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IN-DEPTH PERSPECTIVE

HYDROLOGIC INFORMATION REPORT SUPPORTING WATER AVAILABILITY ASSESSMENT

Swale Creek and Little Klickitat Subbasins, WRIA 30

Prepared for: WRIA 30 Water Resource Planning & Advisory Committee

Project No. 070024-001-01 • June 29, 2007

Project funded through Ecology Grant No. G0700207

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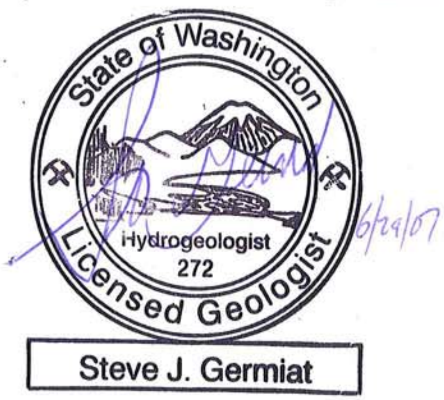

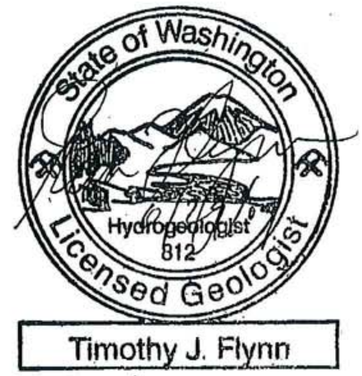

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Project Objectives and Report Organization

Estimated water uses in the Little Klickitat and Swale Creek subbasins are higher than in any other subbasin within Water Resource Inventory Area 30 (WRIA 30) – the Klickitat River Basin. The two subbasins (Figure 1) are areas of WRIA 30 with potential for substantial future growth such that additional water supplies will be needed to meet future demands. Applications for new water rights have been pending in the Swale Creek and Little Klickitat subbasins for more than 15 years.

Swale Creek and the Little Klickitat River are identified as water-quality impaired for water temperature on Ecology's water quality assessment list. A total maximum daily load (TMDL) is in effect to address water temperature in the Little Klickitat River. To date, Ecology has not developed an instream flow rule for WRIA 30; however, an adjudication of surface waters in the Little Klickitat River, and its Blockhouse Creek and Mill Creek tributaries, was completed in the late 1980s. The WRIA 30 Watershed Management Plan therefore anticipates that additional water demands in both subbasins will be met predominantly using new supplies from groundwater, not surface water.

Uncertainty exists regarding the quantity of water available for appropriation of new water rights in these two priority subbasins. The WRIA 30 Watershed Management Plan (WPN and Aspect Consulting 2004) identified data gaps that need to be filled to help determinate water available for appropriation including:

- Refine estimates of actual water use; and
- Delineate specific aquifer zones within the subbasins.

The WRIA 30 Water Resource Planning and Advisory Committee (PAC) obtained grant funding (Grant no. G0700207) from the Washington State Department of Ecology (Ecology) to conduct an assessment to address data gaps related to appropriation of new water rights in the Swale Creek and Little Klickitat subbasins. During scoping of the assessment with the PAC, it was decided that, because Swale Creek subbasin's hydrology is somewhat simpler and currently better understood than that in the Little Klickitat subbasin, and the limited timeframe available to complete the assessment (by June 30, 2007), that the greatest value from the assessment could be gained by focusing on the Swale Creek subbasin.

The PAC coordinated with John Kirk, hydrogeologist for Ecology Central Regional Office, regarding additional information required prior to Ecology's processing of new water right applications in the Swale Creek subbasin. Mr. Kirk's initial thoughts are summarized as follows:

1. Determine how much additional water could be appropriated without exceeding the average annual recharge to the aquifer. Document uncertainty in that estimate.

2. Assuming all the water available was appropriated, quantitatively determine the pumping impact (magnitude and timing/duration) on the following surface waters, and document uncertainty:
   a. Swale Creek;
   b. Little Klickitat River; and
   c. Columbia River.
3. Obtain information about the aquifer hydraulic properties to allow assessment of interference\impairment to existing wells from new pumping.

Issue 1 is related to water available for appropriation. Issues 2 and 3 are related to potential for impairment associated with new appropriations. It was agreed that quantitative assessment of pumping impacts is beyond the scope of this assessment; impairment can also depend on the quantity and location of new water rights being applied for. It was therefore decided that the best value from this assessment can be obtained by refining the hydrogeologic conceptual site model including collection of field data within the subbasin.

Therefore, the objectives of this assessment include:

1. Refinement of the hydrogeologic conceptual model for the Swale Creek subbasin, including the most definitive interpretation of the hydrostratigraphy and groundwater flow system to date;
2. Establishment of a groundwater level monitoring network for the Swale Creek subbasin and immediately surrounding areas; and
3. Refinement of the water balances for Swale Creek and Little Klickitat subbasins that assist in determination of water availability on the subbasin scale.

Report Organization

The following sections of this report include:

- Field Reconnaissance and Well Monitoring Network
- Conceptual Model of Hydrogeologic Conditions
- Interaction of Swale Creek Groundwater and Adjacent Surface Waters
- Estimated Water Use on Subbasin Scale
- Subbasin-Scale Water Balances
- Conclusions and Recommendations

Acknowledgements

We are grateful to members of the PAC and other local community members for their assistance in coordinating the water well field reconnaissance that resulted in establishment of a subbasin groundwater level monitoring network. Specifically, we acknowledge the efforts of J.P. Enderby, Pat Shamek, Dwayne Person, John Grim, Cal Edwards, Dave McClure, and Dave Griffin for the time they invested to obtain permission from local well owners to access their well for measurement. Thanks also to Will Conley, Yakama Nation Fisheries, for providing for this assessment streamflow data from their gaging station at the mouth of Swale Creek.

Field Reconnaissance and Well Monitoring Network

Aspect Consulting personnel conducted a field reconnaissance the week of June 4-8, 2007, with the objective of identifying accessible existing wells in and around the Swale Creek subbasin to include within a groundwater level monitoring network for the watershed. The water level monitoring was conducted in accordance with a Quality Assurance Project Plan prepared for the project (Aspect Consulting 2007). Members of the PAC and local community assisted in this effort by contacting local well owners to request permission to access their well for this purpose and inform them of the study objective. The primary persons that assisted in the effort are noted in the Acknowledgements section of this report.

