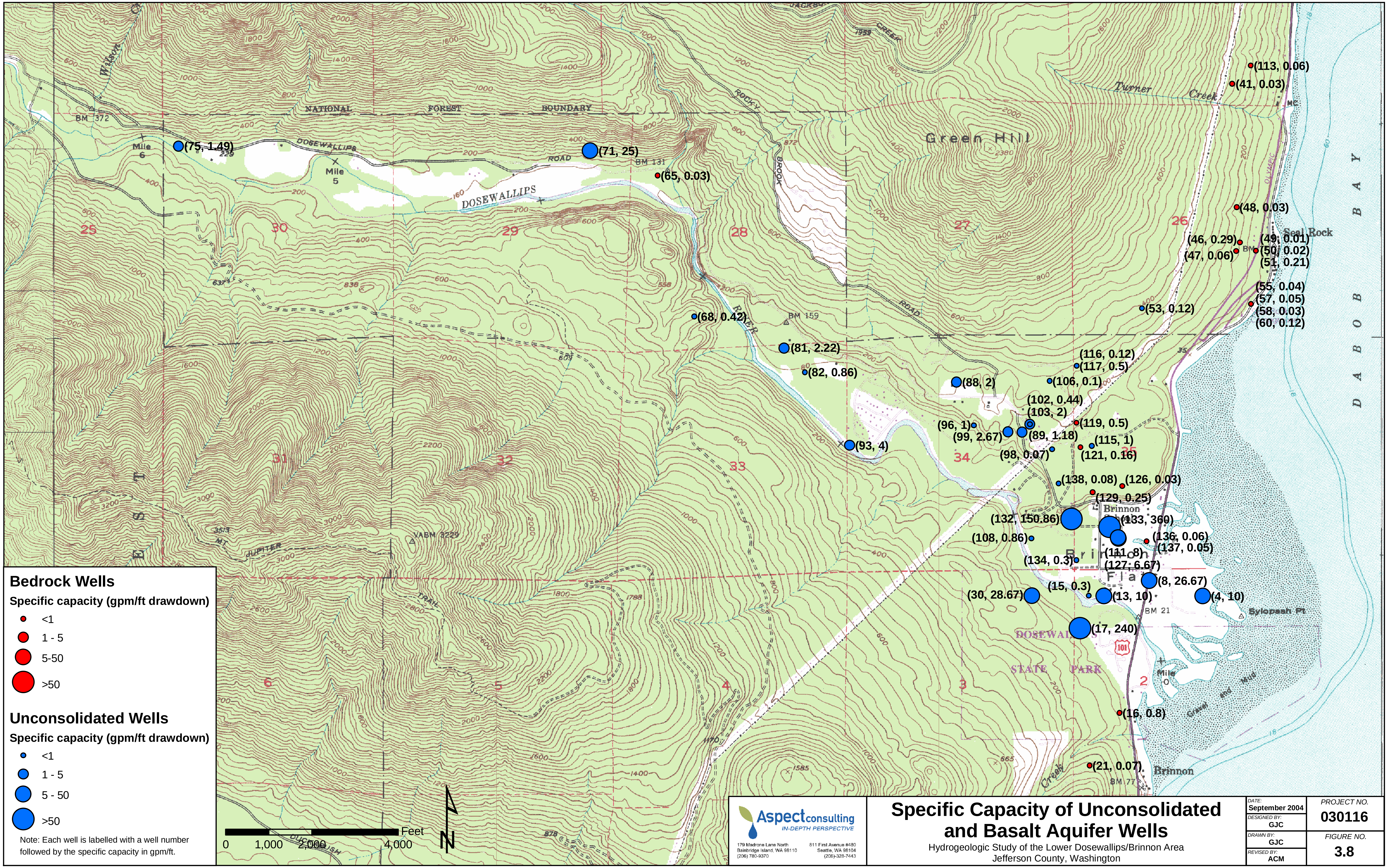
Geologic Cross Section E-E'

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: April 2005
DESIGNED BY: EWM
DRAWN BY: PMB
REVISED BY: PMB

PROJECT NO.
030116

FIGURE NO.
3.7



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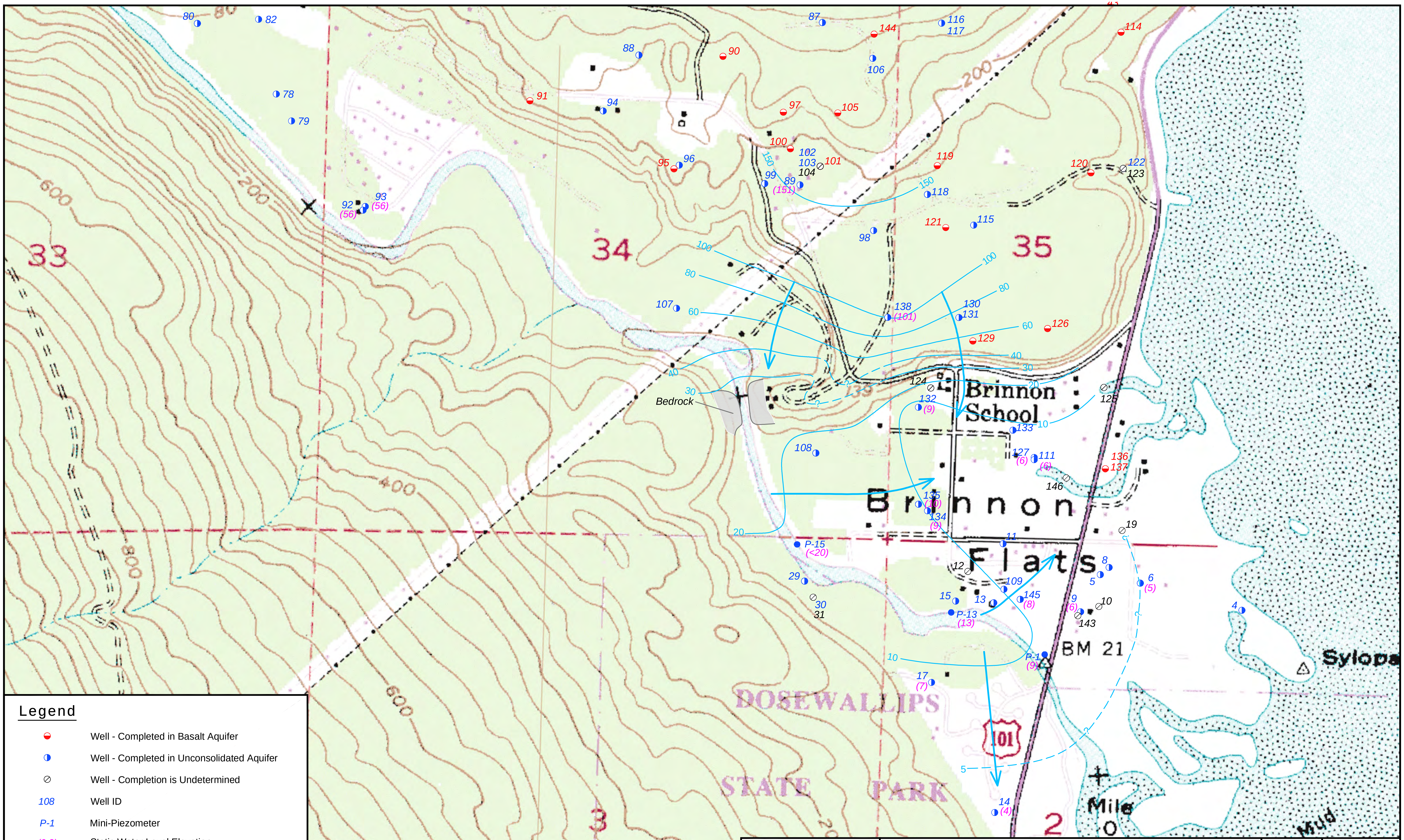
Specific Capacity of Unconsolidated and Basalt Aquifer Wells

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: September 2004
DESIGNED BY: GJC
DRAWN BY: GJC
REVISED BY: ACM
PROJECT NO. 030116
FIGURE NO. 3.8



Legend

- Well - Completed in Basalt Aquifer
- Well - Completed in Unconsolidated Aquifer
- ⊘ Well - Completion is Undetermined

108	Well ID
P-1	Mini-Piezometer
(9.2)	Static Water Level Elevation (NGVD 29, MSL)
50	Groundwater Elevation Contour (Intervals Vary)
←	Groundwater Flow Path

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Groundwater Elevations and Contours for the Unconsolidated Aquifer 6-12-04

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE:	April 2005
DESIGNED BY:	EWM
DRAWN BY:	SDM
REVISED BY:	PMB

PROJECT NO.
030016

FIGURE NO.
3.9

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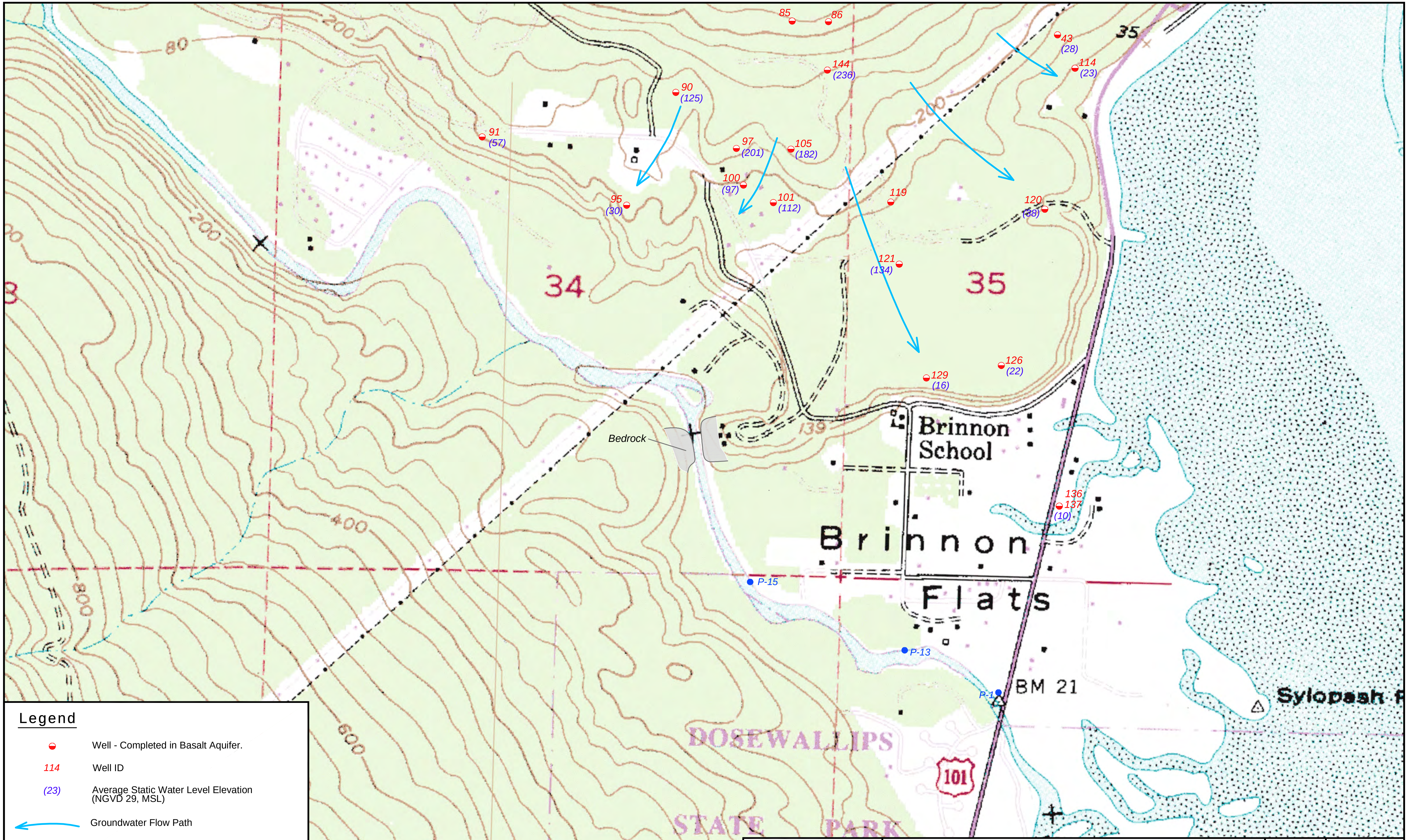

Legend

- ● Well - Completed in Basalt Aquifer.
- 114 Well ID
- (23) Average Static Water Level Elevation (NGVD 29, MSL)
- ← Groundwater Flow Path

Note:
Heads vary over short lateral distances within the basalt aquifer and were not contoured.

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Groundwater Elevations and Flow Paths for the Basalt Aquifer

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: April 2005	PROJECT NO. 030116
DESIGNED BY: EWM	
DRAWN BY: SDM	FIGURE NO. 3.10
REVISED BY: PMB	

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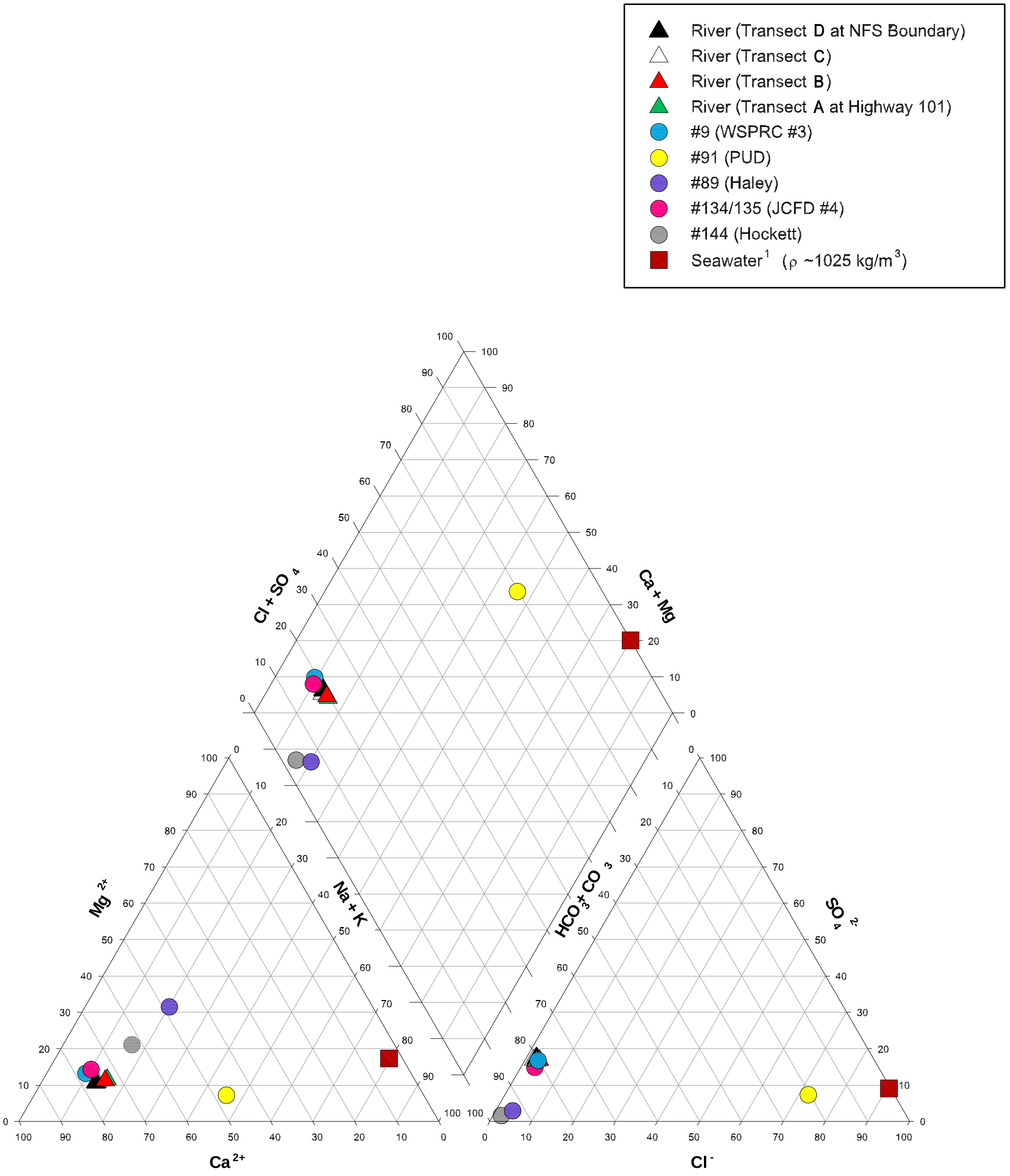

1. Drever, J.I., 1982, The Geochemistry of Natural Waters: Englewood Cliffs, Prentice-Hall.

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Ternary (Piper) Diagram of Major Ions

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: April 2005
DESIGNED BY: EWM
DRAWN BY: PMB
REVISED BY: PMB

PROJECT NO. 030116

FIGURE NO. 3.11

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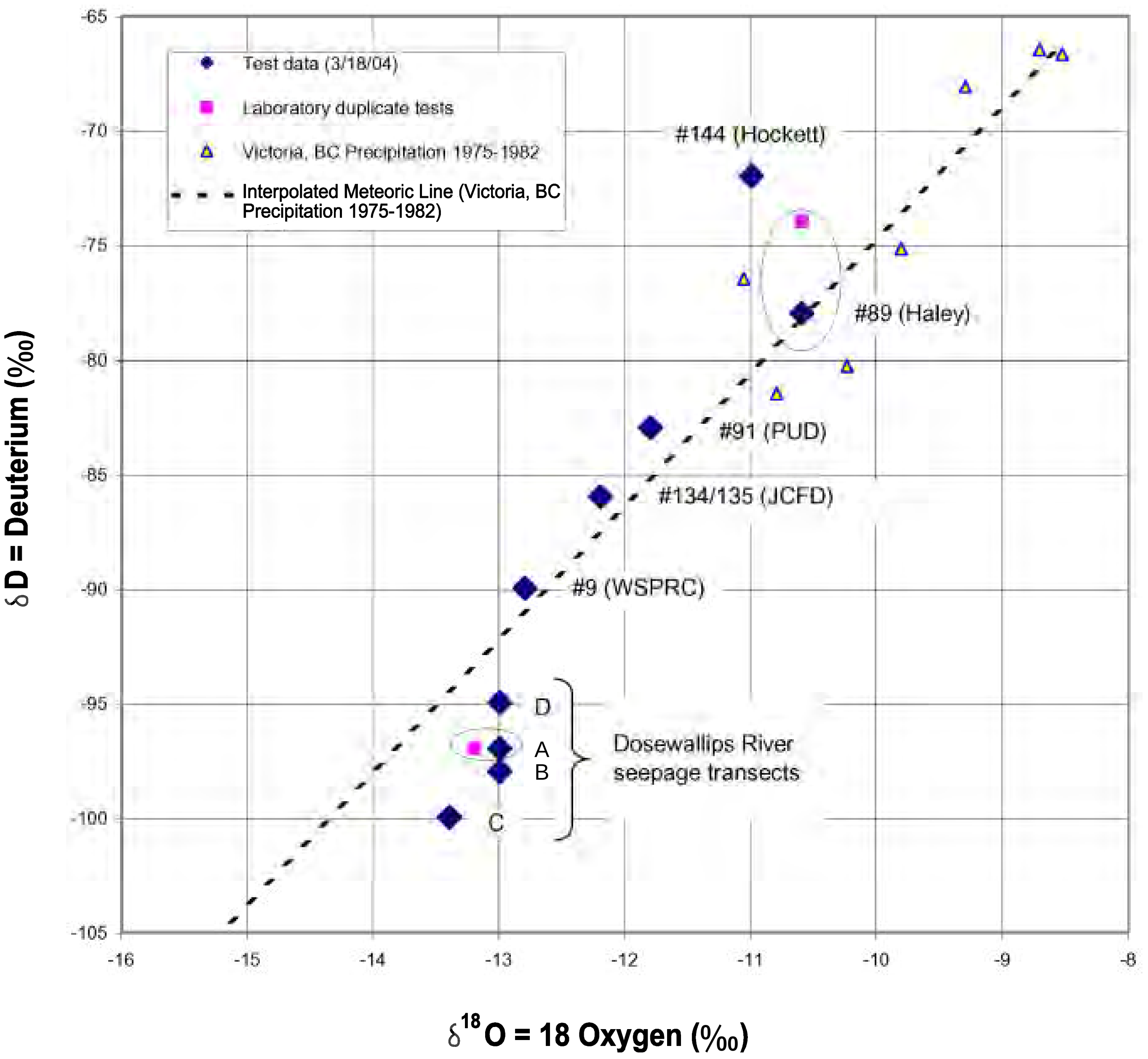

Analyses are reported in ‰ notation and are computed as follows:

$$\delta R_{sample}\ ‰ = \left[\frac{R_{sample}}{R_{standard}} - 1\right] \times 1000, \quad \text{where } D/H_{standard} = 0.000316$$

$$\text{and } ^{18}O/^{16}O_{standard} = 0.0039948$$

Negative values indicate that the concentration of the sample is less than the standard. Values of -100‰ and -70‰ represent concentrations that are 10% and 7%, respectively, less than the standard.