Following completion of the field reconnaissance, the water level monitoring network consists of 41 wells. This includes 25 wells in the Swale Creek subbasin, six of which have been monitored by the City of Goldendale since 2001; 12 wells located in the High Prairie area on the west side of the subbasin; and 4 wells located in the Little Klickitat subbasin north of the Swale Creek subbasin. There were three additional wells for which we received owner permission to monitor, but for which water level measurements could not be collected due to the lack of an access port on the wellhead. Figure 2 depicts locations of wells in the monitoring network. A round of water level measurements was also collected during the field reconnaissance to provide the first round of subasin-wide water level data collected at one time. Table 1 provides a summary of the well monitoring network water level measurements.

In addition to the June 2007 water level measurements, permission was obtained from the well owners to contact them again for additional water level measurements in the future. No wells would be measured without owner permission.

Well Survey

Prior to the field reconnaissance, locations and groundwater levels for wells in the subbasins were based on Ecology’s on-line well log database. Wells in the well log database are located based on the center of the quarter-quarter section listed on the well log. Errors in identifying the appropriate quarter-quarter section on the well logs are relatively common. In addition, the well elevation is assumed to be the elevation at the center of the respective quarter-quarter section as indicated in the USGS' Digital Elevation Model (DEM). In areas of relatively large vertical relief, this can cause significant errors in the well elevation and subsequent calculated groundwater elevations. Therefore, to provide a more accurate and representative picture of groundwater elevations (and thus flow directions), it is necessary to obtain accurate well locations and elevations for wells included in the water level monitoring network.

As part of the field reconnaissance, wells included as part of the water level monitoring network were surveyed by a Klickitat County Public Works surveyor using a high-resolution Global Positioning System (GPS) with a base station on a known control point to allow for real-time differential correction. Because of the distances over which the wells were spread, the surveyor established additional control points throughout the subbasin. The location (Washington State Plane South Coordinates, NAD 83 datum) and elevation (NAVD 88 datum) of the water level measuring point for each well was surveyed to a reported precision of plus or minus 0.1 foot. Table 1 presents the survey data for wells within the monitoring network.

Comparison of Well Locations/Elevations between Survey and Well Logs

Table 2 compares well locations, well elevations, and groundwater levels from well log/DEM data, relative to the surveyed location and groundwater level measurements from the June 2007 field reconnaissance. For the seven wells examined, the surveyed well locations improved between 120 and 820 feet (average difference of 519 feet) and well elevations improved between 1 and 13 feet with an average difference of 9 feet. Depth to groundwater levels were found to vary between 0.2 and 30 feet since measured at the time of well installation as reported on the well log. The resulting calculated groundwater elevations differed by up to 25 feet, with an average difference of about 12 feet.

We conclude from this assessment that the well log/DEM information for well position, elevation, and water levels is of suitable accuracy for a subbasin-scale assessment of groundwater elevations and thus flow direction. This provides general confidence in information obtained from the well logs/DEM information, which is used throughout this study as described below. Nonetheless, well survey is a good investment where practical.

Field Procedures

Prior to the field reconnaissance, addresses of prospective wells to be included in the water level monitoring network were compiled based on well locations from Ecology's database and a site reconnaissance on April 6, 2007. Additional wells were added to the prospective water level monitoring network list based on a previous water quality study to evaluate nitrate (Watershed Professionals Network 2003) and personal contacts of local community members listed in the Acknowledgements section.

The prospective water level monitoring network wells were prioritized in order to (1) provide spatial coverage of the basin and (2) provide a representative number of wells completed in the alluvium and basalt aquifers to allow for differentiation of water levels within the respective hydrostratigraphic units. Across much of the subbasin, the alluvium directly overlies a water-bearing interflow zone (flow top) in the underlying Wanapum basalt; therefore, this interflow zone is effectively part of the alluvium aquifer hydrostratigraphic unit. Water levels in wells open to this interflow zone are considered to represent the alluvium aquifer.

Once the list of prospective water level monitoring network wells was established, local well owners were contacted to request permission to access their wells as part of the field reconnaissance. Only wells for which owner permission was granted were visited as part of the field reconnaissance. If permission was not granted for a well in an area of needed spatial coverage, the well owner of a lower priority prospective water level monitoring network well was contacted in its place. If a well owner granted permission to access their well, but wanted to be present during the measurements, personnel from Aspect Consulting called and set up a time with the respective owner in which to do so.

During the field reconnaissance, each wellhead was examined in the field to determine whether an access port was available for the respective water level measurements. If suitable access existed, the depth to water in the well was measured. Because most of the wells measured had pumps installed, care was taken to avoid getting the water level indicator caught on pump wiring or other items in the well. Only wells that were readily measured using a water level indicator were retained as part of the water level monitoring network. The location of the wells retained for the water level monitoring network were documented with field notes, photographs, and surveyed locations so that subsequent water level measurements can be taken if owner permission is received.

Each depth-to-water measurement was made to a precision of 0.01 foot using an electric water level indicator. The water level indicator was lowered to the depth of water in the well casing (determined by a light or beep on the indicator) and the reading noted. The indicator was then immediately withdrawn from the water and the measurement repeated. If the two readings were consistent, the reading was recorded on a field form along with the measurement date and time. If the two readings were not consistent, measurements were repeated until a reproducible result was obtained. No wells were observed to be pumping during measurement; however, if repeated water level measurements indicated the presence of rising/falling water levels due to previous pumping influences, it was noted as such on the respective field form. Only minor fluctuations were ever observed during measurement. Other pertinent information regarding the well completion or measurement of water levels was also noted on the field forms.

All depth-to-water measurements were made relative to the top of well casing or other defined measuring point at the wellhead. The selected measuring point for each well was marked in permanent marker and documented in the field form so that it can be reproduced during subsequent measurement rounds. Any rust or other visible material on the water level indicator after a measurement was wiped off using a clean paper towel prior to the next measurement.

For this watershed-scale study, data quality objectives for the field reconnaissance were to survey each well to a precision of 1 foot for horizontal position (x, y) and 0.1 foot for elevation (z) (Aspect Consulting 2007). This likewise defines the data quality objectives for the resulting measured groundwater elevations, despite depth to groundwater being measured to a precision of 0.01 foot.

Conceptual Model of Hydrogeologic Conditions

Hydrostratigraphy

A generalized geologic history of the Little Klickitat and Swale Creek subbasins is provided in the WRIA 30 Level 1 watershed assessment (WPN and Aspect Consulting 2004).

Hydrostratigraphic units within the study area include (from youngest to oldest):

- alluvium;
- Simcoe Mountain Volcanics;
- Wanapum basalt (Priest Rapids, Roza, and Frenchman Springs members); and
- Grand Ronde basalt.

Sedimentary interbeds between basalt units are collectively referred to as the Ellensburg Formation, irrespective of the basalt flows they occur between.

The surface geology and geologic structures from Washington Department of Natural Resources (WDNR) 1:100,000 scale digital mapping are shown on Figure 3.

Eight detailed hydrologic cross sections were developed to better define the depth and distribution of hydrostratigraphic units and the occurrence of water-bearing zones within the study area. The cross sections were developed using well logs from Ecology's database, the WDNR geologic mapping, and information from other available studies.

A total of 129 well logs were selected from the nearly 1,500 available well logs in the Little Klickitat and Swale Creek subbasins to create cross sections A-A' through H-H' (Figures 4 through 11). The cross sections integrate the following data from each well log: location of well to the nearest quarter-quarter section, well depth, cased interval, static water level, depth and thickness of geologic units encountered, water-bearing zones if reported, and, from the USGS DEM, surface elevation assuming the well is at the center of the quarter-quarter section (see Well Survey section above).

The cross section locations are shown on Figure 3, and were determined based on available coverage of well logs and features of greatest hydrologic interest, such as subbasin boundaries and geologic structures. The eight cross sections were positioned as follows (Figure 3):

- Figure 4: Section A-A' extends west-east from the High Prairie area, and southwest-northeast along the Swale Creek Syncline; crossing Swale Creek canyon, the Warwick Fault, and the Snipes Butte Fault, and crossing Highway 97 on the east.
- Figure 5: Section B-B' extends northwest-southeast from the Horseshoe Bend Anticline to the Columbia Hills Anticline System; crossing the Swale Creek Syncline.

- Figure 6: Section C-C' extends north-south from the northern border of Swale Creek subbasin to the Columbia Hills Anticline System, generally running along Harms Road; crossing the Warwick Fault and the Swale Creek Syncline.
- Figure 7: Section D-D' extends northeast-southwest along the axis of the Swale Creek Syncline from Warwick to east of Highway 97; crossing the Warwick Fault and the Snipes Butte Fault. This section is the same as A-A' in the eastern portion of the basin, and diverges in the center of Swale valley.
- Figure 8: Section E-E' extends north-south through the southern portion of the Little Klickitat subbasin and the northern portion of the Swale Creek subbasin just west of Goldendale; crossing the Snipes Butte Fault and the Little Klickitat Syncline.
- Figure 9: Section F-F' extends northeast-southwest near Mill Creek and Bowman Creek in the Little Klickitat subbasin, crossing into the Swale Creek subbasin.
- Figure 10: Section G-G' extends west-east generally along the Little Klickitat River, from the confluence with the mainstem Klickitat River on the west to east of Goldendale on the east; crossing the Little Klickitat Syncline, Snipes Butte Fault, and Goldendale Fault.
- Figure 11: Section H-H' extends north-south through the High Prairie area west of Swale Canyon, generally running along Schilling Road.

Groundwater in the Little Klickitat and Swale Creek subbasins occurs within the surficial alluvium (overburden), volcanic deposits, and the basalt bedrock units. Groundwater in the basalts occurs primarily at the tops of the individual flows ("flow top") that became vesicular (porous) as gas bubbles escaped the flows during cooling, and/or at the flow bottoms (sometimes referred to as "pillows"). Flow tops and bottoms – collective referred to as interflow zones - are usually porous and permeable, and therefore transmit water more readily than the intervening massive portions of the basalt flow interior which generally constitute flow barriers except where fractured. A permeable flow top is normally present for each flow, while permeable flow bottoms range from relatively thick units to completely absent. Based on the cross sections developed for this study, interflow zones are generally present in the study area at an average thickness of 10 to 20 feet. The lateral continuity of water-bearing interflow zones is highly variable.

The major hydrostratigraphic units are outlined briefly below.

The geologically younger alluvium can be highly variable in composition (from clay to gravel), with groundwater occurrence limited to the coarse-grained (sand and gravel) portions. The primary occurrences of alluvium are in Swale valley, mostly east of Warwick, and in the Little Klickitat River valley around Goldendale and upstream of it. The greatest thickness of alluvium is in Swale Creek Valley, south of Centerville, where the unit is on the order of 200 feet thick (Figure 4). Within Swale Valley, recent alluvium (Qa) and continental sedimentary rocks (QMc) are mapped (Figure 3). The QMc is more consolidated than the surficial veneer of recent alluvium, but the two units are lumped together hydrostratigraphically, constituting the alluvium aquifer.

The basalt bedrock units in the study area have a collective thickness of several thousand feet. The geologically youngest volcanic rock in the study area is termed the Simcoe

Volcanics where they form the Simcoe Mountains in the northern portion of the Little Klickitat subbasin. In several areas of the Swale Creek subbasin, volcanic rocks of the same geologic age are also mapped by WDNR as Simcoe Volcanics (Figure 3). The thickness of the Simcoe Volcanics is highly variable and reaches a maximum of 200 feet (T04N/R15E) in the study area covered by the cross sections. The City of Goldendale’s chlorination station well, located approximately 5 miles north of the City (T05N/R16E-21), penetrated approximately 340 feet of Simcoe Volcanics.

The Simcoe Volcanics tends to have a high permeability and represent an important source of groundwater north of the Little Klickitat River, including the City of Goldendale’s Simcoe springs and chlorination station well sources. Discharge from numerous springs emanating from the Simcoe Volcanics provides substantial baseflow to Little Klickitat River tributaries that originate in the Simcoe Mountains north of the river.