Aspect consulting
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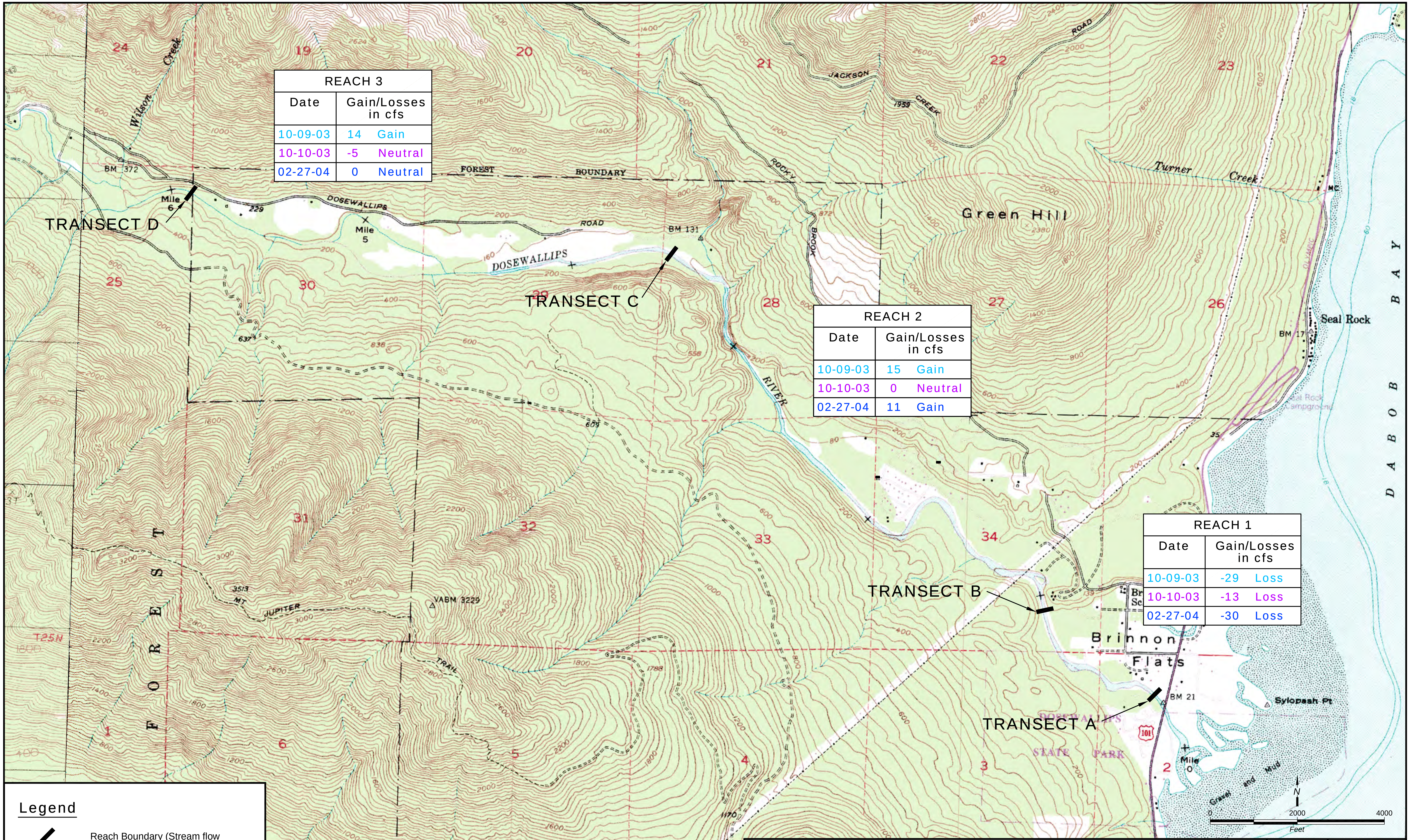
Stable Isotope Analysis

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: April 2005
DESIGNED BY: EWM
DRAWN BY: PMB
REVISED BY: PMB

PROJECT NO. 030116
FIGURE NO. 3.12

Q:\WRIA\030116 WRIA 16\2005-04\030116-04.dwg



REACH 3

Date	Gain/Losses in cfs	
10-09-03	14	Gain
10-10-03	-5	Neutral
02-27-04	0	Neutral

REACH 2

Date	Gain/Losses in cfs	
10-09-03	15	Gain
10-10-03	0	Neutral
02-27-04	11	Gain

REACH 1

Date	Gain/Losses in cfs	
10-09-03	-29	Loss
10-10-03	-13	Loss
02-27-04	-30	Loss

Legend

▬ Reach Boundary (Stream flow measurement transect)

See Appendix B for computation methodology.

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Seepage Survey Results

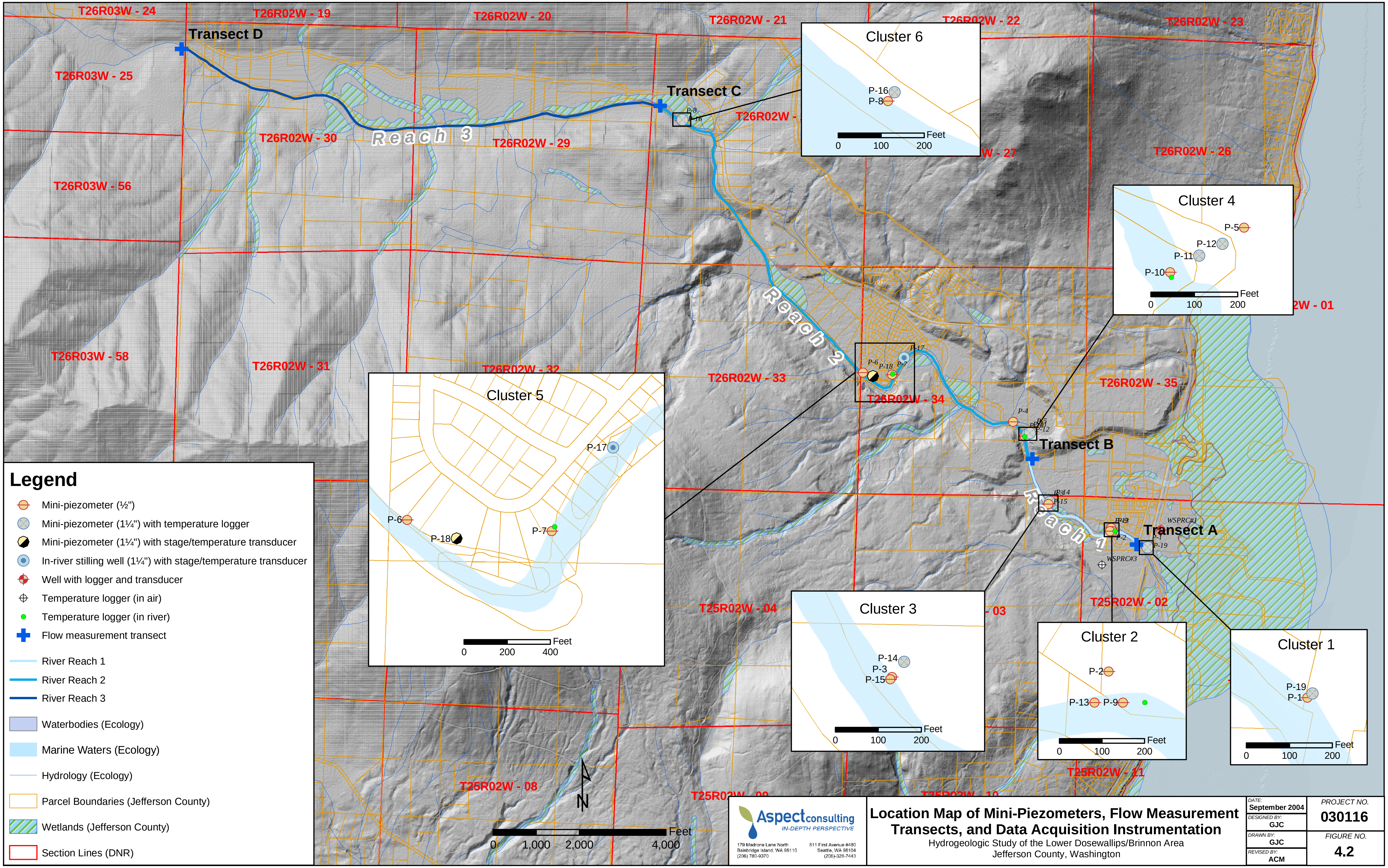
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: April 2005
DESIGNED BY: EWM
DRAWN BY: PMB
REVISED BY: PMB

PROJECT NO. 030116

FIGURE NO. 4.1

Q:\WRIA\030116 WRIA 16\2005-04\030116-03.dwg



Aspect consulting
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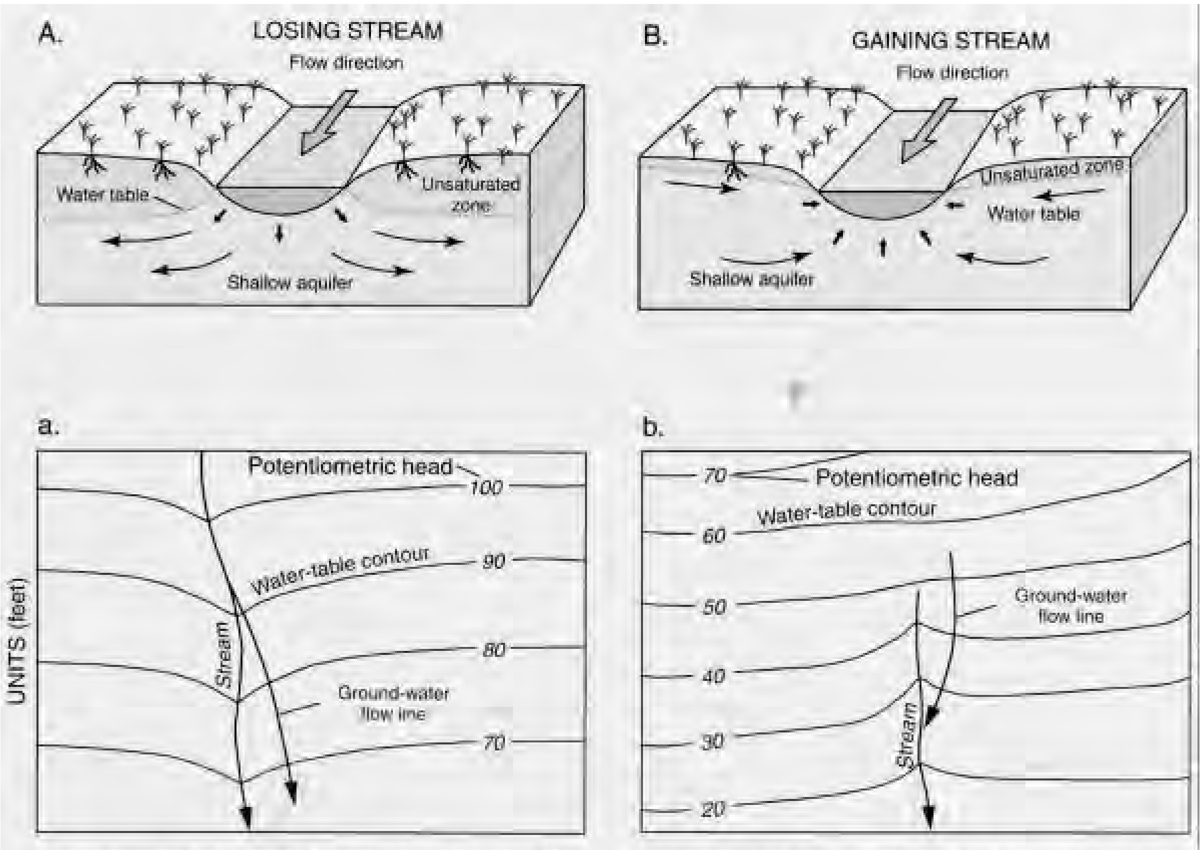
Location Map of Mini-Piezometers, Flow Measurement Transects, and Data Acquisition Instrumentation

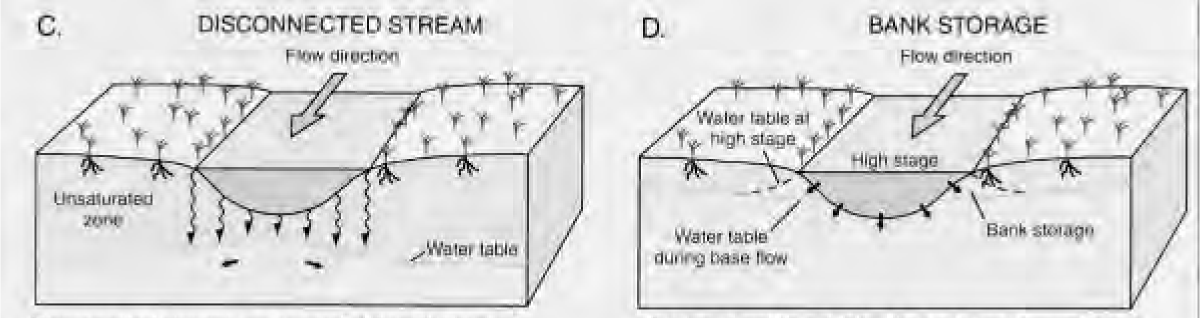
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: September 2004	PROJECT NO. 030116
DESIGNED BY: GJC	
DRAWN BY: GJC	FIGURE NO. 4.2
REVISED BY: ACM	



Losing streams lose water to the ground-water system (A). This can be determined from water-table contour maps because the contour lines point in the downstream direction where they cross the stream (a).

Gaining streams receive water from the ground-water system (B). This can be determined from water-table contour maps because the contour lines point in the upstream direction where they cross the stream (b).



Disconnected streams are separated from the ground-water system by an unsaturated zone.

If stream level rises higher than adjacent ground-water levels, stream water moves into the streambanks as bank storage.

Interaction between surface water and groundwater to form a losing stream, a gaining stream, a disconnected stream, and bank storage.

From Winter et al. (1998) as modified by Simonds and Sinclair (2002).

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Conceptual Surface Water and Groundwater Interaction

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

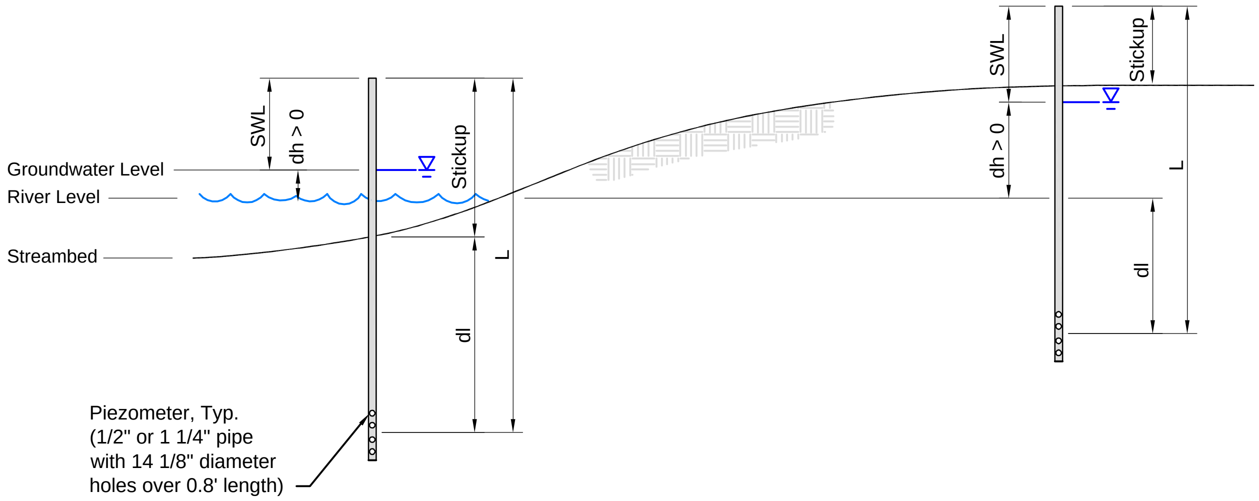
DATE: April 2005
DESIGNED BY: EWM
DRAWN BY: PMB
REVISED BY: PMB

PROJECT NO.
030116

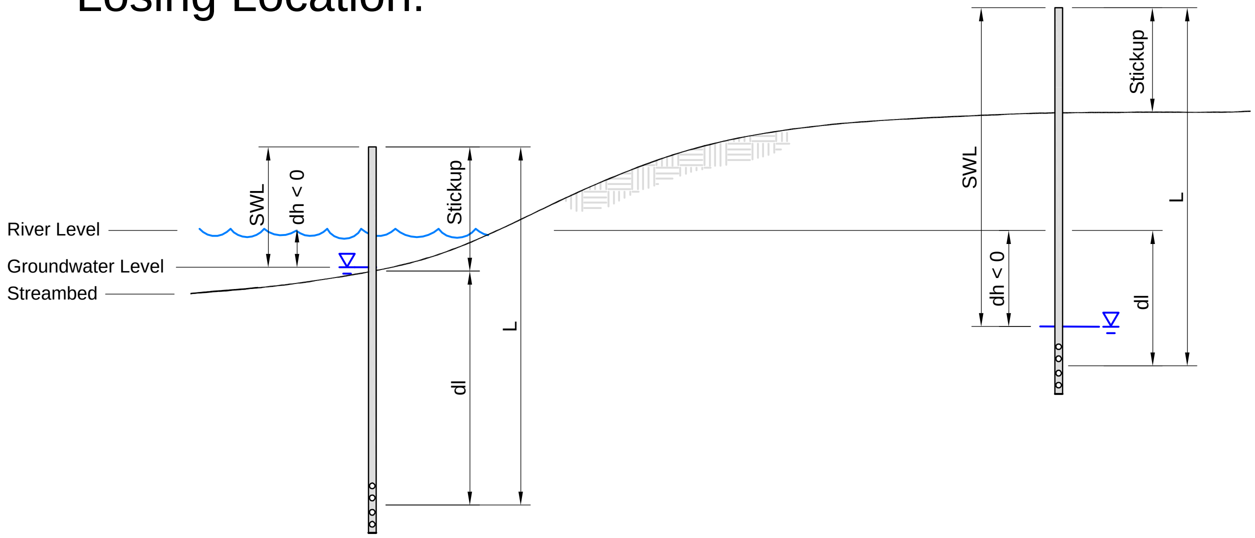
FIGURE NO.
4.3

Q:\WRIA\030116 WRIA 16\2005-04\030116-07.dwg

Gaining Location:



Losing Location:



In-River Formula:

$$\frac{dh}{dl} = \frac{dh}{L - Stickup}$$

Out-of-River Formula:

$$\frac{dh}{dl} = \frac{dh}{L - SWL - dh}$$

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Calculation of Vertical Hydraulic Gradient

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: April 2005
DESIGNED BY: EWM
DRAWN BY: PMB
REVISED BY: PMB

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030116

FIGURE NO.
4.4

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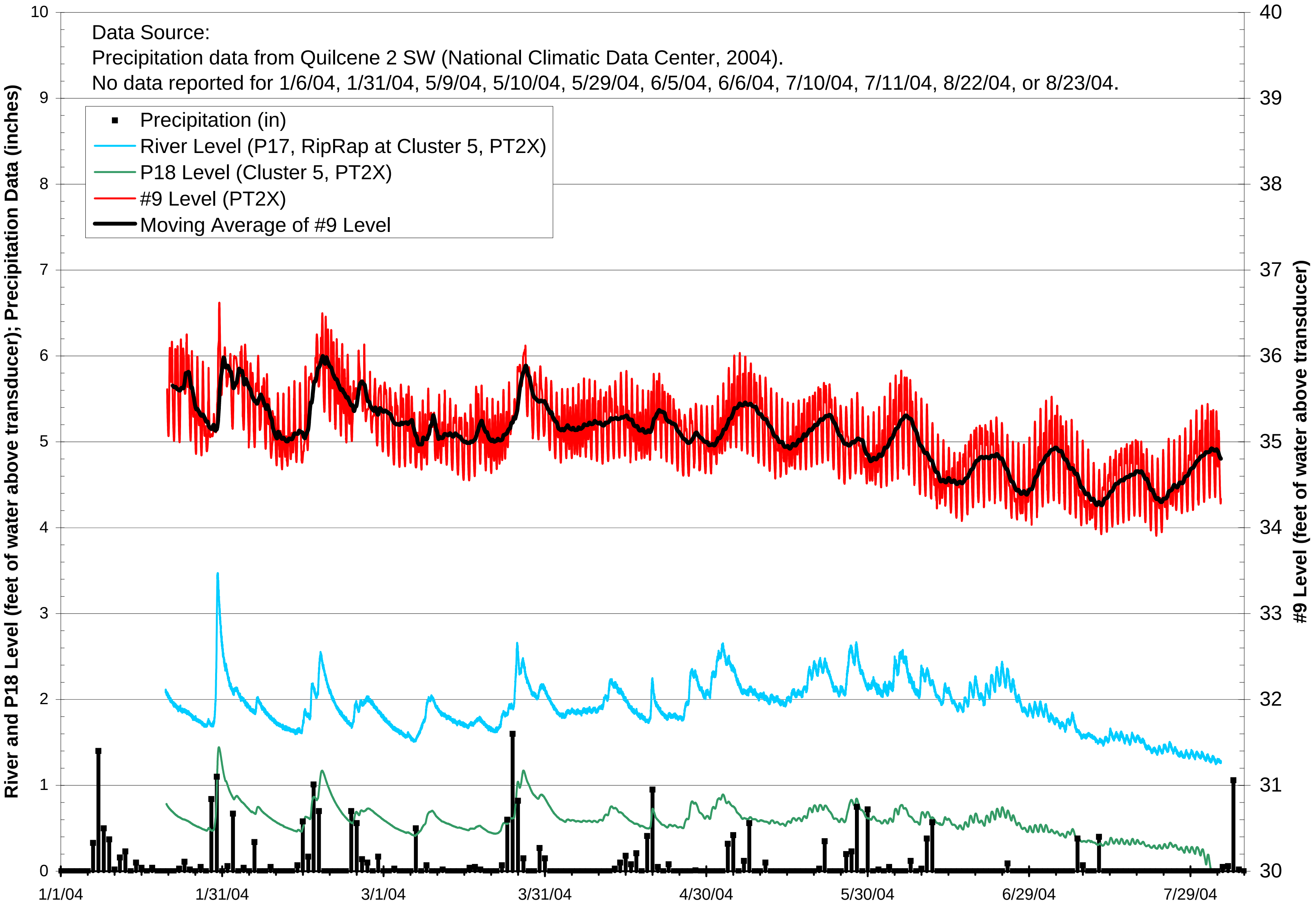

Comparison of Continuous Surface Water and Groundwater Level Measurements

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Figure 4.5

Aspect consulting

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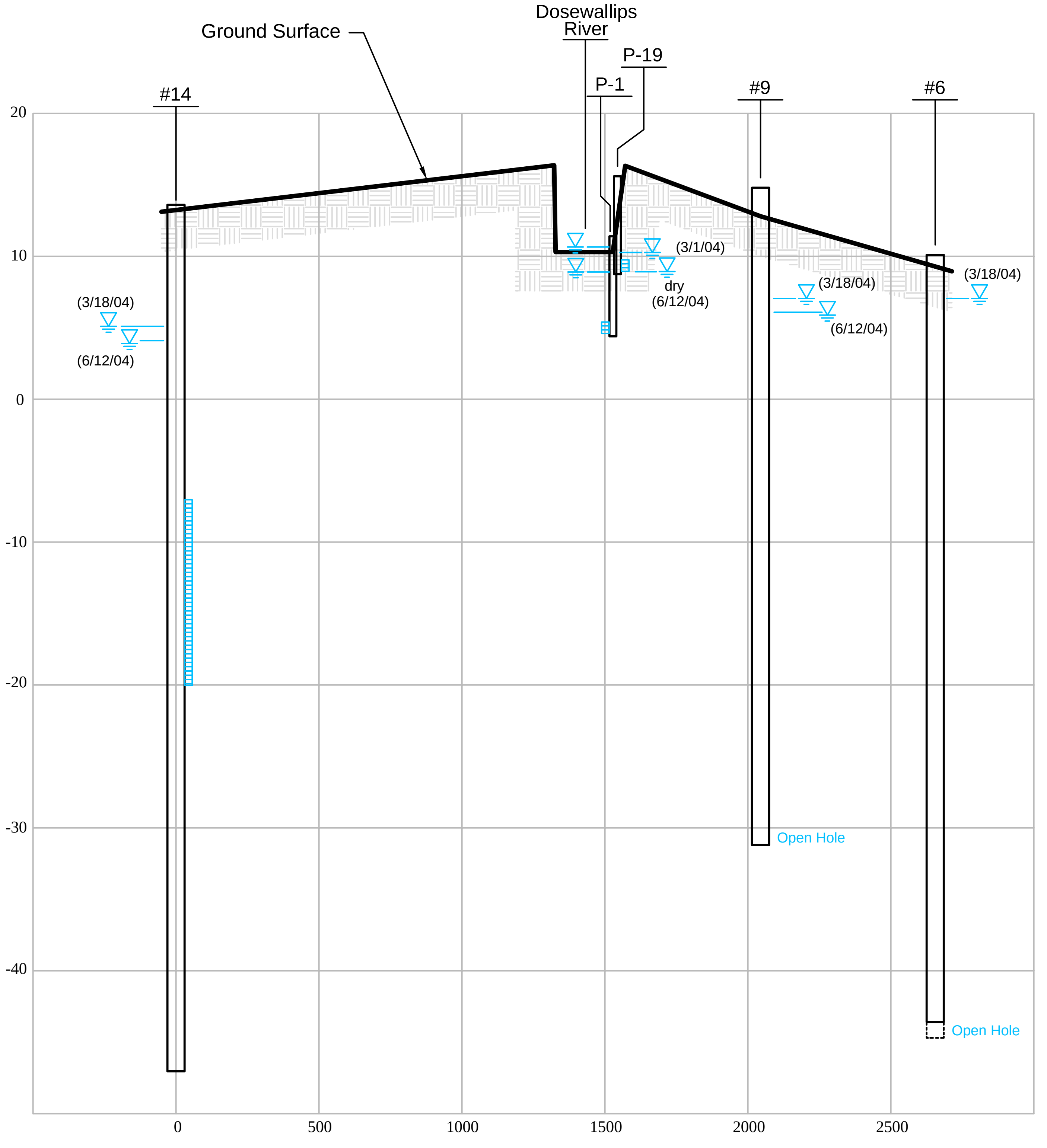
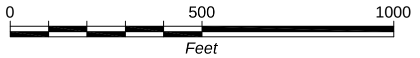


Vertical Exaggeration 50:1
Vertical Scale: 1" = 10'
Horizontal Scale: 1" = 500'



Elevation Datum NGVD 29

Aspect consulting
IN-DEPTH PERSPECTIVE

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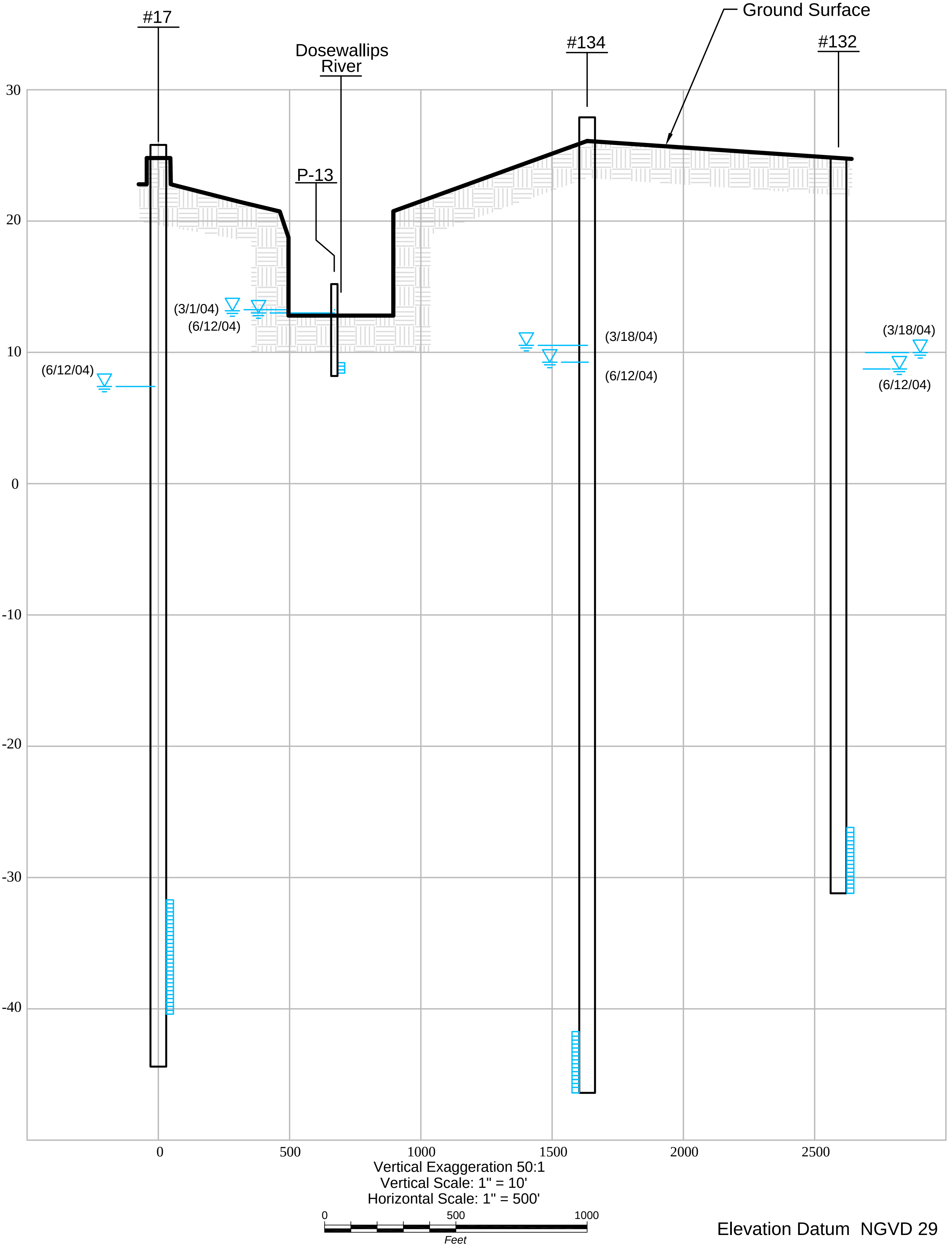
Profile at Cluster 1

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE:	April 2005
DESIGNED BY:	EWM/JAP
DRAWN BY:	PMB
REVISED BY:	PMB
PROJECT NO.	030116
FIGURE NO.	4.6a

Q:\WRIA\030116 WRIA 16\2005-04\030116-CA.dwg



Vertical Exaggeration 50:1
Vertical Scale: 1" = 10'
Horizontal Scale: 1" = 500'

Elevation Datum NGVD 29

Aspect consulting
IN-DEPTH PERSPECTIVE

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Profile at Cluster 2

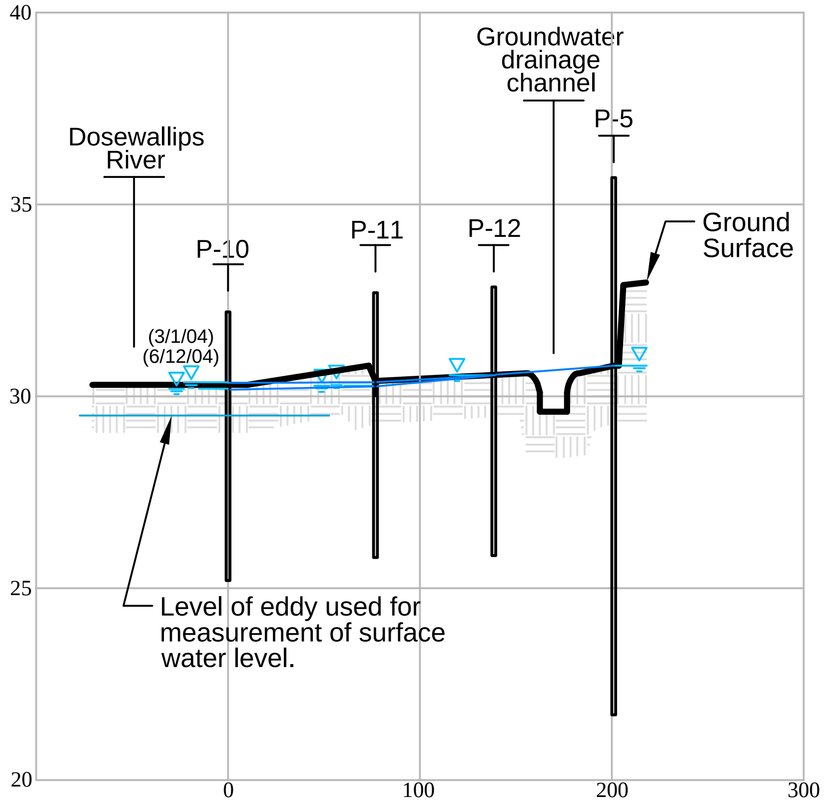
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE:	April 2005
DESIGNED BY:	EWM/JAP
DRAWN BY:	PMB
REVISED BY:	PMB

PROJECT NO.
030116

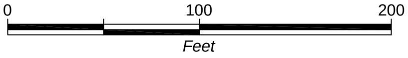
FIGURE NO.
4.6b

Q:\WRIA\030116 WRIA 16\2005-04\030116-CB.dwg



All piezometers at Cluster 4 were measured on both 3/1/04 and 6/12/04.

Vertical Exaggeration 20:1
Vertical Scale: 1" = 5'
Horizontal Scale: 1" = 100'



Elevation Datum NGVD 29

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Profile at Cluster 4

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE: April 2005
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REVISED BY: PMB

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FIGURE NO. 4.6c

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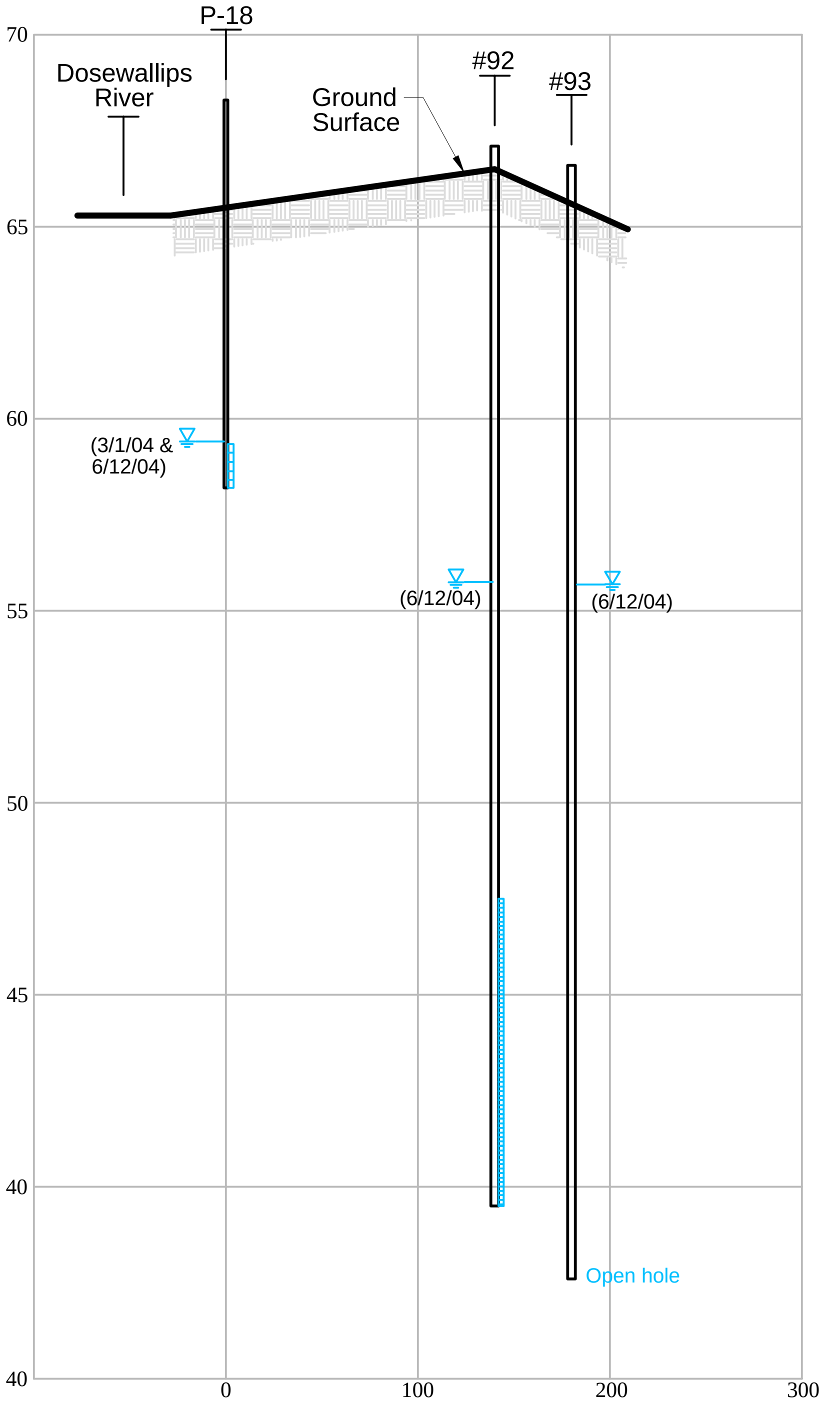
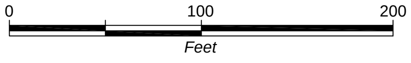


Vertical Exaggeration 20:1
Vertical Scale: 1" = 5'
Horizontal Scale: 1" = 100'



Elevation Datum NGVD 29

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Profile at Cluster 5

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, Washington

DATE:	April 2005
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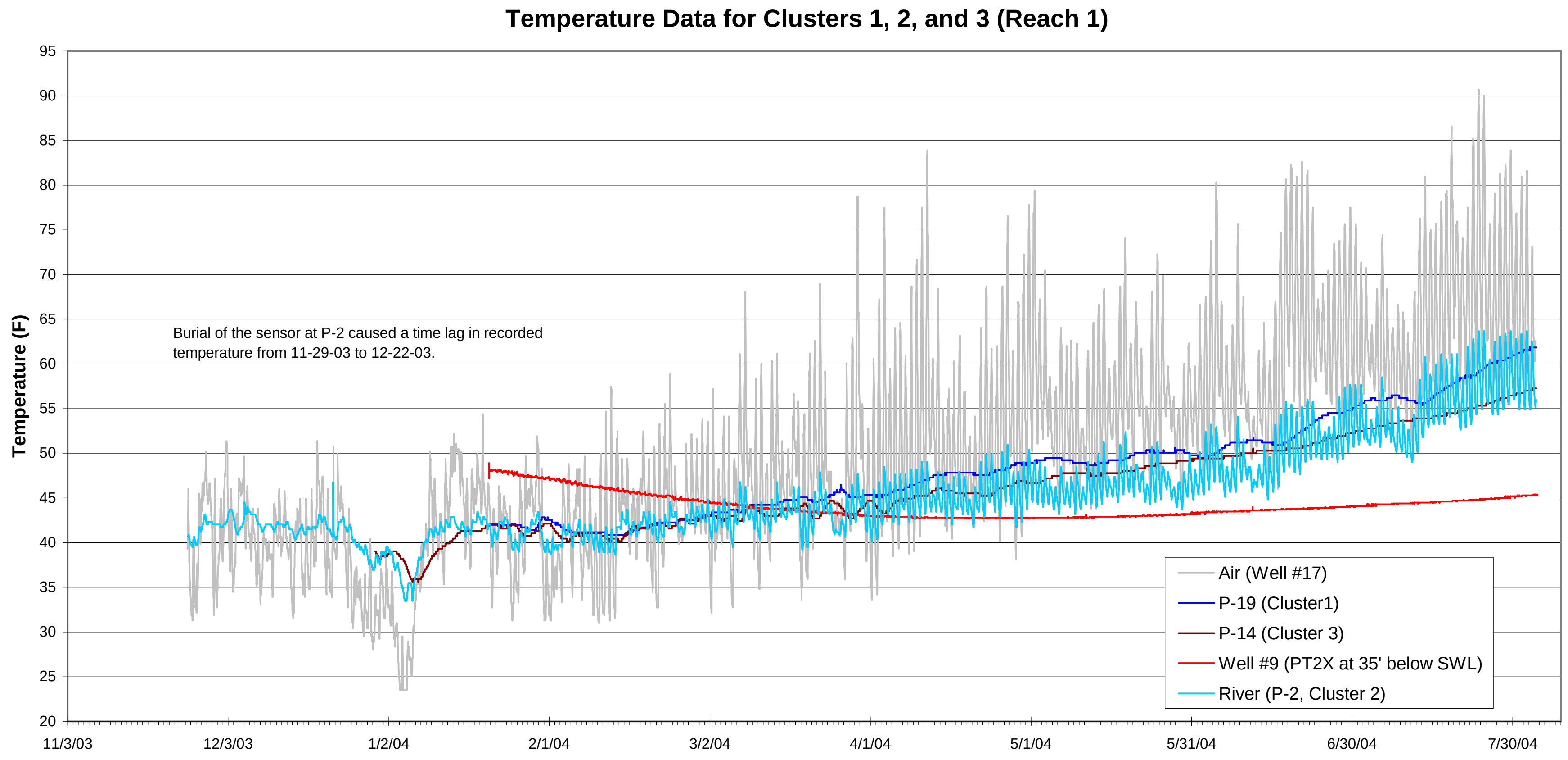
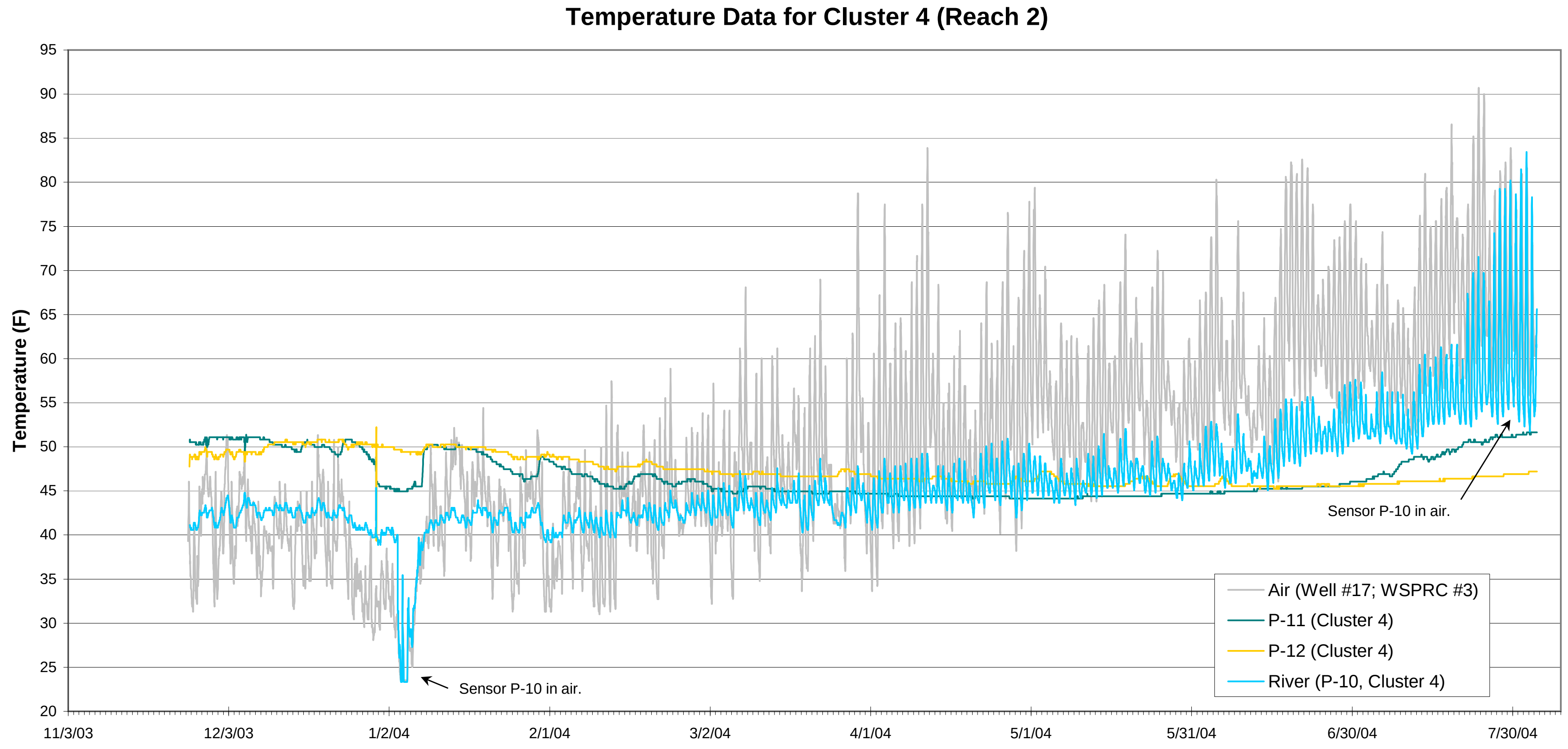
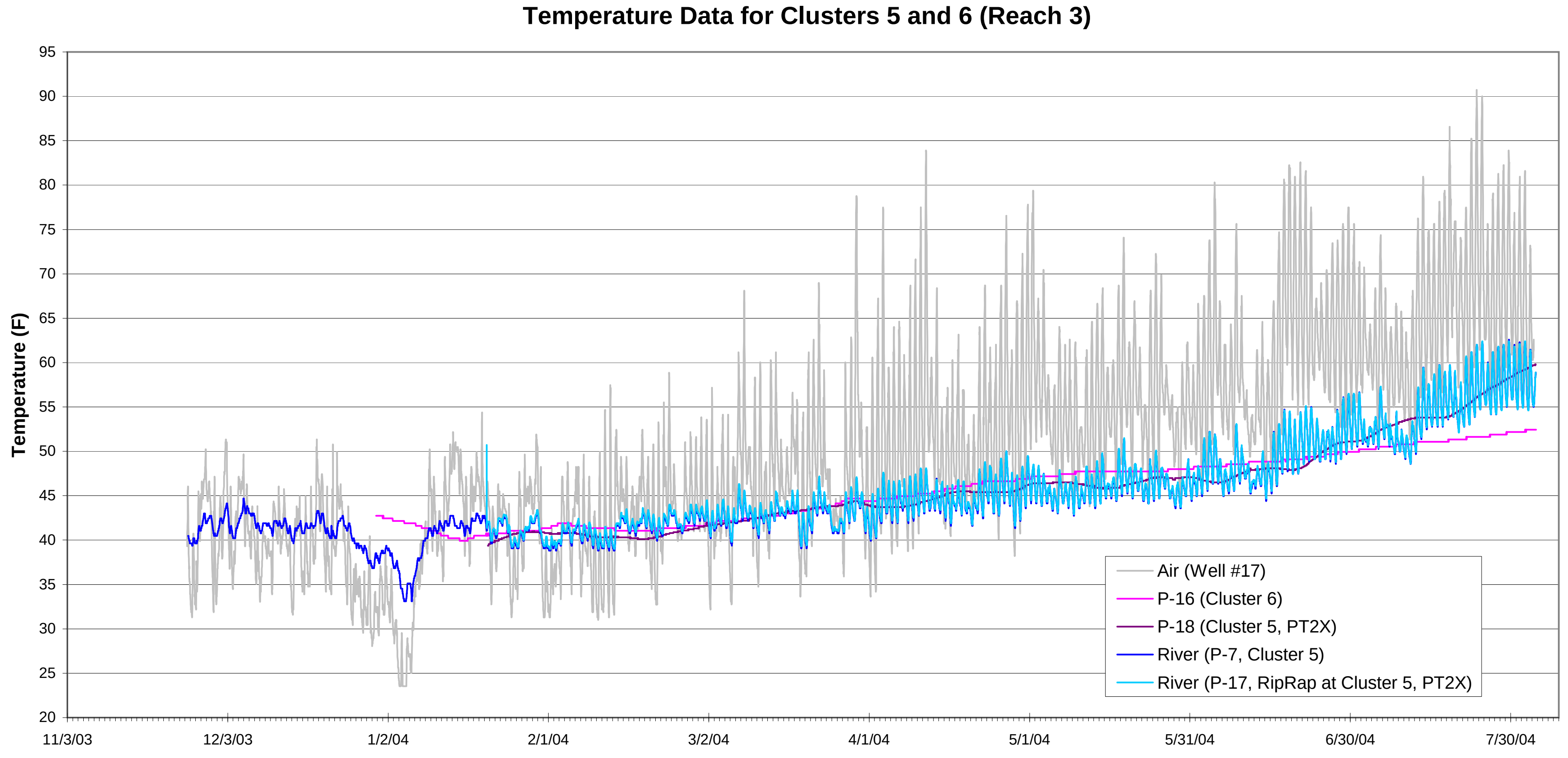
DRAWN BY:	PMB
REVISED BY:	PMB
PROJECT NO.	030116
FIGURE NO.	4.6d

Q:\WRIA\030116 WRIA 16\2005-04\030116-CD.dwg







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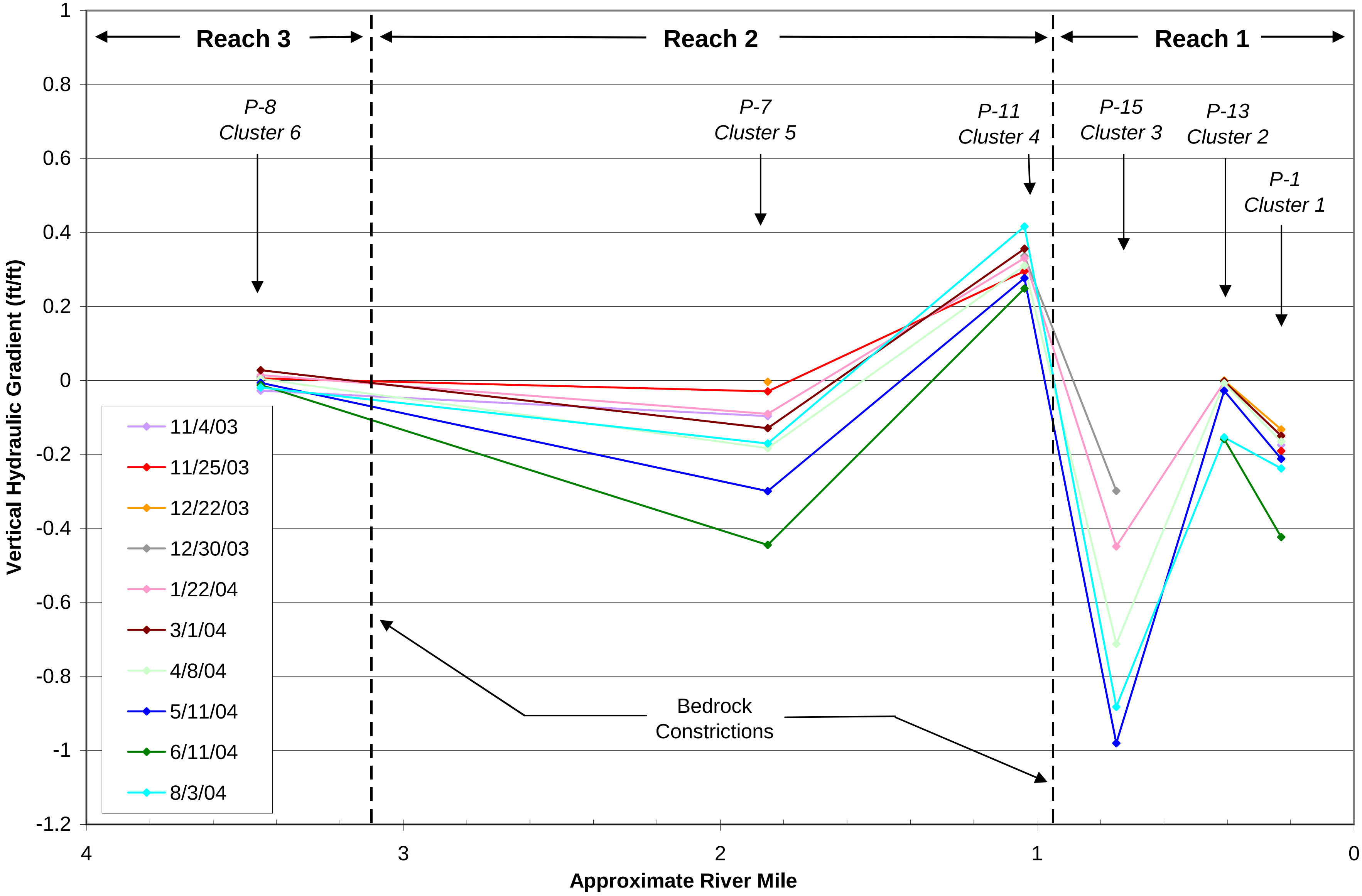
Temperature Data for Reaches 1, 2 and 3
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Figure 4.7



Aspect consulting
IN-DEPTH PERSPECTIVE

W:\030116 WRIA 16\Final Report\piezometer_river_miles.xls

Vertical Hydraulic Gradients Between Surface Water and Groundwater

Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

Figure 4.8

APPENDIX A

Well Data, Survey Results, and Static Water Levels

A.1 Well Log Tabulation Methods

Well data for the WRIA 16 area was compiled from the Washington Department of Ecology well log database (http://apps.ecy.wa.gov/welllog/), Washington State Department of Health (DOH) database, the Jefferson County well database, and the USGS online database (http://waterdata.usgs.gov/nwis). Wells identified during the course of field work were also added. An Excel spreadsheet with well data was developed which summarized locational information, construction details, and data sources for the wells.

Well locations were located with varying degrees of accuracy, and are described here with the associated accuracy code from Table A-1. The lowest accuracy positions are known only to the nearest section and are identified as township-range-section (TRS). These wells were not used for data analysis as a TRS location accuracy is insufficient for analytical purposes. The next grade of accuracy gives locations to the nearest quarter-quarter (¼¼) section (TRSQQ), corresponding to the location listed on Ecology well logs. A combination of tax assessor and GIS data was used to match wells to particular parcels in the WRIA 16 area in order to improve on the ¼¼ section accuracy. Wells that were correlated with the assessor data are located to the center of the matching parcel (PC). Some additional wells have been field located (map) or located with recreational grade GPS (GPS) by Aspect Consulting field staff. Selected wells were surveyed by a contractor to Jefferson County (JC) using survey grade GPS equipment.

Once well locations were established, well elevations were approximated using either LiDAR data, wherever available, or USGS 10-meter DEM data. The accuracy of each method is dependent on the accuracy of the original well location, but, in general, the LIDAR is significantly more accurate than the USGS-supplied DEMs.

A.2 Groundwater Level Measurements and Wellhead Survey

In order to determine groundwater elevation conditions, static water levels and survey data were obtained for the mini-piezometers and selected wells in the study area.

Static water levels for wells were measured on March 18, 2004 and June 12, 2004. Levels in piezometers were measured on March 1, 2004 and June 12, 2004. Measurements were referenced to the top-of-casing using a level indicator (Waterline Model 300 or 500). Stability of water levels was checked to ensure that the wells were not being pumped. A total of 15 wells were sampled on each day, with 13 wells being measured on both days. Eleven of the wells were in Brinnon Flats, two at Lazy C, and four located upslope north and northwest of Brinnon. The wells in Brinnon Flats and at Lazy C were all completed in unconsolidated formations. Of the upslope wells, one was completed in an unconsolidated formation and three in basalt. The selection of specific wells was dependent on acquiring owner permission.

Position and elevation data for all piezometers and wells were determined by a Jefferson County survey. The survey was performed using survey grade GPS equipment owned by Jefferson County and operated by Doug Kelly, LHG.