The average thickness of the Wanapum basalt is on the order of 600 feet throughout the study area, and reaches an apparent maximum thickness of roughly 800 feet (Figure 9, near T04N/R14E). The Wanapum basalt is present beneath the Swale Creek and Little Klickitat subbasins except where it has been eroded in deep incised valleys (e.g., Swale Creek Canyon, Klickitat River) and along major anticlinal features (Columbia Hills Anticline System). The Wanapum basalt contains three separate members: the Priest Rapids, Roza, and Frenchman Springs. The Priest Rapids member averages about 100 feet in thickness and reaches a maximum thickness of roughly 200 feet (Figure 10, west of T04N/R14E). The Roza member averages 100 feet in thickness and reaches a maximum thickness of 250 feet (Figure 9, near T04N/R14E). The Frenchman Springs member averages 400 feet in thickness and reaches a maximum thickness of about 600 feet (Figure 7, T03N/R15E).

The oldest member of the Wanapum basalt sequence is underlain by the Grand Ronde basalt, which is several thousand feet thick under the Swale Creek and Little Klickitat subbasins. There are few wells completed in the Grand Ronde basalt in the Little Klickitat or Swale Creek subbasins. Wells completed in the Grand Ronde basalt often have limited water available, poor water quality, and deep static water levels. The largest number of wells completed in the Grand Ronde basalt is in the High Prairie area of Swale Creek subbasin; static water levels in these deep wells typically exceed 300 feet.

Sediments deposited between the various basalt flows are part of the Ellensburg formation. Where sediments interbedded between basalt flows are coarse grained (sand/gravel), the interbeds may also transmit groundwater in usable quantity. Because the interbeds’ composition, thickness, and extent are highly variable, groundwater production from these units is correspondingly variable. In many localities, the productivity of the interbeds is often low because of limited lateral extent and changes in composition. Interbeds are present between many basalt flows in the study area, but only thick interbeds (greater than 30 feet or so) are depicted on the cross sections due to the vertical scale of the sections.

Geologic Structures

The major geologic structures (faults and folds) in the project area, taken from WDNR geologic mapping, are identified on both the geologic map (Figure 3) and the cross-sections (Figures 4 through 11). The Swale Creek subbasin is a structurally bound subbasin: bound to the north primarily by the southwest-northeast trending Horseshoe Bend anticline and to the south by the primarily east-west trending Columbia Hills anticline/fault system. Several other small southwest-northeast trending anticlines are also located along the northwest boundary of Swale Creek subbasin, near the confluence with the Little Klickitat River. The Swale Creek syncline forms a natural trough between the Horseshoe Bend and Columbia Hills anticlines in which Swale Creek flows (Brown 1979).

Superimposed upon the major east-west trending structures within Swale Creek subbasin are numerous northwest-southeast trending strike-slip faults likely created from a rotational component of the same north-south compression that resulted in the east-west trending folds (Reidel et al. 1989). Strike-slip faults involve horizontal displacement, not vertical displacement. The Laurel Fault is located within the High Prairie area along the southwest boundary of the Swale Creek subbasin, with the Warwick, Snipes Butte and Goldendale Faults located across the basin from west to east (Figure 3). The Columbia Hills are a complex structural feature involving a number of folds and thrust faults (a compressional feature in which older rocks are slid upward over younger rocks). A stacked pair of thrust faults is mapped in the Columbia Hills just south of the Swale Creek subbasin boundary.

In the subsurface, folds and faults may represent partial or complete barriers to groundwater flow, laterally confining flow within Swale Creek subbasin. Newcomb (1961 and 1969) theorized that tight anticlinal folding of basalt forms breccia (broken rock) and fault gouge between the individual flows near the axis of an anticline, which decreases the transmissivity of the basalt and impedes groundwater flow across the anticlinal crest. A hydrogeologist from Ecology’s Central Regional Office confirmed that, based on his regional experience, anticlines typically represent restrictions to lateral groundwater flow (John Kirk, personal communication, February 2005). Fault gouge may also decrease the transmissivity of the basalts in the vicinity of thrust and strike-slip faults.

Groundwater Conditions

Alluvium Aquifer

Of the 41 wells within the water level monitoring network, there are a total of seven wells completed within either the alluvium or a water-bearing interflow zone within the Wanapum basalt directly below the alluvium (Table 1 and Figure 2). Based on the well logs for these seven wells, the alluvium generally consists of brown clay, silt and shale with some gravel (Ron Crawford well log T03N/R15E-14) and sandstone (Bruce Cameron well log, T03N/R15E-23). The underlying basalt interflow zone is generally vesicular and fractured; because it occurs directly under the alluvium, the upper basalt interflow is considered to form a single hydrostratigraphic unit with the alluvium. During the June 2007 reconnaissance, depth to water measurements for the alluvium wells ranged between 5 and 62 feet below top of casing. In general, depths to water in the alluvium are shallowest nearest Swale Creek. Swale Creek within Swale Valley, between approximately Highway 97 and Warwick, is an expression of the water table in the alluvium aquifer. During spring runoff from the Columbia Hills and surrounding ridges, the creek directly recharges the alluvium.

The locations of the scattered alluvium wells relative to basalt wells do not allow reliable direct comparison of vertical gradients between the alluvium aquifer and the underlying basalt aquifer system. The pair of alluvium (alluvium/basalt) and basalt wells located closest to each other is in sections 10 and 14 of T03/R15E; both are part of the subbasin monitoring network (Figure 2). The June 2007 water levels from these wells (surveyed) suggest a subtle upward gradient; however, the head difference is less than 2 feet and occurs in two wells about ¾ mile apart (Figure 3). In general, it is expected that there is a downward gradient particularly in the early part of the year, and therefore recharge, from the alluvium aquifer into the deeper basalt aquifer.

There are an insufficient number for alluvium wells with water level data to document groundwater flow directions in the alluvium aquifer with confidence. However, the available data indicate that groundwater in the alluvium flows generally down-basin toward the west. Alluvium groundwater presumably discharges into the creek until the time of year that the water table drops below the creek bottom. Because the water table is shallowest on the west end of the basin, we expect this area would dry up last. This is consistent with observations of ponded water in the western end of the valley near Warwick, late into year.