Table A-1
Study Area Well Summary
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

General Information																	Installation Details				Production Zone		Well Test Information					Summary of Static Water Level (SWL) Readings			Geologic Information	
Aspect Well ID Number	Owner Name (from Well Log)[1]	Well Address	DOH Source Name	Ecology Well Tag	Jeff. Co. Database Tracking #	Parcel ID Number	TRS	Northing (SP83 WA HARN)	Easting (SP83 WA HARN)	XY Method	XY Source	Ground Surface Elevation (NAVD88 ft)	Z Accuracy Code	Well Use	DOH Well Group	PWSID	Drilled Hole Depth (feet)	Completed Well Depth (feet)	Well Diameter (inches)	Installation Date	Top of Open Interval (feet)	Bottom of Open Interval (feet)	Specific Capacity (gpm/ft)	Pump Rate (gpm)	Drawdown (feet)	Test Duration (hours)	Test Type	Average (feet)	Minimum (feet)	Maximum (feet)	Completed Unit Type	Depth to Bedrock (feet)
1	Ward, ?	Blk 3 Lot 19 Carrols Canal View Estate #1			991206		25N 02W 02	257190	1132945	TRS	AC	8	LIDAR	D			30	30	6	10/1/1976	30				30		Bailer Test	10	10	10	U	
2	Ingle, Al						25N 02W 02	257190	1132945	TRS	AC	8	LIDAR	D			35	35	6	2/14/1986	35		1.05	20	19	2	Bailer Test	6	6	6	U	
3	Sakneffer, Paul						25N 02W 02 A	258990	1133620	TRSQQ	DOE	9.6	LIDAR	D			275	275	6	8/24/1983	12	275		1	250	3	Bailer Test	25	25	25	B	4
4	Engman, Gary				960453		25N 02W 02 B	259155	1133515	TRSQQ	DOE	10.6	LIDAR	D			39	39	6	5/5/1980	39		10.00	100	10	4	Bailer Test	10	10	10	U	
5	Johnston, Stan	East Side of Highway 101, Brinnon				502022005	25N 02W 02 C	259484	1132209	PC	AC	13.7	LIDAR	D			39	38.58	6	8/11/1994	38.58			50		1	Air Test	7.33	7.33	7.33	U	
6	Seeley, Ernie	163 Sylopash Lane, Brinnon				502022010	25N 02W 02 C	259405	1132578	GPS	JC	12.81	SURVEY	D			54	53.1	6	8/22/1994	53.1			30		1	Air Test	4.53	4.05	5	U	
7	Mullinax, Porter					602331007	25N 02W 02 C	265062	1123349	PC	AC	93.4	LIDAR	D			40	39.6	6	9/8/1994	39.6			50			Air Test	7	7	7	U	
8	Casey, William				960452		25N 02W 02 C	259550	1132290	GPS	USGS	13.3	LIDAR	M			24	24	6	9/1/1970	19	24	26.67	80	3	3	Pump Test	8	8	8	U	
9	Dosewallips State Park (Well #1)	306565 Hwy. 101 Brinnon				502022006	25N 02W 02 C	259141	1132027	GPS	JC	16.37	SURVEY	D			44	44	6	10/22/2002	42			20		1	Air Test	8.17	7.88	8.63	U	
10	"Flock in Travel" Trailer Park		WELL 1				25N 02W 02 C	259190	1132195	TRSQQ	DOE	17.6	LIDAR	GRPB	B	25605	28															
11	Johnson, Arnold	Corey Lane			H00295	941700209	25N 02W 02 D	259769	1131312	PC	AC	21	LIDAR	D			36	35	6	10/5/1992	35			52		1	Air Test	9	9	9	U	
12	Brinnon Booster Club		WELL #1			941700301	25N 02W 02 D	259513	1130987	PC	AC	24.4	LIDAR	GRPB	A	58691	30															
13	Bloomquist				960451	941700323	25N 02W 02 D	259224	1131226	PC	AC	20.3	LIDAR	D			34	34	6	6/12/1973	34		10.00	50	5	2	Bailer Test	10	10	10	U	
14	State Parks & Recreation Comission (Well #4)		WELL #1				25N 02W 02 D	257290	1131235	GPS	JC	16.55	SURVEY	TNC	A	SP215	60	60		3/2/1964	20	33	12.00	60	5	3.5	Pump Test	7.83	5.5	9.48	U[2]	57
15	Eldred, Roy				960450 / 960454		25N 02W 02 D	259240	1130875	TRSQQ	DOE	24.3	LIDAR	D			31	31	6	3/2/1974	31		0.30	6	20	1	Bailer Test	8	8	8	U	
16	Geoduck Tavern / Mr Murrey		GEODUCK TAVERN	ACM 517			25N 02W 02 E	256502	1131515	GPS	DOH	17	LIDAR	TNC	A	09556	144	144	6	5/14/1990	20	144	0.80	80	100	2	Bailer Test	4	4	4	B	40
17	State of Washington Parks and Recreation Commision (Well #3)	Dosewallips State Park		ACM 515		M	25N 02W 02 E	258490	1130652	GPS	JC	26.36	SURVEY	T			69	65	8	1/17/1984	54.375	65	240.00	60	0.25	4	Pump Test	15.57	12.75	18.39	U	
19	Brinnon General Store Inc	306413 Hwy. 101	WELL #1			602353026	25N 02W 02 H	259891	1132409	PC	AC	14.8	LIDAR	TNC	A	32944	31															
20	Figuly, Laurie	67 Moose Mount Road, Brinnon			H00746	502105014	25N 02W 02 N	253613	1128274	PC	AC	417.1	LIDAR	D			160	160	6	8/24/1999	160.9			15		1	Air Test	118	118	118	B	108
21	Nelson, Hank						25N 02W 02 N	255305	1130785	TRSQQ	AC	233	LIDAR	D			400	400	6	6/28/1989	62	400	0.07	20	297	4	Bailer Test	103	103	103	B	60
22	Gail, Hunter	Old Brinnon Hwy.					25N 02W 02 N	255305	1130785	TRSQQ	AC	233	LIDAR	D			112	112	6	7/6/1993	112			20		1	Air Test	84	84	84	U	
23	Jefferson County Fire District #4					M	25N 02W 03	257280	1127525	TRS	DOE	445	SEC	O			154	133	6	12/20/1985	123	133	0.31	20	64	2.5	Pump Test	6	6	6	B	154
24		BOS 36221 Hwy 101			960456		25N 02W 03	257280	1127525	TRS	DOE	445	SEC	D			99	99	6	7/13/1983	63	83	0.50	2	4	4	Pump Test	17	17	17	B	82
25	Hardie, Duane				960457		25N 02W 03	257280	1127525	TRS	DOE	445	SEC	D			240	240	6	3/1/1982	231	235	0.06	0.75	12	0.13	Pump Test	222	222	222	B	239
26	Olympic Canal Truck (??)						25N 02W 03	257280	1127525	TRS	DOE	445	SEC	D			99	99	6	7/13/1984	63	83	0.07	2	29	1.5	Bailer Test	17	17	17	B	82
27					960458		25N 02W 03	257280	1127525	TRS	DOE	445	SEC	O			103	133	6	12/20/1995	123	133	0.44	28	64	2.5	Pump Test	6	6	6	U	
28	Chapman, Floyd				960461		25N 02W 03	257280	1127525	TRS	DOE	445	SEC	D			29	29	6	2/23/1971	29			40	0	2	Bailer Test	8	8	8	U	
29	Almasi, William K.				961049		25N 02W 03 A	259424	1129481	GPS	USGS	27	LIDAR	M			45	45	6	6/11/1974	45			80	0	1	Bailer Test	14	14	14	U	
30	Pullen, William N.				960460		25N 02W 03 A	259275	1129560	TRSQQ	DOE	28.8	LIDAR	D			50	47	6	7/26/1983	42	47	28.67	86	3	3	Bailer Test	13	13	13	U	
31	Alco #3		WELL 1				25N 02W 03 A	259275	1129560	TRSQQ	DOE	28.8	LIDAR	GRPB	B	36825	45															
32	Olson, Paul	370 Pullock Drive			H00664	502312014	25N 02W 03 G	233076	1110189	PC	AC	368.9	DEM	D			485	485	6	10/30/1998	485			6		1	Air Test	257	257	257	B	29
33	Blackmore, Calvin M.				960459	502101014	25N 02W 03 R	252822	1129035	PC	AC	307.4	LIDAR	D			68	68	6	10/10/1986	68		2.50	10	4	1	Bailer Test	52	52	52	U	
34	Boling, Michael	1113 Black Point Road			H00940	502101024	25N 02W 03 R	254186	1128930	PC	AC	312.3	LIDAR	D			378	378	6	10/10/2001	38	41		1.5		2	Air Test	14	14	14	B	178
36	Braun, Walt						26N 02W 16 D	280840	1120665	TRSQQ	AC	3207.6	DEM	D			36	36	6	11/5/1990	36		30.00	30	1	4	Bailer Test	5	5	5	U	
37	Allen, Mary E.	871 Seal Rock Drive, Brinnon				993600101	26N 02W 26	267840	1133005	TRS	DOE	440	SEC	D			183	180	6	8/20/1988	140	180	0.05	4	80	1	Bailer Test	2	2	2	B	1
38	Nealey, Michael						26N 02W 26	267840	1133005	TRS	DOE	440	SEC	D			200	200	6	4/1/1974	20	200	0.06	10	180	1	Bailer Test	20	20	20	B	8
39	Engberg, Vic	Seal Rock Brinnon					26N 02W 26	267840	1133005	TRS	DOE	440	SEC	D			183	180	6	8/20/1988	140	180	0.05	4	80	1	Bailer Test	2	2	2	B	1
40	Weigand, George						26N 02W 26	267840	1133005	TRS	DOE	440	SEC	D			108	108	6	6/1/1972	75	108		1	0	0.5	Bailer Test	25	25	25	B	14
41	Brinnon Beach Estates					936100023	26N 02W 26 A	271010	1134532	PC	AC	257.5	LIDAR	GRPB	B	25326	403	400	6	9/24/1985	25	400	0.03	12	366	2	Pump Test	34	34	34	B	6
42	Durham, Ramona						26N 02W 26 A	270124	1134899	GPS	USGS	133.3	LIDAR	D			104	104	6	6/1/1972	100	104		4	0	1	Bailer Test	25	25	25	B	14
43	Broderson, DeEtte	305504 Hwy. 101				602352023	26N 02W 26 H	264792	1132239	PC	AC	173.2	LIDAR	D			257	257	6	2/17/1992	237	257		7		1	Air Test	142	142	142	B	11
44	Olsen, J.W. & Rosanne	304694 Hwy. 101 Brinnon			H00374	964600002	26N 02W 26 H	267938	1134621	PC	AC	90	LIDAR	D			282.5	282.5	6	11/25/1996	182	282.5		6		0.25	Air Test	7.83	7.83	7.83	B	12
45	Neely, Mike				H00297	602264006	26N 02W 26 J	267411	1134522	PC	AC	81.7	LIDAR	D			193	193	6	8/8/1993	173	193		7		1	Air Test	70	70	70	B	14
46	Baxter, Marvin					602264025	26N 02W 26 J	267326	1134606	PC	AC	63.4	LIDAR	D			229	229	6	1/8/1988	18	229	0.29	40	136	1.5	Bailer Test	89	89	89	B	3
47	Ellingson, Glen	30252 Hwy. 101				602264033	26N 02W 26 J	267125	1134518	PC	AC	70.8	LIDAR	D			260	260	6	1/12/1988	23	260	0.06	12	190	1.5	Bailer Test	70	70	70	B	17
48	Olson, Jim	Hwy 101 Brinnon			H00421	964601601	26N 02W 26 J	268145	1134555	PC	AC	115.1	LIDAR	D			227	229.25	6	5/28/1993	217	222	0.03	3.5	133	5	Bailer Test	93.16	93.16	93.16	B	12
49	Tomson, Al				960442		26N 02W 26 J	267125	1134975	TRSQQ	DOE	22.6	LIDAR	D			350	350	6	12/31/1987	29	350	0.01	4	349	1.5	Bailer Test	1	1	1	B	26
50	Hendricks, Gail	Seal Rock Brinnon			960444		26N 02W 26 J	267125	1134975	TRSQQ	DOE	22.6	LIDAR	D			260	260	6	9/14/1988	18	260	0.02	3.5	195	1.5	Bailer Test	60	60	60	B	6
51	Odmon, Del						26N 02W 26 J	267125	1134975	TRSQQ	DOE	22.6	LIDAR	D			150	150	6	9/24/1979	10	150	0.21	20	95	2.5	Bailer Test	50	50	50	B	6
52	Shuokur, Erving						26N 02W 26 K	267160	1133655	TRSQQ	DOE	257	LIDAR	D			195	195	6	7/28/1977	20	195		6			Bailer Test	43	43	43	B	16
53	Kelly, Ervin						26N 02W 26 P	265865	1132300	TRSQQ	DOE	367.5	LIDAR	D			100	100	6	9/21/1989	100		0.12	10	83	1.5	Bailer Test	17	17	17	U	
54	Almasi, Bill						26N 02W 26 Q	265840	1133620	TRSQQ	DOE	139.7	LIDAR	D			295	290	6	7/5/1990	12	250		40		3	Bailer Test	7	7	7	B	20
55	Almasi, WRK				960437		26N 02W 26 R	265895	1134830	TRSQQ	DOE	7.5	LIDAR	D			200	199	6	1/4/1989	34	199	0.04	8	195	1.5	Bailer Test	6	6	6	B	30
56	Jefferson County PUD				960440		26N 02W 26 R	265895	1134830	TRSQQ	DOE	7.5	LIDAR	T			503	503	8	5/10/1984	27	503						79	79	79	B	14
57	Thornton, Shaun				960447		26N 02W 26 R	265895	1134830	TRSQQ	DOE	7.5	LIDAR	D			185	185	6	12/16/1987	18	185	0.05	10	183	1.5	Bailer Test	2	2	2	B	14
58	Lormee, Bob						26N 02W 26 R	265895	1134830	TRSQQ	DOE	7.5	LIDAR	D			385	380	6	12/21/1987	18	380	0.03	10	380	1.5	Bailer Test	4	4	4	B	15
59	Pfaff, Chris						26N 02W 26 R	265895	1134830	TRSQQ	DOE	7.5	LIDAR	D			290	290	6	7/7/1991	34	290		6		3	Bailer Test	10	10	10	B	31
60	Richerson, Kathlen						26N 02W 26 R	265895	1134830	TRSQQ	DOE	7.5	LIDAR	D			185	184	6	1/6/1989	18	184	0.12	20	171	1.5	Bailer Test	14	14	14	B	12
61	Lazy C #4	Lazy C Ranch Lot 243 Brinnon			961085	966900202	26N 02W 27 N	265235	1126975	PC	AC	364.1	LIDAR	T			440	440	8	12/2/1989	50	440		10		2	Air Test				B	35
62	Brackett				H00227	602282003	26N 02W 28	269491	1121541	PC	AC	277.8	DEM	D			144	144	6	11/10/1994	30	144		2		1	Air Test	9	9	9	B	8
63	Baisch, Joe	3485 Dosewallips Road, Brinnon	WELL #1			602291012	26N 02W 28	269387	1119224	PC	AC	160.8	DEM	TNC	A	04416	29	27	6	4/27/1992	27			30		0.5	Air Test	11	11	11	U	
64	Johnston, Stan	Rocky Brook Road			H00872	602281002	26N 02W 28 A	269210	1124223	PC	AC	919.7	LIDAR				240	240	6	8/18/2000	240			5		1	Air Test	56	56	56	B	16
65	Kuklok, Dennis	3003 Dosewallips Road, Brinnon			H00834	602285005	26N 02W 28 F	269260	1121160	GPS	AC	144	DEM	D			98	98	6	5/17/2000	55	96	0.03	3	98	1	Pump Test	>1	>1	>1	B	63
66	Buckholtz, Kenneth				H00994	602283011	26N 02W 28 L	267524	1122226	PC	AC	315.3	DEM	D			137	137	6	10/23/2001	130	137		6		2	Air Test	124	124	124	B	129
67	Shock, Ken						26N 02W 28 P	265970	1121915	TRSQQ	DOE	309.6	LIDAR	D			305	305	6	10/22/1986	57	61		5		0.5	Bailer Test	59	59	59	B	64
68	Shock, Ken				961086		26N 02W 28 P	265970	1121915	TRSQQ	DOE	309.6	LIDAR	D			60	60	6	7/10/1984	60		0.42	25	60	1.5	Bailer Test	44.5	44.5	44.5	U	
69	Johnston, Stan	Dosewallips River Road			H00983	602283010	26N 02W 28 Q	266166	1123602	PC	AC	203.4	LIDAR	D			318	318	6	5/11/2001	318			4		1	Air Test	82	82	82	B	25

Table A-1
Study Area Well Summary
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