The Mattson well (T03N/R14E-25), located next to Swale Creek immediately east of the Warwick Fault, does not have a well log but is reportedly an 80-foot deep basalt well based on information from the long-term USGS/Ecology water level conducted in it since 1983. Based on the hydrostratigraphic interpretation in that area (see Figure 4), an 80-foot depth puts it approximately to the bottom of the alluvium; therefore, we infer it is completed across the alluvium and first basalt interflow underlying it – like many of the wells in the valley. Water levels in this well have consistently been 20 feet or more below grade over the more than 20-year period of monitoring (long-term trends discussed below). The marshy conditions around Swale Creek near Warwick indicates the water table is near groundwater surface in this area. Therefore, 20-foot water level in this deeper well may be indicative of a downward gradient within the alluvium aquifer.

The hydrologic interaction between the alluvium aquifer and Swale Creek near Warwick remains an uncertainty that warrants additional investigation. It is necessary to clearly understand how the magnitude and timing of discharge from the alluvium aquifer influences baseflow to Swale Creek, and how seasonal pumping of the deeper basalt aquifer affects the alluvium aquifer, when assessing potential impairment from permitting additional groundwater withdrawals in the Swale Valley. The PAC is therefore applying for Ecology funding to install a dedicated alluvium aquifer monitoring well near Warwick as well as streamflow gages in Swale Creek.

Basalt Aquifer

Figure 12 presents a groundwater elevation contour map for the basalt aquifer system, compiled using water level data from both the well log/DEM data and from the June 2007 meaurements. The groundwater flow map was initially created using only well log/DEM elevations, and was updated with the June 2007 surveyed water level data (Table 1). Based on the comparison of surveyed and non-surveyed water level data, the well log-derived water level data are considered suitably accurate for this basin-scale assessment, as discussed above (Table 2).

The well log water levels have been collected over decades of time, and multiple seasons of the year (irrigation and non-irrigation). Because of annual and seasonal changes in groundwater levels, and errors associated with well locations and DEM elevations, surveyed wells measured during the June 2007 field reconnaissance trip were used to verify and supplement the historical data by gathering a basin-wide “snapshot” of groundwater levels over a time period of four days.

The resulting groundwater elevation contour map, containing well log and surveyed water level elevation data, represents an aggregate interpretation of the basalt aquifer groundwater data that are currently available for the subbasin. Due to the disparity in accuracy between the well log water levels and surveyed water levels, and the fact that the water levels are from wells spanning one or more vertically distinct water bearing zones within the basalt, the interpreted groundwater elevation contours may be inconsistent with water level measurements in individual wells, but are considered representative of the (Wanapum) basalt aquifer groundwater flow system on the subbasin scale. Despite the possible error sources in producing the groundwater elevation contour map, it represents the most detailed evaluation to date of the basalt aquifer system groundwater flow system in Swale Creek subbasin. Establishment of the water level monitoring network also allows for future monitoring to document seasonal or longer-term changes in the flow system. These data augment the City of Goldendale’s water level monitoring program in Swale Valley that was initiated in 2001 and includes twice annual (pre-irrigation and post-irrigation season) water level monitoring in select alluvium and basalt wells. These data are discussed under the long-term water level trends section below.

The groundwater elevation contour map (Figure 12) indicates that the Swale Creek subbasin is isolated by groundwater divides to the south, the west, and partially bound by a groundwater divide to the north.

- To the south, the Columbia Hills anticline system acts as a groundwater flow divide, although the exact location of the divide is unknown due to a lack of water level data near the ridge of the Columbia Hills. Data collected in other locations near the Columbia River generally indicate that the geologic folds/faults in the Columbia Hills are a flow barrier. Because the structural features are regionally continuous and deep-seated, we expect negligible hydraulic continuity between groundwater in Swale Creek subbasin and the Columbia River.

- In the High Prairie area forming the western boundary of Swale Creek subbasin, a groundwater divide is generally aligned with the Laurel Fault (T03N/R13E; Figure 12). The Laurel Fault, as with other faults in the Swale Creek area, is topographically expressed as an anticline (Brown 1979). Groundwater east of the divide flows toward Swale Canyon; that to the west flows toward the Klickitat River. The large differences in groundwater elevations observed in the High Prairie wells reflect differences in water-bearing zones tapped by the different wells (see cross section H-H’; Figure 11). There is a strong downward gradient in this area, indicative of a groundwater recharge area.

- Along the northern boundary of the Swale Creek subbasin, the basin is partially bound by a groundwater divide formed by the Horseshoe Bend Anticline. The groundwater divide is most pronounced immediately east of the Warwick Fault, becoming gradually less pronounced toward the east, and becoming indiscernible near the Snipes Butte Fault.

The combined well log and surveyed water level data confirm that the Warwick Fault significantly impedes westerly groundwater flow from Swale Valley into Swale Creek Canyon, where the fault is east of the canyon. The eastern portion of the groundwater mound formed east of the Warwick Fault was partially mapped by Luzier (1969), but was not fully defined in the vicinity of the Warwick Fault. Based on regional assessment of geologic structures in the basalts, Newcomb (1969) concluded that the Warwick Fault forms a structural closure to the Swale Creek valley and thus should create an impoundment of groundwater to the east of the fault. The current data set provides the most definitive documentation of groundwater mounding on the upgradient side of the Warwick Fault, and the groundwater flow patterns adjacent to it.

Groundwater elevation measurements in the vicinity of the Warwick Fault indicate that fault gouge or deformation/offset of the interflow zones has locally decreased the Wanapum basalt's transmissivity. Groundwater impoundment may also be associated with anticlinal folding along the fault, which is consistent with the other strike-slip faults in the area. Although the fault plane appears to act as a zone of decreased permeability, it is not impermeable across its full length; groundwater likely flows through the fault at a decreased rate relative to flow in interflow zones away from the fault.

This interpretation of the Warwick Fault as a flow barrier is also consistent with the lack of spring discharge observed on the eastern side of Swale Creek Canyon during field visits completed in April and September 2003 as part of the WRIA 30 multipurpose water storage screening assessment (Aspect Consulting 2003a and 2003b). In addition, the Yakama Nation's 100-foot deep Grande Ronde well near Wahkiacus, just east (upgradient) of the Warwick Fault, is flowing artesian with a reported flow of 700 gpm and a shut-in pressure of 10 psi. The presence of considerable excess pressure upgradient of the fault is consistent with groundwater impoundment by the fault.