General Information																	Installation Details				Production Zone		Well Test Information					Summary of Static Water Level (SWL) Readings			Geologic Information	
Aspect Well ID Number	Owner Name (from Well Log)[1]	Well Address	DOH Source Name	Ecology Well Tag	Jeff. Co. Database Tracking #	Parcel ID Number	TRS	Northing (SP83 WA HARN)	Easting (SP83 WA HARN)	XY Method	XY Source	Ground Surface Elevation (NAVD88 ft)	Z Accuracy Code	Well Use	DOH Well Group	PWSID	Drilled Hole Depth (feet)	Completed Well Depth (feet)	Well Diameter (inches)	Installation Date	Top of Open Interval (feet)	Bottom of Open Interval (feet)	Specific Capacity (gpm/ft)	Pump Rate (gpm)	Drawdown (feet)	Test Duration (hours)	Test Type	Average (feet)	Minimum (feet)	Maximum (feet)	Completed Unit Type	Depth to Bedrock (feet)
70	Thompson, Dennis	2322 Dosewallips Road, Brinnon			H00520	602284007	26N 02W 28 Q	266404	1123361	PC	AC	268.7	LIDAR	D			408	408	6	6/24/1997	208	408		2.5		1	Air Test	195	195	195	B	93
71	Schlagel, Ao						26N 02W 29 A	269875	1119610	TRSQQ	AC	344.8	DEM	D			30	30	6	8/14/1973	30		25.00	50	2	2	Bailer Test	6	6	6	U	
72	Radebaugh, C.D.	Dosewallips River Road					26N 02W 29 F	268705	1116875	TRSQQ	AC	148.4	DEM	D			58	58	6	11/6/1991	58			66		1	Air Test	27	27	27	U	
73	Goodwin	6640 Dosewallips Rd			H00683	603234001	26N 02W 30	273423	1103683	PC	AC	365.8	DEM				145	140	6	1/2/1999	40	140		15		1	Air Test	1	1	1	B	8
74	Bailey, Harry L.	4541 Dosewallips Road, Brinnon				602301001	26N 02W 30 A	269196	1114201	PC	AC	171.2	DEM	D			41	41	6	12/30/1994	36	41		30		1	Air Test	3	3	3	U	
75	Winnem, Howard E.	5131 Dosewallips Road, Brinnon				602301011	26N 02W 30 D	270255	1110070	TRSQQ	DOE	231.1	DEM	D			58	58	6	10/30/2002	58		1.49	58	39	1	Air Test	17	17	17	U	
76	Mattson, Kathrine	Dosewallips River Road				602331018	26N 02W 33	262655	1122445	TRS	AC	610	SEC	D			36	33	6	5/28/1991	33			18		2	Air Test	19	19	19	U	
77	Akin, Arthur						26N 02W 33	262655	1122445	TRS	AC	610	SEC	D			38	38	6	7/12/1981	33	38	12.50	25	2	2	Bailer Test	20	20	20	U	
78	Schweiger, Rick	2027 Dosewallips Road, Brinnon			H00635	602331005	26N 02W 33 A	263916	1124608	PC	AC	75.5	LIDAR	D			37	37	6	8/21/1998	37			50		1	Air Test	21	21	21	U	
79	McKeever, E.J.	2039 Dosewallips River Road				602331008	26N 02W 33 A	263668	1124749	PC	AC	77.3	LIDAR	D			37	37	6	7/20/1992	37			42		1	Air Test	12	12	12	U	
80	Johnston, Stan	Nearest to 2039 Dosewallips River Road				602331012	26N 02W 33 A	264567	1123880	PC	AC	84.7	LIDAR	D			37	36	6	8/6/1992	36			42		1	Air Test	12	12	12	U	
81	Wash. Conference Seven Day Advent Church		WELL #1			602331016	26N 02W 33 A	265180	1123976	PC	AC	144.4	LIDAR	GRPB	B	00242	79	79	6	5/6/1979	79		2.22	20	9	1	Bailer Test	49	49	49	U	
82	Donahue, John				961087		26N 02W 33 A	264605	1124445	TRSQQ	DOE	83.7	LIDAR				31	31	6	1/20/1989	31		0.86	25	29	1.5	Bailer Test	19	19	19	U	
83	Lazy C Properties					M	26N 02W 34	262585	1127685	TRS	AC	55	SEC	M			29	29	6	6/28/1976	29		4.00	40	10	3	Bailer Test	12	12	12	U	
84	Brinnon Square		BRINNON SQUARE WELL	ACM 514			26N 02W 34	262585	1127685	TRS	AC	53.4	LIDAR	TNC	A	10481	35															
85	Cooper, David	Green Mt. Road			H00397	602341033	26N 02W 34 A	264919	1129798	PC	AC	431.7	LIDAR	D			260	255	6	4/15/1991	235	255		15		2	Air Test	180	180	180	B	40
86	McIntyre, Mike	484 Green Moutain Lane			H00170	602341038	26N 02W 34 A	264913	1130132	PC	AC	418.5	LIDAR	D			325	325	6	4/8/1994	105	325		5		1	Air Test	0	0	0	B	2
87	Castle, Ron						26N 02W 34 A	264575	1129645	TRSQQ	DOE	346.2	LIDAR	D			144	144	6	11/19/1979	67			14	?	1	Bailer Test	63	63	63	U	
88	Crowell, Robert					602341003	26N 02W 34 B	264275	1127953	PC	AC	245.2	LIDAR	D			140	140	6	12/15/1976	128	138	2.00	18	9	1	Bailer Test	110	110	110	U	
89	Haley, Bob	890 Dosewallips Road, Brinnon				602341021	26N 02W 34 B	263078	1129439	GPS	JC	180.45	SURVEY	D			40	40	6	3/31/1988	40		1.18	40	34	1.5	Bailer Test	16.37	10	26.95	U	
90	Evans, Mike	Rocky Brook Road, Brinnon			H00711	602341004	26N 02W 34 C	264263	1128728	PC	AC	283.8	LIDAR	I			258	248	6	5/7/1999	248			12		2	Air Test	155	155	155	B	90
91	PUD No. 1 of Jefferson County	Off Dosewallips River Road				602342001	26N 02W 34 D	263854	1126947	GPS	JC	217.16	SURVEY	T			485	485	6	4/10/1995	380	480		30		1	Air Test	157.88	153.7	162.06	B	102
92	Lazy C Well #2					966900030	26N 02W 34 E	262845	1125408	GPS	JC	69.99	SURVEY	D			27	27	6	5/25/1966	19	27						11.48	11.055	12	U	
93	Lazy C Properties #1					966900030	26N 02W 34 E	262879	1125429	GPS	JC	69.12	SURVEY	D			29	29	6	6/28/1976	29		4.00	40	10	3	Bailer Test	11.23	10.68	12	U	
94	Brown, George						26N 02W 34 F	263760	1127624	MAP	AC	249.2	LIDAR	D			98	98	6	4/30/1966	98							66	66	66	U	
95	Crowell, A. c/o James Town Tribe	Dosewallips River Road			H00819	602341005	26N 02W 34 G	263226	1128276	PC	AC	220.5	LIDAR	D			290	290	6	3/16/2000	290			20		1	Air Test	187	187	187	B	88
96	Call, Richard				961088		26N 02W 34 G	263260	1128325	TRSQQ	DOE	220	LIDAR	D			66	66	6	6/26/1973	66		1.00	20	20	1	Bailer Test	38	38	38	U	
97	Yankee, Albert				H00184	602341009	26N 02W 34 H	263748	1129285	PC	AC	238.5	LIDAR	D			68	68	6	4/10/1975	68			50	0	2	Bailer Test	34	34	34	B	52
98	Field, Wm					602341011	26N 02W 34 H	262657	1130118	PC	AC	155.6	LIDAR	D			69	69	6	3/14/1974	69		0.07	5	68	1	Bailer Test	1	1	1	U	
99	Gietl, Frank					602341025	26N 02W 34 H	263090	1129113	PC	AC	190.4	LIDAR	D			40	40	6	3/4/1974	40		2.67	40	15	1	Bailer Test	15	15	15	U	
100	Browning, Pat	994 Dosewallips Road. Brinnon				602341026	26N 02W 34 H	263411	1129350	PC	AC	200.9	LIDAR	D			227	227	6	6/14/1991	43	227		2		2	Air Test	138	138	138	B	42
101	Millard, Jim						26N 02W 34 H	263250	1129625	TRSQQ	DOE	194.4	LIDAR	D			150	150	6	9/6/1978	56	150		35	0	2	Bailer Test	79	79	79	B	56
102	Cook, Jess W.						26N 02W 34 H	263250	1129625	TRSQQ	DOE	194.4	LIDAR	D			74	74	6	10/15/1975	74		0.44	12	27	1	Bailer Test	42	42	42	U	
103	Brekke, S.C.						26N 02W 34 H	263250	1129625	TRSQQ	DOE	194.4	LIDAR	D			75	73	6	9/7/1978	73		2.00	10	5	2	Bailer Test	46	46	46	U	
104	Call, Richard K.						26N 02W 34 H	263250	1129625	TRSQQ	DOE	194.4	LIDAR	D/I			3	3	36	???	2	3										
105	Snow, Cherie	Olympic Canal Tracts Lot 2				602341051	26N 02W 34 J	263741	1129787	PC	AC	261.7	LIDAR	D			318	318	6	10/27/1991	60	318		1		1.5	Air Test	76	76	76	B	58
106	Karla J. Whitting	394 Green Mountain				602341034	26N 02W 34 J	264245	1130110	MAP	AC	280	LIDAR	D			156	156	6	9/10/1986	156		0.10	15	154	1.5	Bailer Test	120	120	120	U	
107	Nelson, Susan	1990 Discovery Road				990400155	26N 02W 34 K	261940	1128300	TRSQQ	DOE	41.9	LIDAR				130	130	6	10/18/1989	125	130		15		1	Air Test	101	101	101	U	
108	Sartain, Jim						26N 02W 34 R	260605	1129585	TRSQQ	DOE	33.9	LIDAR	D			31	31	6	6/17/1986	31		0.86	25	29	1.5	Bailer Test	14	14	14	U	
109	Corey, Donald	Corey Lane				941700318	26N 02W 35	259349	1131320	PC	AC	23.8	LIDAR	D			37	37	6	7/1/1991	37			50		2	Air Test	18	18	18	U	
110	Richardson, Rick						26N 02W 35	262645	1131955	TRS	DOE	140	SEC	ID			36	36		4/12/1974	31	36		50	0	1	Bailer Test	7	7	7	U	
111	Sather, Ann & Gardens, Whitney						26N 02W 35	260544	1131599	GPS	JC	19.23	SURVEY	D			63	63	6	8/14/1978	36		8.00	72	9	3	Bailer Test	10.5	9.31	12	U	
112	Brinnon Water Co.		KELLY WELL				26N 02W 35 B	264764	1133515	TRSQQ	AC	0.1	LIDAR	GRPB	B	24029	39															
113	Pederson, Dick	Hwy. 101 and Seal Rock, Brinnon			H00287	602234014	26N 02W 35 C	271416	1134977	PC	AC	164.8	LIDAR	D			287	287	6	6/3/1993	247	282	0.06	10.5	188	1	Pump Test	75	75	75	B	3
114	Reynolds, Anita						26N 02W 35 C	264485	1132400	TRSQQ	AC	96	LIDAR	D			170	167	6	7/27/1983	140	167		5	?	?	Bailer Test	70	70	70	B	140
115	Look, Barbara					602352014	26N 02W 35 D	262707	1131041	PC	AC	144.9	LIDAR	D			45	45	6	4/29/1980	45		1.00	10	10	1.5	Bailer Test	30	30	30	U	
116	Germeau, Norman	Hyw. 101 Brinnon				602352018	26N 02W 35 D	264570	1130745	TRSQQ	DOE	312.9	LIDAR	D			87	87	6	9/15/1989	87		0.12	10	85	1.5	Bailer Test	13	13	13	U	
117	Aflin, Ike						26N 02W 35 D	264570	1130745	TRSQQ	DOE	312.9	LIDAR	D			100	100	6	7/6/1982	100		0.50	10	20	1.5	Bailer Test	70	70	70	U	
118	Thornton, Richard P.	337 Church Road, Brinnon				602352008	26N 02W 35 D/E?	262990	1130614	PC	AC	154.4	LIDAR	D			88	88	6	10/28/1992	88			5		1	Air Test	19	19	19	U	
119	Mejnenger, Clayton						26N 02W 35 E	263255	1130705	TRSQQ	DOE	159.1	LIDAR	D			275	275	6	4/6/1982	80	275	0.50	10	20	1.5	Bailer Test	234	234	234	B	79
120	Irle, Roger	305743 Hyw. 101 Brinnon			H00982	602352002	26N 02W 35 F	263189	1132122	PC	AC	59.8	LIDAR	D			260	260	6	10/8/2001	240	260		5		2	Air Test	18	18	18	B	11
121	Thornton, Richard P.					602352026	26N 02W 35 G	262684	1130783	PC	AC	148.8	LIDAR	D			345	345	6	3/9/1977	122	345	0.16	20	125	3	Bailer Test	11	11	11	B	128
122	Springer, Charles	Dosewallips River Road					26N 02W 35 G	263230	1132420	TRSQQ	DOE	47.4	LIDAR	D			38	38	6	12/3/1991	38			33		1	Air Test	9	9	9	U	
123	Sun Rock Mobile Home Park		WELL #1				26N 02W 35 G	263230	1132420	TRSQQ	DOE	47.4	LIDAR	GRPB	B	48826																
124	Brinnon School District #46		WELL ON SCHOOL PROP.	ACM 521		602353002	26N 02W 35 L	261205	1130645	MAP	AC	27	LIDAR	NTNC	A	21689	30															
125	Brinnon Sr Center/Bayshore Motel	31503 Hwy. 101	WELL #2	ACM 516			26N 02W 35 L	261210	1132242	GPS	DOH	12.8	LIDAR	TNC	A	08430	75															
126	Baling, Steve						26N 02W 35 L	261753	1131722	GPS	JC	139.11	SURVEY	D			380	378	6	8/6/1984	226	378	0.03	10	370	1.5	Bailer Test	115.84	115	116.68	B	226
127	Gardens, Whitney						26N 02W 35 L	260564	1131599	GPS	JC	19.32	SURVEY	D			61	61	6	6/8/1993	55.5	60	6.67	100	15	1	Bailer Test	10.32	9.8	10.66	U	
129	Blenz, Bob					602353045	26N 02W 35 M	261638	1131033	PC	AC	144.8	LIDAR	D			256	256	6	4/27/1982	80	256	0.25	10	40	1.5	Bailer Test	125	125	125	B	75
130	Sather, Ceerce					602353022	26N 02W 35 M	261855	1130905	TRSQQ	AC	146	LIDAR	D/IR/C			27	27	6	8/30/1972	27		4.00	20	5	1	Bailer Test	6	6	6	U	
131	Springer, Larry						26N 02W 35 M	261855	1130905	TRSQQ	AC	146	LIDAR	D			135	134	6	5/25/1979	134			10	0	2	Bailer Test	75	75	75	U	
132	Brinnon School Dist. #46	46 Schoolhouse Road, Brinnon				602353002	26N 02W 35 N	261027	1130531	GPS	JC	28.54	SURVEY	D			56	56	6	7/12/2002	51	56	150.86	88	0.58	24	Pump Test	15.63	14.82	16.08	U	
133	Wasell, Walt					602353014	26N 02W 35 N	260816	1131403	PC	AC	16.3	LIDAR	D			67	67	6	5/25/1988	57	67	360.00	90	0.25	4	Pump Test	11.5	11.5	11.5	U	
134	Jefferson County Fire District #4	250 Schoolhouse Road, Brinnon			H00745	602353029	26N 02W 35 N	260073	1130615	GPS	JC	29.61	SURVEY	D			72.5	72.5	6	7/10/1999	68	72.5	0.30	12	40	2	Pump Test	17.02	15	18.67	U	
135	Jefferson County Fire District #4	Corner of Brinnon Lane and Schoolhouse Road				602353029	26N 02W 35 N	260133	1130532	GPS	JC	26.10	SURVEY	D			39	38	6	8/9/1994	38			50		1	Air Test	13.97	13.22	14.69	U	
136	Sea Farms Pacific				961089		26N 02W 35 P	260460	1132255	TRSQQ	AC	16	LIDAR	GRPB	B	00383	170	170	6	5/6/1980	80	170	0.06	10	170	4	Pump Test				B	76

Table A-1
Study Area Well Summary
Hydrogeologic Study of the Lower Dosewallips/Brinnon Area
Jefferson County, WA

General Information																	Installation Details				Production Zone		Well Test Information					Summary of Static Water Level (SWL) Readings			Geologic Information	
Aspect Well ID Number	Owner Name (from Well Log)[1]	Well Address	DOH Source Name	Ecology Well Tag	Jeff. Co. Database Tracking #	Parcel ID Number	TRS	Northing (SP83 WA HARN)	Easting (SP83 WA HARN)	XY Method	XY Source	Ground Surface Elevation (NAVD88 ft)	Z Accuracy Code	Well Use	DOH Well Group	PWSID	Drilled Hole Depth (feet)	Completed Well Depth (feet)	Well Diameter (inches)	Installation Date	Top of Open Interval (feet)	Bottom of Open Interval (feet)	Specific Capacity (gpm/ft)	Pump Rate (gpm)	Drawdown (feet)	Test Duration (hours)	Test Type	Average (feet)	Minimum (feet)	Maximum (feet)	Completed Unit Type	Depth to Bedrock (feet)
137	Engman, Gary						26N 02W 35 P	260460	1132255	TRSQQ	AC	16	LIDAR	D			155	155	6	2/29/1980	80	155	0.05	7	155	1.5	Bailer Test	3	3	3	B	76
138	Bailey, Henry / Brinnon Cemetery						26N 02W 35 R	261856	1130248	GPS	JC	154.59	SURVEY	D			135	130	6	4/12/1988	130		0.08	10	125	1.5	Bailer Test	58.14	48	75	U	
139	US Forest Service			ACM 520			26N 03W 20 E	274143	1084093	GPS	DOE	722.8	DEM	O			56	56	6	4/2/1979	51.5	56		45			Artesian	27	27	27	U	
140	Pollgreen, Thomas	5964 Dosewallips Rd. Brinnon			H00110	603243013	26N 03W 24	273037	1105985	PC	AC	668.2	DEM	D			233	233	6	8/17/1993	213	233		4		2	Air Test	12	12	12	B	13
141	Kennedy, Jim & Sandy	6380 Dosewallips River Rd. Brinnon				603243007	26N 03W 24 N	272282	1105263	PC	AC	337.1	DEM	D			118	118	6	4/24/1993	85	118		7		1	Air Test	50	50	50	B	56
142	Bettinger, Tom	5911 Dosewallips Rd. Brinnon				603243009	26N 03W 24 P	272249	1106398	PC	AC	406.1	DEM	D			262	262	6	2/23/1995	242	262		7		1	Air Test	17	17	17	B	0
143	Washington State Parks (Well #2)							259105	1132001	PC	AC	15.5	LIDAR						2													
144	Hockett, Vernie & Margaret					602341040	26N 02W 34 J?	264468	1130122	GPS	JC	305.12	SURVEY	D			258	258		1/1/1984				50	0	110	Unknown	67.32	63.23	72.7	B	15
145	Mathews, Mike					941700314	26N 02W 35	259256	1131470	GPS	JC	21.27	SURVEY	D			35.85											9.945	9.04	10.85	U	
146	Whitney Gardens							260375	1131895	GPS	AC	13	LIDAR				35		6													

Notes:
1 - The owners common well reference name or DOH well reference name may also be included.
2 - Well #14 is completed in the unconsolidated formation (20' to 33' bgs), yet also cased 3' into basalt (57' to 60' bgs).

Legend:
Parcel ID Number:
M - Indicates that multiple parcel numbers are associated with a given name, and that no unique match could be made.

XY Method Codes:
GPS - Wells located with a GPS unit.
MAP - Well locations based on coordinates field located on a map.
PC - Well locations based on coordinates at the center of the parcel.
TRS - Well located to the nearest section.
TRSQQ - Well located to the nearest 1/4 1/4 section.

XY Source Codes:
AC - Aspect Consulting
DOE - Washington State Department of Ecology
DOH - Washington State Department of Health
JC - Jefferson County
USGS - United States Geological Survey

Z Accuracy Codes:
DEM - Elevations are based on USGS 10 meter DEM data. However, elevation accuracy is also dependent on XY locational accuracy.
LIDAR - Elevations are based on LIDAR data from the Puget Sound LIDAR Consortium. However, elevation accuracy is also dependent on XY locational accuracy.
SEC - Due to limited XY accuracy, the elevations for these wells have been determined at the center of the section. The elevation is taken from LIDAR data where available, or DEM data. All data rounded to the nearest five feet..
SURVEY - Elevations based on Survey Grade GPS.

Well Use:
C = Commercial
D = Domestic
GRPB = Group B DOH Well
ID = Industrial
IR = Irrigation
M = Municipal Well
NTNC = Non-Transient Non-Community
O = Other
T = Test Well
TNC = Transient Non-Community

PWSID: Public Water System ID

Production Zone: Wells listing only top of open interval are completed with an open end casing at total well depth. For wells with multiple open intervals, only the top opening of the upper interval and the lowest opening of the bottom interval are shown.

Completed Unit Type:
B - The well was completed in a basalt unit.
U - The well was completed in an unconsolidated unit.

APPENDIX B

Surface Water/Groundwater Interaction: Field Methods and Laboratory Data

This Appendix provides a description of the field methods used in the hydrogeologic investigation of the lower Dosewallips/Brinnon Area.

B.1 Discharge Measurements

Discharge measurements of the Dosewallips River and Rocky Brook were made using the USGS standard six-tenths depth area-velocity technique (Rantz, 1982). Transect locations varied slightly in order to minimize turbulence, avoid eddies, and select a wadeable site for the stream conditions encountered. For flow measurement, a transect is divided into 20 to 25 stations using a tape placed across the channel. The stream depth and the velocity at six-tenths depth are measured at each station using a Swoffer Model 3000 current meter with a calibrated 2-inch propeller. Total flow is calculated as the sum of the velocity-area products for the stations. All measurements are stored in the meter. Velocity measurements and total flow are later adjusted to the propeller calibration curve. Measurement accuracy for the area-velocity technique is estimated to be +/- 3 percent.

Flow measurements in cubic feet per second (cfs) are summarized in the following table:

	Transect A	Transect B	Rocky Brook	Transect C	Transect D
10/9/03	183	212	1 est.	196	182
10/10/04	145	158	1 est.	156	161
2/27/04	533	564	63	448	417 est.

During low flow conditions, discharges were measured at four transects on October 9 and again on October 10, 2003. The first flow measurements each day began at Transect A, followed by Transects B, C, and D. Discharge and stage at the Highway 101 Bridge (Transect A) were measured at both the beginning and end of the day. The river flow was decreasing during both days. The flow measurements at upstream transects were corrected to the time of the first flow measurement at the bridge. A linear change in flow during the period of measurements was assumed and flows reduced accordingly. These adjustments in flow varied from 1 percent to 8 percent, although the difference in adjustment between the upstream and downstream location for any given reach was relatively small, ranging from 1.3 percent to 3.7 percent. Other than inflow of about 1 cfs from Rocky Brook, no tributary inflow was identified during the October measurements. Small flow (estimated at about 20 gpm) was noted in the upstream portion of an unnamed tributary on the south side of Reach 3, but infiltrated into subsurface soils before reaching the Dosewallips River.

Flows were again measured during high water levels on February 27, 2004 at Transects A, B, and C and at Rocky Brook. Transect D could not be safely waded at that time. Flows at Transects C and D (Reach 3) were measured on March 4, 2004. These flows were adjusted to February 27, 2004 flows based on the proportional difference in flow at

Transect C on the 2 days for the purposes of applying tributary inflow estimates from the February 27 gaging.

During the February and March measurements, tributary inflow was occurring down several steep gradient streams that were not readily measurable. Tributary inflow for this period was estimated based Rocky Brook gaging. Runoff per unit area was calculated based on Rocky Brook gaging and applied to the ungaged tributary areas for Reaches 2 and 3. As such, computed seepage values for the February/March measurements are considered estimated for Reaches 2 and 3. No adjustment was made to Reach 1 for tributary inflow. This reach has a relatively small catchment to the south as State Park Creek intercepts a large portion of the runoff from the south. No inflows were identified along the north side of the channel on this reach.

B.2 Piezometer Installations and Measurements

Mini-piezometers were installed to measure groundwater levels. The piezometers were hand-driven ½-inch or 1¼-inch steel pipe typically 7 feet long. In two cases (P-5 and P-18), the pipes were extended with couplers in order to reach groundwater. The tip of a ½-inch pipe was flattened into a wedge. Three triangles were cut from the tip of a 1¼-inch pipe and the remaining points sections hammered into a point. Each pipe was perforated with a total of fourteen 1/8-inch holes, which were set in four rows and located at 0.2 to 1.0 feet from the tip.

The piezometers were developed by continuous pumping (with a Geotech peristaltic pump) and intermittent surging (with ¼-inch by 3/8-inch vinyl tubing). Development was regarded complete when surging did not bring sediment into the piezometer. Two piezometers were abandoned. P-6 produced insufficient water, probably due to installation in silt. The P-4 installation was considered in direct communication with the river based on identical head values. Additional probes were installed during the study to replace or supplement those impacted by changes in the channel. All probes were surveyed with survey grade GPS by Jefferson County.

The ½-inch pipes were installed as in-stream piezometers. The 1¼-inch-diameter pipes were installed back from the river edge and were instrumented with temperature loggers (see below). Measurements were made monthly. The measurements for the ½-inch in-stream piezometers included stickup, static water level (SWL), submergence, head difference between surface and groundwater, and conductivity and temperature for both surface water and groundwater. The 1¼-inch piezometers were monitored for stickup, SWL, and temperature. A peristaltic pump was used to pull both surface and groundwater through 0.170 x ¼-inch LDPE or ¼ x ¾-inch vinyl tubing for measurement of specific conductivity and temperature. Flow was directed into an open bottle containing the instrument probe. The flow was continuous except when readings were made (Appendix B.4).

Groundwater to surface water head differences were measured with a 36-inch-long, inverted U-tube manometer (Winter et al., 1988). Groundwater was pulled up through one tube of the manometer using suction from the peristaltic pump until the flow was stable and free of bubbles. The bottom of the first tube was then closed and surface water pulled through the other tube. The bottoms of both tubes were then opened to their respective sources, the top of the U-tube closed, the pump disconnected, and air bled into the top of the U-tube. The fluid levels were allowed to equilibrate, the values recorded, and the differential head calculated. Accuracy of reading was +/- 0.1 inch of water.

Surface water head was usually measured at the instream piezometer. For out-of-stream piezometers, the surface water head was measured at the nearest in-stream piezometer. A special circumstance existed at Cluster 4. All four piezometers measured surface water at a downstream eddy which was receiving groundwater discharge between the row of piezometers and a bedrock wall (see inset on Figure 4.2). Vertical hydraulic gradient (dh/dl) was calculated as the difference in groundwater and surface water heads (dh) divided by a length (dl). For instream piezometers, the point of interaction was taken to be the stream bottom and the length (dl) calculated as the difference between the stream bottom and middle of the perforated interval. For out-of-stream piezometers, interaction was taken to be at a point projected horizontally from the top of the stream. Length (dl) was then calculated as piezometer length less static water level less head difference. These relationships are depicted graphically in Figure 4.4.

B.3 Temperature and Level Monitoring

Continuous monitoring of temperature was conducted at ten locations. Level was also monitored at three of those sites.

Seven recording temperature sensors (Onset Tidbits) were installed. These sensors are approximately 1.2-inch diameter and 0.8-inches thick. Accuracy was verified in an ice-water bath prior to deployment. Air temperature was monitored at the Dosewallips State Park under the eave of the pump house at well 17. River temperature was monitored at Clusters 2 and 4 by protecting the sensor in a short length of steel pipe that was cabled to an anchor. Groundwater temperature was monitored in four out-of-stream 1¼-inch piezometers. Sensors were hung at the mid-point of the perforations.

Temperature/level transducer/loggers (Instrumentation Northwest, Model PT2X, 15 psi range) were installed in well 9, in stilling well P-17 in the Dosewallips River at Lazy C, and in out-of-stream piezometer P-18, also at Lazy C. The transducer elevation, or depth-to-transducer, was monitored for quality assurance.

B.4 Geochemical Tracer Testing and Analysis

Water sampling for the purpose of measuring field temperature and conductivity was performed with a peristaltic pump as described above in section B.1. A YSI Model 30 conductivity meter was used to measure specific conductivity and temperature. The meter was calibrated with a 447 micro/siemens per (µS/cm) standard solution prior to each day’s use. Readings were made periodically until stable values were achieved.

B.5 Laboratory Reported Analytical Testing Results

Water samples were collected on March 12, 2004 at the four river transects and from five wells. Water quality parameters (specific conductivity and pH) were measured at the time of collection. Major ion analysis was conducted by North Creek Analytical, Inc. following EPA method 200.7 for dissolved metals (calcium, potassium, magnesium, and sodium), Standard Method SM 2320B for carbonate, bicarbonate, hydroxide, and total alkalinity, and EPA method 300.0 for anions (chloride and sulfate). Stable isotope ratio analyses for 18-oxygen and deuterium were performed by Geochron Laboratories. Sample were collected in laboratory prepared sample jars. Major ion samples were stored on blue ice during shipping. All samples were transported using standard chain of custody protocol. Laboratory reported data sheets are included at the end of this Appendix.

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02 April 2004

Joe Lubischer
Aspect Consulting - Bainbridge Island
179 Madrone Lane N
Bainbridge Island, WA/USA 98110
RE: Dosewallips

Enclosed are the results of analyses for samples received by the laboratory on 03/20/04 09:30. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

Jeff Gerdes

Jeff Gerdes
Project Manager

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Aspect Consulting - Bainbridge Island
179 Madrone Lane N
Bainbridge Island, WA/USA 98110

Project: Dosewallips
Project Number: 030116
Project Manager: Joe Lubischer

Reported:
04/02/04 12:48

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
#1 Transect 4	B4C0590-01	Water	03/18/04 16:00	03/20/04 09:30
#2 Transect 3	B4C0590-02	Water	03/18/04 08:25	03/20/04 09:30
#4 Transect 2	B4C0590-03	Water	03/18/04 18:50	03/20/04 09:30
#5 Transect 1	B4C0590-04	Water	03/18/04 08:00	03/20/04 09:30
#6 PUD	B4C0590-05	Water	03/18/04 11:15	03/20/04 09:30
#7 Haley	B4C0590-06	Water	03/18/04 17:00	03/20/04 09:30
#8 Fire	B4C0590-07	Water	03/18/04 11:50	03/20/04 09:30
#9 Well 9	B4C0590-08	Water	03/18/04 11:00	03/20/04 09:30
#10 Hockett	B4C0590-09	Water	03/18/04 16:00	03/20/04 09:30

North Creek Analytical - Bothell

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Jeff Gerdes

Jeff Gerdes, Project Manager

Aspect Consulting - Bainbridge Island	Project: Dosewallips	
179 Madrone Lane N	Project Number: 030116	**Reported:**
Bainbridge Island, WA/USA 98110	Project Manager: Joe Lubischer	04/02/04 12:48

Dissolved Metals by EPA 200 Series Methods
North Creek Analytical - Bothell

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
#1 Transect 4 (B4C0590-01) Water Sampled: 03/18/04 16:00 Received: 03/20/04 09:30									
Calcium	**18.6**	0.250	mg/l	1	4C23017	03/23/04	03/23/04	EPA 200.7	
Potassium	**2.28**	2.00	"	"	"	"	03/24/04	"	
Magnesium	**1.63**	0.500	"	"	"	"	03/23/04	"	
Sodium	**2.21**	0.250	"	"	"	"	"	"	
#2 Transect 3 (B4C0590-02) Water Sampled: 03/18/04 08:25 Received: 03/20/04 09:30									
Calcium	**18.7**	0.250	mg/l	1	4C23017	03/23/04	03/23/04	EPA 200.7	
Potassium	**2.47**	2.00	"	"	"	"	03/24/04	"	
Magnesium	**1.68**	0.500	"	"	"	"	03/23/04	"	
Sodium	**2.20**	0.250	"	"	"	"	"	"	
#4 Transect 2 (B4C0590-03) Water Sampled: 03/18/04 18:50 Received: 03/20/04 09:30									
Calcium	**17.6**	0.250	mg/l	1	4C23017	03/23/04	03/23/04	EPA 200.7	
Potassium	**3.04**	2.00	"	"	"	"	03/25/04	"	
Magnesium	**1.67**	0.500	"	"	"	"	03/23/04	"	
Sodium	**2.17**	0.250	"	"	"	"	"	"	
#5 Transect 1 (B4C0590-04) Water Sampled: 03/18/04 08:00 Received: 03/20/04 09:30									
Calcium	**18.0**	0.250	mg/l	1	4C23017	03/23/04	03/23/04	EPA 200.7	
Potassium	**2.97**	2.00	"	"	"	"	03/25/04	"	
Magnesium	**1.76**	0.500	"	"	"	"	03/23/04	"	
Sodium	**2.47**	0.250	"	"	"	"	"	"	
#6 PUD (B4C0590-05) Water Sampled: 03/18/04 11:15 Received: 03/20/04 09:30									
Calcium	**28.1**	0.250	mg/l	1	4C23017	03/23/04	03/23/04	EPA 200.7	
Potassium	**2.42**	2.00	"	"	"	"	03/25/04	"	
Magnesium	**2.71**	0.500	"	"	"	"	03/23/04	"	
Sodium	**29.7**	0.250	"	"	"	"	"	"	

North Creek Analytical - Bothell

Jeff Gerdes

Jeff Gerdes, Project Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Aspect Consulting - Bainbridge Island
179 Madrone Lane N
Bainbridge Island, WA/USA 98110

Project: Dosewallips
Project Number: 030116
Project Manager: Joe Lubischer

Reported:
04/02/04 12:48

Dissolved Metals by EPA 200 Series Methods
North Creek Analytical - Bothell

#7 Haley (B4C0590-06) Water Sampled: 03/18/04 17:00 Received: 03/20/04 09:30

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Calcium	**10.3**	0.250	mg/l	1	4C23017	03/23/04	03/23/04	EPA 200.7	
Potassium	ND	2.00	"	"	"	"	03/25/04	"	
Magnesium	**4.08**	0.500	"	"	"	"	03/23/04	"	
Sodium	**4.79**	0.250	"	"	"	"	"	"	

#8 Fire (B4C0590-07) Water Sampled: 03/18/04 11:50 Received: 03/20/04 09:30

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Calcium	**14.2**	0.250	mg/l	1	4C23017	03/23/04	03/23/04	EPA 200.7	
Potassium	ND	2.00	"	"	"	"	03/25/04	"	
Magnesium	**1.66**	0.500	"	"	"	"	03/23/04	"	
Sodium	**2.07**	0.250	"	"	"	"	"	"	

#9 Well 9 (B4C0590-08) Water Sampled: 03/18/04 11:00 Received: 03/20/04 09:30

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Calcium	**14.7**	0.250	mg/l	1	4C23017	03/23/04	03/23/04	EPA 200.7	
Potassium	ND	2.00	"	"	"	"	03/25/04	"	
Magnesium	**1.55**	0.500	"	"	"	"	03/23/04	"	
Sodium	**1.95**	0.250	"	"	"	"	"	"	

#10 Hockett (B4C0590-09) Water Sampled: 03/18/04 16:00 Received: 03/20/04 09:30

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Calcium	**25.0**	0.250	mg/l	1	4C23017	03/23/04	03/23/04	EPA 200.7	
Potassium	ND	2.00	"	"	"	"	03/25/04	"	
Magnesium	**5.16**	0.500	"	"	"	"	03/23/04	"	
Sodium	**7.29**	0.250	"	"	"	"	"	"	

North Creek Analytical - Bothell

Jeff Gerdes

Jeff Gerdes, Project Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Aspect Consulting - Bainbridge Island	Project: Dosewallips	
179 Madrone Lane N	Project Number: 030116	**Reported:**
Bainbridge Island, WA/USA 98110	Project Manager: Joe Lubischer	04/02/04 12:48

Conventional Chemistry Parameters by APHA/EPA Methods

North Creek Analytical - Bothell

#1 Transect 4 (B4C0590-01) Water Sampled: 03/18/04 16:00 Received: 03/20/04 09:30

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Bicarbonate Alkalinity	**44.6**	5.00	mg/L as CaCO3	1	4C23039	03/23/04	03/23/04	SM 2320B	
Carbonate Alkalinity	ND	5.00	"	"	"	"	"	"	
Hydroxide Alkalinity	ND	5.00	"	"	"	"	"	"	
Total Alkalinity	**44.6**	5.00	"	"	"	"	"	"	

#2 Transect 3 (B4C0590-02) Water Sampled: 03/18/04 08:25 Received: 03/20/04 09:30

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Bicarbonate Alkalinity	**46.8**	5.00	mg/L as CaCO3	1	4C23039	03/23/04	03/23/04	SM 2320B	
Carbonate Alkalinity	ND	5.00	"	"	"	"	"	"	
Hydroxide Alkalinity	ND	5.00	"	"	"	"	"	"	
Total Alkalinity	**46.8**	5.00	"	"	"	"	"	"	

#4 Transect 2 (B4C0590-03) Water Sampled: 03/18/04 18:50 Received: 03/20/04 09:30

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Bicarbonate Alkalinity	**43.2**	5.00	mg/L as CaCO3	1	4C23039	03/23/04	03/23/04	SM 2320B	
Carbonate Alkalinity	ND	5.00	"	"	"	"	"	"	
Hydroxide Alkalinity	ND	5.00	"	"	"	"	"	"	
Total Alkalinity	**43.2**	5.00	"	"	"	"	"	"	

#5 Transect 1 (B4C0590-04) Water Sampled: 03/18/04 08:00 Received: 03/20/04 09:30

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Bicarbonate Alkalinity	**43.8**	5.00	mg/L as CaCO3	1	4C23039	03/23/04	03/23/04	SM 2320B	
Carbonate Alkalinity	ND	5.00	"	"	"	"	"	"	
Hydroxide Alkalinity	ND	5.00	"	"	"	"	"	"	
Total Alkalinity	**43.8**	5.00	"	"	"	"	"	"	

#6 PUD (B4C0590-05) Water Sampled: 03/18/04 11:15 Received: 03/20/04 09:30

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
Bicarbonate Alkalinity	**30.8**	5.00	mg/L as CaCO3	1	4C23039	03/23/04	03/23/04	SM 2320B	
Carbonate Alkalinity	**8.80**	5.00	"	"	"	"	"	"	
Hydroxide Alkalinity	ND	5.00	"	"	"	"	"	"	
Total Alkalinity	**39.6**	5.00	"	"	"	"	"	"	

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Jeff Gerdes

Jeff Gerdes, Project Manager

Aspect Consulting - Bainbridge Island
179 Madrone Lane N
Bainbridge Island, WA/USA 98110

Project: Dosewallips
Project Number: 030116
Project Manager: Joe Lubischer

Reported:
04/02/04 12:48

Conventional Chemistry Parameters by APHA/EPA Methods
North Creek Analytical - Bothell

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
#7 Haley (B4C0590-06) Water Sampled: 03/18/04 17:00 Received: 03/20/04 09:30									
Bicarbonate Alkalinity	**50.0**	5.00	mg/L as CaCO3	1	4C23039	03/23/04	03/23/04	SM 2320B	
Carbonate Alkalinity	ND	5.00	"	"	"	"	"	"	
Hydroxide Alkalinity	ND	5.00	"	"	"	"	"	"	
Total Alkalinity	**50.0**	5.00	"	"	"	"	"	"	
#8 Fire (B4C0590-07) Water Sampled: 03/18/04 11:50 Received: 03/20/04 09:30									
Bicarbonate Alkalinity	**38.4**	5.00	mg/L as CaCO3	1	4C23039	03/23/04	03/23/04	SM 2320B	
Carbonate Alkalinity	ND	5.00	"	"	"	"	"	"	
Hydroxide Alkalinity	ND	5.00	"	"	"	"	"	"	
Total Alkalinity	**38.4**	5.00	"	"	"	"	"	"	
#9 Well 9 (B4C0590-08) Water Sampled: 03/18/04 11:00 Received: 03/20/04 09:30									
Bicarbonate Alkalinity	**37.8**	5.00	mg/L as CaCO3	1	4C23039	03/23/04	03/23/04	SM 2320B	
Carbonate Alkalinity	ND	5.00	"	"	"	"	"	"	
Hydroxide Alkalinity	ND	5.00	"	"	"	"	"	"	
Total Alkalinity	**37.8**	5.00	"	"	"	"	"	"	
#10 Hockett (B4C0590-09) Water Sampled: 03/18/04 16:00 Received: 03/20/04 09:30									
Bicarbonate Alkalinity	**98.0**	5.00	mg/L as CaCO3	1	4C23039	03/23/04	03/23/04	SM 2320B	
Carbonate Alkalinity	ND	5.00	"	"	"	"	"	"	
Hydroxide Alkalinity	ND	5.00	"	"	"	"	"	"	
Total Alkalinity	**98.0**	5.00	"	"	"	"	"	"	

North Creek Analytical - Bothell

Jeff Gerdes

Jeff Gerdes, Project Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Aspect Consulting - Bainbridge Island
179 Madrone Lane N
Bainbridge Island, WA/USA 98110

Project: Dosewallips
Project Number: 030116
Project Manager: Joe Lubischer

Reported:
04/02/04 12:48

Anions by EPA Method 300.0
North Creek Analytical - Bothell

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
#1 Transect 4 (B4C0590-01) Water Sampled: 03/18/04 16:00 Received: 03/20/04 09:30									
Chloride	**0.711**	0.400	mg/l	1	4C30001	03/29/04	03/29/04	EPA 300.0	
Sulfate	**7.72**	0.400	"	"	4C28007	03/26/04	03/26/04	"	
#2 Transect 3 (B4C0590-02) Water Sampled: 03/18/04 08:25 Received: 03/20/04 09:30									
Chloride	**0.707**	0.400	mg/l	1	4C30001	03/29/04	03/29/04	EPA 300.0	
Sulfate	**7.72**	0.400	"	"	4C28007	03/26/04	03/26/04	"	
#4 Transect 2 (B4C0590-03) Water Sampled: 03/18/04 18:50 Received: 03/20/04 09:30									
Chloride	**0.828**	0.400	mg/l	1	4C30001	03/29/04	03/29/04	EPA 300.0	
Sulfate	**7.28**	0.400	"	"	4C28007	03/26/04	03/26/04	"	
#5 Transect 1 (B4C0590-04) Water Sampled: 03/18/04 08:00 Received: 03/20/04 09:30									
Chloride	**0.820**	0.400	mg/l	1	4C30001	03/29/04	03/29/04	EPA 300.0	
Sulfate	**7.34**	0.400	"	"	4C28007	03/26/04	03/26/04	"	
#6 PUD (B4C0590-05) Water Sampled: 03/18/04 11:15 Received: 03/20/04 09:30									
Chloride	**62.7**	20.0	mg/l	50	4C30001	03/29/04	03/29/04	EPA 300.0	
Sulfate	**8.98**	0.400	"	1	4C28007	03/26/04	03/26/04	"	
#7 Haley (B4C0590-06) Water Sampled: 03/18/04 17:00 Received: 03/20/04 09:30									
Chloride	**1.18**	0.400	mg/l	1	4C30001	03/29/04	03/29/04	EPA 300.0	
Sulfate	**1.33**	0.400	"	"	4C28007	03/26/04	03/26/04	"	
#8 Fire (B4C0590-07) Water Sampled: 03/18/04 11:50 Received: 03/20/04 09:30									
Chloride	**0.834**	0.400	mg/l	1	4C30001	03/29/04	03/29/04	EPA 300.0	
Sulfate	**5.59**	0.400	"	"	4C28007	03/26/04	03/26/04	"	

North Creek Analytical - Bothell

Jeff Gerdes

Jeff Gerdes, Project Manager

Aspect Consulting - Bainbridge Island
179 Madrone Lane N
Bainbridge Island, WA/USA 98110