Groundwater impounded east of the Warwick Fault and on the north side of Horseshoe Bend Anticline divide discharges in a northern direction into the Little Klickitat subbasin and the lower portion of Swale Creek canyon (Figure 13). There are springs originating from the basalt in the lower portions of Swale Creek canyon, and they may sustain isolated pools throughout the year. These springs are likely fed by impounded groundwater flowing north from the Warwick Fault; however, they do not provide enough flow to sustain baseflow in the lower canyon year-round.

In contrast to the Warwick Fault, the Snipes Butte Fault to the east does not appear to restrict groundwater flow. The available water level data in the vicinity of the fault do not indicate a head loss across the fault that would indicate it restricts groundwater flow. The minimal surface expression and displacement of this fault may suggest that fracturing/deformation and fault gouge is less developed on this fault compared to the Warwick Fault. Near the Snipe Butte Fault, groundwater in basalt aquifer under the Swale Valley appears to be discharging to the north across the Horseshoe Bend Anticline and into the Little Klickitat subbasin; however, there are few data to infer whether a subtle groundwater divide may in fact extend that far east.

Groundwater from the High Prairie area west of Swale Creek canyon discharges into the Swale Creek subbasin. The High Prairie area is located near the western boundary of the Swale Creek subbasin, where the Laurel Fault forms an anticlinal groundwater divide. East of the groundwater divide, basalt head levels indicate easterly flow as well as a downward gradient between the interflow zones of the Wanapum and Grand Ronde basalts (Figure 11). Field observations (Aspect Consulting, 2003a and 2003b) confirm surface water drainage (<0.5 cfs) entering Swale Canyon from Stacker Canyon and the drainage near the intersection of Centerville Highway and Schilling Road (T03N/R14E-19). Where the Warwick Fault separates High Prairie from Swale Canyon in its lower reaches, it likely restricts flow from High Prairie into the canyon, such that flow may be diverted toward the mainstem Klickitat River to the northwest.

Groundwater supply in the High Prairie area appears to be sourced from the Wanapum and Grand Ronde basalts (Figure 11). Wells completed in a shallow interflow zone of the Wanapum basalt are typically less than 400 feet deep, with shallow static water levels (~100 feet). Wells completed into the Grande Ronde basalt range in depth from 700 to over 1000 feet, with static water level depths commonly greater than 400 feet. The shallow Wanapum basalt interflow zones are not laterally consistent in terms of available groundwater, causing residents to rely on deep wells completed in the Grand Ronde basalt.

Because a single basalt formation (e.g., Wanapum basalt) is comprised of multiple individual basalt flows, it can encompass multiple vertical zones in terms of groundwater occurrence – a layered sequence of aquifer zones within the interflows separated by flow interiors serving as aquitards. Vertical hydraulic gradients can be evaluated between interflow zones when nearby wells are open to different interflow zones in the subsurface. Where sufficient water level data are available to assess vertical gradients within the basalts, the vertical gradient is downwards throughout the Swale Creek and Little Klickitat subbasins. For example, downward vertical gradients can be observed between the alluvium and the Wanapum basalt in Swale Creek valley (Figure 7); between the Simcoe Volcanics and the Wanapum basalt in the northern Little Klickitat subbasin (Figures 9 and 10); and between the Wanapum basalt and the Grand Ronde basalt in the High Prairie area of Swale Creek subbasin (Figure 11).

Aquifer Hydraulic Parameters

A summary of both regional and local aquifer hydraulic parameters, including lateral hydraulic conductivity, transmissivity and storativity are provided in Table 3. Hydraulic conductivity is a quantitative measure of an aquifer's ability to transmit water. Transmissivity is hydraulic conductivity multiplied by aquifer thickness and is a measure of how much water can move through the aquifer and thus the aquifer's productivity. Storativity is the product of specific storage and aquifer thickness, where specific storage is defined as the volume of water (cubic feet) that a 1 cubic foot volume of aquifer releases from storage when the water level drops 1 foot.

Regional hydraulic parameters for the Columbia Plateau aquifer system were estimated by the USGS as part of its Regional Aquifer System Analysis program (Vaccaro 1999).

Estimates of lateral hydraulic conductivity were initially based on specific capacity data from select well logs. Values for a well's specific capacity (pumping rate divided by drawdown) can be used to calculate aquifer transmissivity based on the empirical equation (Driscoll 1986):

$$T = 2000 \frac{Q}{s}$$

Where: T = Transmissivity (gpd/ft)

Q = Yield of well (gpm)

s = Drawdown in well (ft)

In addition, the USGS provided estimates of hydraulic conductivity, transmissivity, and storage coefficient values based on hydrogeologic modeling of the Columbia River basalt aquifer system throughout the Columbia Plateau (Vacarro 1999; Hansen et al. 1994; Whiteman et al. 1994).

More localized aquifer hydraulic parameters for the Wanapum basalt within Swale Creek and Little Klickitat River subbasins were estimated based on pumping tests of the City of Goldendale's Basse production wells (#1 and #2), and specific capacity data from several wells in the water level monitoring network (Table 3).

Pumping tests of the Basse wells indicate transmissivity values of between 700 and 2,700 ft^2/day (5,000 to 20,000 gpd/ft) and storativity values of between 9 $x10^{-5}$ and 2 $x10^{-4}$ for the Frenchman Springs member of the Wanapum (Aspect Consulting 2002). Specific capacity data from the Marvin Norris well log indicates a slightly higher transmissivity value (9,300 ft^2/day; 70,000 gpd/ft) apparently drawing from the Roza-Frenchman Springs interflow of the Wanapum toward the eastern end of Swale Valley (T03N/R16E-2). It is important to note that productivity of the Columbia River basalt aquifers can be highly variable due to the presence of geologic structures, and the nature and extent of interflow zones

The transmissivity of the alluvium within Swale Creek valley was estimated to be slightly lower than that of the Wanapum basalt, ranging between 450 and 630 ft^2/day with a geometric mean value of 530 ft^2/day (4,000 gpd/ft). These transmissivity estimates were based solely on specific capacity data from the Struck (T03N/R13E-28), Crawford (T03N/R15-14), and Agri Chem (T04N/R16-32) well logs (Table 3).