Project: Dosewallips
Project Number: 030116
Project Manager: Joe Lubischer

Reported:
04/02/04 12:48

Anions by EPA Method 300.0
North Creek Analytical - Bothell

Analyte	Result	Reporting Limit	Units	Dilution	Batch	Prepared	Analyzed	Method	Notes
#9 Well 9 (B4C0590-08) Water Sampled: 03/18/04 11:00 Received: 03/20/04 09:30									
Chloride	**0.870**	0.400	mg/l	1	4C30001	03/29/04	03/29/04	EPA 300.0	
Sulfate	**5.96**	0.400	"	"	4C28007	03/26/04	03/26/04	"	
#10 Hockett (B4C0590-09) Water Sampled: 03/18/04 16:00 Received: 03/20/04 09:30									
Chloride	**1.02**	0.400	mg/l	1	4C30001	03/29/04	03/29/04	EPA 300.0	
Sulfate	**1.49**	0.400	"	"	4C28007	03/26/04	03/26/04	"	

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Jeff Gerdes

Jeff Gerdes, Project Manager

Aspect Consulting - Bainbridge Island
179 Madrone Lane N
Bainbridge Island, WA/USA 98110

Project: Dosewallips
Project Number: 030116
Project Manager: Joe Lubischer

Reported:
04/02/04 12:48

Dissolved Metals by EPA 200 Series Methods - Quality Control
North Creek Analytical - Bothell

Batch 4C23017: Prepared 03/23/04 Using EPA 200 Series

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Blank (4C23017-BLK1)										
Calcium	ND	0.250	mg/l							
Potassium	ND	2.00	"							
Magnesium	ND	0.500	"							
Sodium	ND	0.250	"							
LCS (4C23017-BS1)										
Calcium	4.67	0.250	mg/l	5.00		93.4	85-115			
Potassium	9.26	2.00	"	10.0		92.6	85-115			
Magnesium	4.75	0.500	"	5.00		95.0	85-115			
Sodium	4.81	0.250	"	5.00		96.2	85-115			
LCS Dup (4C23017-BSD1)										
Calcium	4.74	0.250	mg/l	5.00		94.8	85-115	1.49	20	
Potassium	9.32	2.00	"	10.0		93.2	85-115	0.646	20	
Magnesium	4.72	0.500	"	5.00		94.4	85-115	0.634	20	
Sodium	4.74	0.250	"	5.00		94.8	85-115	1.47	20	
Duplicate (4C23017-DUP1)					**Source: B4C0590-01**					
Calcium	19.0	0.250	mg/l		18.6			2.13	20	
Potassium	2.28	2.00	"		2.28			0.00	20	
Magnesium	1.66	0.500	"		1.63			1.82	20	
Sodium	2.19	0.250	"		2.21			0.909	20	
Matrix Spike (4C23017-MS1)					**Source: B4C0590-01**					
Calcium	23.4	0.250	mg/l	5.00	18.6	96.0	80-120			
Potassium	12.6	2.00	"	10.0	2.28	103	80-120			
Magnesium	6.58	0.500	"	5.00	1.63	99.0	80-120			
Sodium	7.06	0.250	"	5.00	2.21	97.0	80-120			

Dissolved Metals by EPA 200 Series Methods - Quality Control

North Creek Analytical - Bothell

Batch 4C23017: Prepared 03/23/04 Using EPA 200 Series

Matrix Spike (4C23017-MS2) **Source: B4C0600-01**

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Calcium	27.6	0.250	mg/l	5.00	23.1	90.0	80-120			
Potassium	14.1	2.00	"	10.0	5.25	88.5	80-120			
Magnesium	22.1	0.500	"	5.00	18.0	82.0	80-120			
Sodium	16.0	0.250	"	5.00	11.3	94.0	80-120			

Jeff Gerdes

Aspect Consulting - Bainbridge Island
179 Madrone Lane N
Bainbridge Island, WA/USA 98110

Project: Dosewallips
Project Number: 030116
Project Manager: Joe Lubischer

Reported:
04/02/04 12:48

Conventional Chemistry Parameters by APHA/EPA Methods - Quality Control
North Creek Analytical - Bothell

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 4C23039: Prepared 03/23/04 Using General Preparation										
Blank (4C23039-BLK1)										
Bicarbonate Alkalinity	ND	5.00	mg/L as CaCO3							
Carbonate Alkalinity	ND	5.00	"							
Hydroxide Alkalinity	ND	5.00	"							
Total Alkalinity	ND	5.00	"							
Blank (4C23039-BLK2)										
Bicarbonate Alkalinity	ND	5.00	mg/L as CaCO3							
Carbonate Alkalinity	ND	5.00	"							
Hydroxide Alkalinity	ND	5.00	"							
Total Alkalinity	ND	5.00	"							
Duplicate (4C23039-DUP1)					**Source: B4C0590-01**					
Bicarbonate Alkalinity	44.4	5.00	mg/L as CaCO3		44.6			0.449	20	
Carbonate Alkalinity	ND	5.00	"		ND			NA	20	
Hydroxide Alkalinity	ND	5.00	"		ND			NA	20	
Total Alkalinity	44.4	5.00	"		44.6			0.449	20	

Aspect Consulting - Bainbridge Island	Project: Dosewallips	
179 Madrone Lane N	Project Number: 030116	**Reported:**
Bainbridge Island, WA/USA 98110	Project Manager: Joe Lubischer	04/02/04 12:48

Anions by EPA Method 300.0 - Quality Control

North Creek Analytical - Bothell

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 4C28007: Prepared 03/26/04 Using General Preparation										
Blank (4C28007-BLK1)										
Sulfate	ND	0.400	mg/l							
LCS (4C28007-BS1)										
Sulfate	6.06	0.400	mg/l	6.00		101	90-110			
LCS Dup (4C28007-BSD1)										
Sulfate	5.99	0.400	mg/l	6.00		99.8	90-110	1.16	20	
Duplicate (4C28007-DUP1)					**Source: B4C0590-01**					
Sulfate	7.72	0.400	mg/l		7.72			0.00	25	
Duplicate (4C28007-DUP2)					**Source: B4C0608-01**					
Sulfate	1.38	0.400	mg/l		1.34			2.94	25	
Matrix Spike (4C28007-MS1)					**Source: B4C0590-01**					
Sulfate	13.8	0.800	mg/l	6.00	7.72	101	58-135			
Matrix Spike (4C28007-MS2)					**Source: B4C0608-01**					
Sulfate	7.28	0.400	mg/l	6.00	1.34	99.0	58-135			
Batch 4C30001: Prepared 03/29/04 Using General Preparation										
Blank (4C30001-BLK1)										
Chloride	ND	0.400	mg/l							
LCS (4C30001-BS1)										
Chloride	1.91	0.400	mg/l	2.00		95.5	90-110			

Jeff Gerdes

Jeff Gerdes, Project Manager

Aspect Consulting - Bainbridge Island
179 Madrone Lane N
Bainbridge Island, WA/USA 98110

Project: Dosewallips
Project Number: 030116
Project Manager: Joe Lubischer

Reported:
04/02/04 12:48

Anions by EPA Method 300.0 - Quality Control
North Creek Analytical - Bothell

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch 4C30001: Prepared 03/29/04 Using General Preparation										
LCS Dup (4C30001-BSD1)										
Chloride	1.95	0.400	mg/l	2.00		97.5	90-110	2.07	20	
Duplicate (4C30001-DUP1)					**Source: B4C0590-01**					
Chloride	0.775	0.400	mg/l		0.711			8.61	25	
Duplicate (4C30001-DUP2)					**Source: B4C0590-07**					
Chloride	0.811	0.400	mg/l		0.834			2.80	25	
Matrix Spike (4C30001-MS1)					**Source: B4C0590-01**					
Chloride	2.67	0.400	mg/l	2.00	0.711	98.0	52-134			
Matrix Spike (4C30001-MS2)					**Source: B4C0590-07**					
Chloride	2.67	0.400	mg/l	2.00	0.834	91.8	52-134			

Jeff Gerdes

Jeff Gerdes, Project Manager

Notes and Definitions

DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis
RPD	Relative Percent Difference

11720 North Creek Pkwy N Suite 400, Bothell, WA 98011-9508 425-420-9200 FAX 420-9210 ☐
11115 E Montgomery Suite B, Spokane, WA 99206-4776 509-924-9200 FAX 924-9290 ☐
9405 SW Nimbus Ave, Beaverton, OR 97008-7132 503-906-9200 FAX 906-9210 ☐
20332 Empire Ave Suite F-1, Bend, OR 99701-5711 541-383-9310 FAX 382-7588 ☐
3209 Denali St, Anchorage, AK 99503-4030 907-334-9200 FAX 334-9210 ☐

CHAIN OF CUSTODY REPORT

Work Order #: B4C0590

CLIENT: ASPECT CONSULTING
REPORT TO: 179 MADRONE LANE
ADDRESS: BAINBRIDGE IS, WA 98110
ATTN: JOE LUBISCHER
PHONE: 206-780-9370 FAX: 206-780-9438

INVOICE TO: ASPECT CONSULTING, LLC.
179 MADRONE LANE
BAINBRIDGE ISLAND, WA 98110
P.O. NUMBER: 030116-001-04

TURNAROUND REQUEST
in Business Days *
Organic & Inorganic Analyses
[✓ 10 STD.] ☐ 7 ☐ 5 ☐ 4 ☐ 3 ☐ 2 ☐ 1 ☐ <1
Petroleum Hydrocarbon Analyses
☐ 5 STD. ☐ 4 ☐ 3 ☐ 2 ☐ 1 ☐ <1
☐ OTHER Specify:
** Turnaround Requests less than standard may incur Rush Charges.*

PROJECT NAME: DOSEWALLIPS
PROJECT NUMBER: 030116
SAMPLED BY: JSL

PRESERVATIVE
REQUESTED ANALYSES

	CLIENT SAMPLE IDENTIFICATION	SAMPLING DATE/TIME	Calcium	Magnesium	Potassium	Sodium	Bicarbonate	Carbonate	Chloride	Sulfate	MATRIX (W, S, O)	# OF CONT.	LOCATION / COMMENTS	NCA WO ID
1	#1 TRANSECT 4	3-18-04 16:00	↓	↓	↓	↓	↓	↓	↓	↓				-01
2	#2 TRANSECT 3	8:25	↓	↓	↓	↓	↓	↓	↓	↓				-02
3	~~—~~	~~—~~	↓	↓	↓	↓	↓	↓	↓	↓				
4	#4 TRANSECT 2	18:50	↓	↓	↓	↓	↓	↓	↓	↓				-03
5	#5 TRANSECT 1	8:00	↓	↓	↓	↓	↓	↓	↓	↓				-04
6	#6 PUD	11:15	↓	↓	↓	↓	↓	↓	↓	↓				-05
7	#7 HALEY	17:00	↓	↓	↓	↓	↓	↓	↓	↓				-06
8	#8 FIRE	11:50	↓	↓	↓	↓	↓	↓	↓	↓				-07
9	#9 WELL 9	11:00	↓	↓	↓	↓	↓	↓	↓	↓				-08
10	#10 HOCKETT	16:00	↓	↓	↓	↓	↓	↓	↓	↓				-09

RELEASED BY: Joseph Lubischer DATE: 3-19-04
PRINT NAME: JOSEPH LUBISCHER FIRM: ASPECT TIME: 15:00
RECEIVED BY: DATE: 3-20-04
PRINT NAME: Demi Heardman FIRM: NCA TIME: 9:30

RELEASED BY: DATE:
PRINT NAME: FIRM: TIME:
RECEIVED BY: DATE:
PRINT NAME: FIRM: TIME:

ADDITIONAL REMARKS: SAMPLES TO BE FILTERED BEFORE TESTING
TEMP: 2.2
PAGE OF

COC REV 1/03

W/CS

GEOCHRON LABORATORIES a division of
KRUEGER ENTERPRISES, INC.
711 CONCORD AVENUE ◆ CAMBRIDGE, MASSACHUSETTS 02138 ◆ U.S.A
TELEPHONE: (617) 876-3691 TELEFAX: (617) 661-0148

STABLE ISOTOPE RATIO ANALYSES

REPORT OF ANALYTICAL WORK

Submitted by:
Joseph Lubischer
Aspect Consulting, LLC
179 Madrone Lane
Bainbridge Is WA 98110

Date Received: 3/26/2004
Date Reported: 5/19/2004
Your Reference: PO# 030185-001-01

Our Lab. Number	Your Sample Number	Description	δD*	$\delta^{18}O$*
HOR- 110618	#1 Transect 4	Water	-95	-13.0
HOR- 110619	#2 Transect 3	Water	-100	-13.4
HOR- 110620	#4 Transect 2	Water	-98	-13.0
HOR- 110621	#5 Transect 1	Water	-97	-13.0, -13.2**
HOR- 110622	#6 PUD	Water	-83	-11.8
HOR- 110623	#7 Haley	Water	-78, -74**	-10.6
HOR- 110624	#8 Fire	Water	-86	-12.2
HOR- 110625	#9 Well 9	Water	-90	-12.8
HOR- 110626	#10 Hockett	Water	-72	-11.0

** Duplicate analyses on separate aliquots of the original sample.

---

*Unless otherwise noted, analyses are reported in ‰ notation and are computed as follows:

$$\delta R_{\text{sample}}‰ = \left[\frac{R_{\text{sample}}}{R_{\text{standard}}} - 1 \right] \times 1000$$

Where:

D/H standard is SMOW
$^{18}O/^{16}O$ standard is SMOW

And:

$D/H_{\text{standard}} = 0.000316$**
$^{18}O/^{16}O_{\text{standard}} = 0.0039948$**

**Double atom ratio

CHAIN OF CUSTODY

Page # 1 of 1

Send Report To JOSEPH LUBISCHER
Company ASPECT CONSULTING, LLC
Address 179 MADRONE LANE
City, State, ZIP BAINBRIDGE IS., WA 98110
Phone # 206-780-9370 Fax # 206-780-9438

SAMPLERS (signature)

PROJECT NAME/NO.	PO #
DOSEWALLIPS	030185-001-01

REMARKS To: Geochron Laboratories
711 Concord Ave.
Cambridge, MA 02138-1002
617-876-3691

TURNAROUND TIME
☒ Standard (2 Weeks)
☐ RUSH
Rush charges authorized by:

SAMPLE DISPOSAL
☒ Dispose after 30 days
☐ Return samples
☐ Will call with instructions

						ANALYSES REQUESTED											
Sample ID	Lab ID	Date	Time	Sample Type	# of containers	TPH-Diesel	TPH-Gasoline	BTEX by 8021B	VOCs by 8260	SVOCs by 8270	HFS		Hydrogen δD	Oxygen δ18O			Notes
#1 Transect 4		3-18-04	18:00	WATER	1								↓	↓			HOR-110618
#2 Transect 3		↓	8:20	↓	1								↓	↓			110619
#4 Transect 2		↓	18:50	↓	1								↓	↓			110620
#5 Transect 1		↓	8:00	↓	1								↓	↓			110621
#6 PUD		↓	11:15	↓	1								↓	↓			110622
#7 Haley		↓	17:00	↓	1								↓	↓			110623
#8 Fire		↓	11:50	↓	1								↓	↓			110624
#9 Well 9		↓	11:00	↓	1								↓	↓			110625
#10 Hockett		↓	15:50	↓	1								↓	↓			110626

SIGNATURE	PRINT NAME	COMPANY	DATE	TIME
Relinquished by:	Joseph Lubischer	Aspect	3-24-04	15:00
Received by:			3/26/04	
Relinquished by:				
Received by:				

APPENDIX C

Hyporheic Zone

(Prepared by Kerrie McArthur of MCS Environmental, Inc.)

The hyporheic zone is the active zone between surface water and groundwater. Depending on the streambed topography and porosity, the hyporheic zone often extends laterally beneath the banks to alluvial aquifers that could be kilometers from the main channel. Within the hyporheic zone, exchanges of water, nutrients, organic matter, and materials between the groundwater, alluvial aquifers, and the surface water occur. Upwelling groundwater supplies stream organisms with nutrients while down welling surface water provides dissolved oxygen and organic matter to microbes and invertebrates in the hyporheic zone (Boulton et al. 1998; Boulton 2000; Reidy and Clinton 2004).

Dynamic gradients exist at all scales and vary temporally. Regardless of scale, the importance of the hyporheic zone's functions is dependant upon its activity and connection to the surface water. At the microscale, gradients in redox-potential control chemical and microbial nutrient transformations occurring on particle surfaces (Boulton et al 1998; Boulton 2000). The microbial biofilms coating the sediments act like a biological filter, enhancing water quality. These microbial communities are an important component of the heterotrophic food web within the hyporheic zone and perform essential functions (Feris et al 2003). At the reach scale, gradients in faunal composition, uptake of dissolved organic carbon, and nitrification indicate hydrological exchange rates and water residence times (Boulton et al. 1998).

The hyporheic zones in many areas are threatened by siltation, pollutants, increasing acidity, physical extraction for gravel, or altered groundwater inputs through pumping (Boulton 2000; Payn 2003). Infiltration of fines into the stream substrate can reduce hydraulic conductivity, further reducing hyporheic exchange of stream water and associated organic matter and nutrients to microbial habitat, thus, decreasing the retention of biologically active solutes (Payn 2003). Feris et al (2003) examined metal concentrations of sediment and biological communities within the hyporheic zone. Although there was no correlation between metal concentration and the total hyporheic microbial biomass present, microbial community structure showed a significant linear relationship with the sediment—metal loads. Channel homogenization can reduce hydrologic forces driving hyporheic exchange, also changing the faunal composition and rates of organic carbon uptake and nitrification (Payn 2003).

Fluvial geomorphic processes control many of the physical conditions that are required for spawning habitat. These conditions also promote connectivity between groundwater and surface water. Recent studies indicate that certain characteristics of the hyporheic zone (e.g. vertical head gradient, permeability, and nutrient flux) also aid salmon in the selection of spawning sites (Asbury 2003; Geist et al. 2001). Asbury (2003) found that groundwater upwelling through the hyporheic zone and high substrate porosity was an important feature for salmon in selecting a spawning site. Giest et al (2001) looked at the physiochemical characteristics of chum (*Oncorhynchus keta*) and chinook (*O. tshawytscha*) spawning sites at Ives Island in the Columbia River. Chum salmon spawned in areas where relatively warm water from the hyporheic zone up welled into the river. In contrast, chinook salmon spawned in areas where river water down welled into the bed. Brook trout (*Salvelinus fontinalis*) and sockeye salmon (*O. nerka*) have also been observed to preferentially spawn in sandy and silty substrate sites where upwelling is present, rather than use clean gravel in areas where upwelling is absent (Webster and Eiriksdottir 1976; Carline 1980; Witzel and MacCrimmon 1983; Curry and Noakes 1995;

Lorenz and Eiler 1989 as cited in Geist et al 2001). Areas of upwelling within the hyporheic zone are thought to protect developing embryos from freezing, optimizing incubation and emergence periods (Curry et al. 1995). Earlier emergence is an adaptation that benefits salmon fry by reducing competition for food with species that emerge later in the year (Geist et al 2001). Egg survival is typically attributed to inadequate supply of oxygen caused by infiltration of fine sediment into the interstices of the streambed. However, a recent study has shown that upwelling low-oxygenated groundwater also causes egg mortality. In redds where some eggs survive, the survival rate was proportional to the average oxygen level of upwelling groundwater in the hyporheic zone (FRS 2003).

The importance of salmon carcasses as a marine-derived nutrient for riparian vegetation and the aquatic food web is well known (Gende et al. 2002; Bartz et al. 2002; Willson et al. 1998, Cederholm et al. 1999). Hyporheic zones contain much greater epilithic surface area than streambed surface area for benthos to live (Edwards 1999). Microbial biofilms on sediment surfaces are a potential storage site for salmon-derived nutrients. These biofilms have been observed using the dissolved organic matter derived from salmon carcasses within the first few meter of subsurface flow (O'Keefe, T.C. and R.T. Edwards. 2002). The biofilms store these nutrients for weeks or months, before they are mineralized and reintroduced into the flowstream, where they become available to surface algae during the following growing season. Since hyporheic flows may extend several hundred meters into riparian floodplain forests, the hyporheic zone creates an enormous potential for storing a large volume of salmon-derived nutrients (Gende et al. 2002; Clinton et al. 2002).

Appendix C References

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