Long-Term Water Level Trends

As discussed in a previous section, six of the wells included in the water level monitoring network have been monitored by the City of Goldendale since 2001. The City also monitors groundwater levels in three additional wells not included in the current monitoring network due to lack of permission in June 2007. Of the nine wells monitored by the City, three wells are completed within alluvium and the remaining six are completed within basalt. Water level measurements are collected semiannually, prior to the start of irrigation season and following the completion of irrigation season. The long-term water level data (depth to water) are illustrated on Figure 13.

Alluvium Aquifer

Two of the alluvium wells included in the water level monitoring network have been monitored by the City of Goldendale since 2001 (Dave Mattson T03N/R14E-25 and Henry Miller T03N/R15E-20; Table 1). The USGS and Ecology have also periodically monitored the water level in the Dave Mattson well since 1983. In addition to the Mattson and Miller wells, the City has also monitored groundwater levels in the Old Basse #3 well (T03N/R16E-7), which is completed in both alluvium and basalt (Figure 13).

Based on the data in Figure 13, long-term groundwater levels are relatively stable within the alluvium aquifer. Groundwater levels in both the Miller and Old Basse #3 wells are currently at or above groundwater levels measured during 2002 and 2003. The Mattson well, which has been monitored since 1983, shows a relatively small decrease in groundwater levels (approximately 2 ft) since the start of monitoring; however, there has been very little to no decrease in groundwater levels in the Mattson well since 2001.

Basalt Aquifer

With the exception of the Magnuson well, and during periods of intermittent pumping of the City's Basse #1 and Basse #2 wells, all of the basalt aquifer wells monitored show little to no long-term decrease in groundwater levels during the period of monitoring (2001 - 2007). Short-term declines in water levels are observed in response to pumping; however, the water levels recover on an annual basis over the period of record. The fact that groundwater levels measured in June 2007 were comparable to those observed at the time of drilling in wells drilled over the past few decades further indicates little long-term change.

Although the Magnuson well shows a decrease in the groundwater level during the period of monitoring, the decrease is relatively small (less than 4 ft) and is not observed in nearby wells. Therefore, long-term groundwater levels within the basalt aquifers appear to be relatively stable.

The available data indicate that basalt aquifer storage is not being depleted and that current and recent historical pumpage in Swale Creek subbasin is sustainable on a regional scale.

Precipitation Trends

Based on the National Oceanic and Atmospheric Administration (NOAA) Weather Observation Station (Goldendale Station #453222), Goldendale has a mean annual precipitation of 16.70 inches over the station's period of record (1931 - 2007). The upper half of Figure 14 presents both the annual precipitation and the mean annual precipitation in Goldendale for the period of record. It is important to note that individual months with more than 5 days of missing data were not used for monthly or annual precipitation statistics.

In addition, a cumulative departure from the mean annual precipitation is presented in the lower half of Figure 14. Based on Figure 14, it is observed that, with the exception of 1996 (29.57 inches), annual precipitation has been at or below the mean annual precipitation since 1984. Below average precipitation could thus provide small scale declines in groundwater levels between 1984 and 2007, which provides one possible explanation for the decline in groundwater levels within the Magnuson well.

Interaction of Swale Creek Groundwater and Adjacent Surface Waters

Swale Creek

Swale Creek between approximately Highway 97 and Warwick is an expression of the water table in the alluvium aquifer. As such, it is intermittent (seasonal) and directly related to the groundwater level in the alluvium. In early spring, groundwater levels in the alluvium are generally high (shallow depth below the ground surface). Localized flooding of the low-lying areas around Swale Creek has occurred during particularly wet periods in the late winter and early spring. This portion of the creek is generally dry by late spring/early summer and for the balance of the year as groundwater levels in the alluvium decline.

The presence of the Warwick Fault on the western margin of Swale Creek Valley, which impedes westerly groundwater flow within the basalts, together with low summer surface water flows within Swale Creek Canyon (west of Warwick), indicate little baseflow contribution of groundwater from the basalts to the creek. The April 2003 field reconnaissance of the entire Swale Creek Canyon (prior to start of irrigation pumping in the region) confirmed very low quantities of spring discharge from the basalts (Aspect Consulting 2003a). None of these observed springs had significant discharge, which is consistent with their lack of mapping in Brown (1979). Anecdotal information from a 40-year resident (Mr. Tony Sareson) of the upper Swale Creek Canyon indicates that, as soon as surface runoff from the Columbia Hills stops, Swale Creek dries up every year that he has lived there, except at Warwick and in scattered pools throughout the canyon. Field observations from a September 2003 field reconnaissance of Swale Creek confirm this. At that time, there was approximately 0.25 cubic feet per second (cfs) entering Swale Creek from Stacker Canyon (presumably spring discharge from a higher elevation) and approximately 0.25 cfs present at the mouth of Swale Creek (Aspect Consulting 2003b). There was no evidence that stream flow had increased as a result of groundwater contribution from the basalt aquifers down the canyon, although there were isolated pools of standing water in the canyon’s lower reach that are likely sustained by groundwater discharge.

Based on the collective information, flows in Swale Creek are supported principally by runoff from numerous small tributaries draining the surrounding uplands downstream of Warwick (e.g., Columbia Hills and High Prairie). Groundwater discharge provides minimal baseflow to Swale Creek. Low-discharge springs and seeps that contribute to isolated pools in lower Swale Creek Canyon are likely sourced from groundwater impounded by the Warwick Fault.

Little Klickitat River

In general terms, groundwater in the western half of the Swale Creek subbasin is hydraulically isolated from the Little Klickitat River. Based on the existing groundwater flow interpretation, the majority of groundwater in Swale Creek subbasin that flows north from the Horseshoe Bend groundwater divide discharges to the lowest reaches of Swale Canyon. Groundwater south of the divide is not in hydraulic continuity with the Little Klickitat River.

In the eastern half of the Swale Creek subbasin, there is no apparent groundwater divide separating groundwater in the Swale Creek and Little Klickitat subbasins. Groundwater in southeastern portion of the Swale Creek subbasin appears to flow generally westward and does not affect the Little Klickitat River. The available data indicate that groundwater in the northeastern portion of the subbasin can flow toward and ultimately discharge to the Little Klickitat River.

Columbia River

The available regional information indicates that the geologic structures underlying the Columbia Hills are, in many places, an effective barrier to groundwater flow. The regionally extensive thrust fault/anticline system between Swale Creek subbasin's southern boundary and the Columbia River is likely an effective hydraulic barrier between the two. We conclude that groundwater in Swale Creek subbasin is not in hydraulic continuity with the Columbia River.

Estimated Water Use on Subbasin Scale

This section updates estimates of actual water use for the Swale Creek and Little Klickitat subbasins previously presented in the Level 1 watershed assessment (WPN and Aspect Consulting 2004). The water use information is an important element of the subbasin-scale water balances, which support the assessment of water availability for each subbasin.

As done in the Level 1 assessment, water use is estimated for the major categories of use including irrigation, residential, and non-residential (e.g., commercial/ industrial). The water use estimates are intended to represent average current conditions, and are based on available information and numerous assumptions. In fact, actual use may vary for any given time period due to factors such as temperature, precipitation, or cropping practices. The methods and results of estimating each of these water uses are presented below.

Estimated Irrigation Water Use

Annual irrigation water use (acre-feet/year) by subbasin is estimated by multiplying the irrigated area (acres) in that subbasin by a representative annual irrigation requirement, or water duty (feet/year). While it is a simple methodology, the challenge is obtaining, for each subbasin, an accurate accounting of the irrigated acreages by crop type and assigning a representative average water duty for each crop type.

Irrigation Acreage Estimates

After reviewing a number of potential options for obtaining irrigated acreage estimates for the two subbasins, we concluded that most reliable method was using acreage information provided by the U.S. Department of Agriculture Farm Service Agency (FSA) office in Goldendale. Irrigated areas are provided annually to the FSA by local farmers, and this is the same methodology used in the Level 1 assessment. Discussion with FSA indicates that most all irrigators, possibly excluding small “hobby farms”, are participating in the FSA programs and therefore they are reliable estimates for irrigated acreages. As of June 2007, FSA staff indicated that irrigated acreages for the two subbasins used in the Level 1 assessment (2002 data) are essentially unchanged since that time. Based on information from the FSA, the total irrigated areas in the Little Klickitat and Swale Creek subbasins are 2,860 and 1,674 acres, respectively.

According to FSA and Central Klickitat Conservation staff, alfalfa makes up the vast majority of irrigated cropland in both the Little Klickitat and Swale Creek subbasins, and it is a reasonable assumption on the subbasin scale to assume all irrigated acreage is in alfalfa.

A water duty of 3.4 acre-feet/acre (40.8 inch/year) was assumed for all irrigated acres, which is the alfalfa water duty used for all irrigation water rights in the 1980s adjudication of surface water rights for the Little Klickitat River Basin.

Irrigation Water Use Estimates

Using the acreage and water duty described above, annual irrigation water use (acre-feet/year) is estimated by multiplying the irrigated area (acres) by the annual water duty (feet/year). By this analysis, we estimate that nearly 9,720 acre-feet/year of water is used for irrigation in the Little Klickitat subbasin and 5,690 acre-feet/year in the Swale Creek subbasin (Table 4). Estimated consumptive use versus return flow components of this use is discussed below.

Estimated Public Water System Water Use

Current information on the public water systems (PWS) located in WRIA 30 was compiled from the state Department of Health (DOH) PWS database, and divided into subbasins based on the location of each PWS water source. PWS are classified by size as either Group A or Group B systems. A Group A PWS serves 15 or more residential connections, or 25 or more people per day for 60 or more days per year. A Group B PWS serves 2 to 14 residential connections or less than 25 persons per day. From the DOH database, 4 Group A and 31 Group B PWS were identified in the Little Klickitat subbasin. There is one Group A PWS and three Group B PWS in the Swale Creek subbasin. Table 5 lists information for all the PWS in each subbasin as obtained from the DOH database.

The City of Goldendale operates the largest PWS in the WRIA, serving 3,760 people in the Little Klickitat subbasin. To support the water budget analysis for each subbasin, the City’s PWS is listed under both the Swale Creek and Little Klickitat subbasins in Table 5. A portion of the City’s water supply is withdrawn from the Basse wellfield located in the Swale Creek subbasin, even though all of the water is used in the Little Klickitat subbasin. Using 2006 data, 100 acre-feet of the City’s 1,783 acre-feet production was pumped from the Basse wellfield. All of this water is imported for use in the Little Klickitat subbasin; therefore there is not a population served or number of connections listed for the City of Goldendale PWS in the Swale Creek subbasin.

In the DOH database, PWS water use includes numbers of connections for both residential (domestic) and non-residential (e.g., commercial and industrial) purposes. Water use estimated for residential and non-residential use categories is discussed in the following subsections.

PWS-Supplied Residential Usage

The total PWS-supplied residential water use is approximately 593 and 32 acre-feet/year from the Little Klickitat and Swale Creek subbasins, respectively (Table 5). The majority of this water use (535 and 30 acre-feet/year from each subbasin) is supplied by the City of Goldendale PWS. Again, the City's withdrawals from the Swale subbasin are not used there, but, for the purposes of the water budgets, the withdrawal from Swale subbasin and associated return flows in Little Klickitat subbasin are tracked.

Numbers of connections for the City of Goldendale PWS was obtained from the DOH and confirmed by officials at the City. City officials indicated that the DOH numbers were current, but the City is experiencing significant growth that will increase the number of residential connections served in the near future.

Water usage data from the City's three water sources indicate a total production volume of 1,783 acre-feet of water in 2006. Approximately 30% (565 acre-feet/year) of the total production is estimated to be used for residential purposes. This use value was calculated based on population served and a residential (domestic) per capita water use of approximately 127 gallons per person per day (termed gallons per capita day; gpcd) determined from Klickitat Public Utility District (PUD) gpcd statistics from multiple PWS.

As discussed above, 100 acre-feet of the total production is withdrawn from the Swale Creek subbasin, therefore 30% (30 acre-feet/year) is attributed to residential use there (Table 5).

Two other PWS in the Little Klickitat subbasin currently serve more than twenty residents. The Ponderosa Park Water System and the Rimrock Water Association are both managed by the Klickitat PUD. Recent water use statistics were obtained from the Klickitat PUD for the Ponderosa PWS and the Rimrock PWS. The water systems produce approximately 25 and 9.6 acre-feet of water per year for residential purposes (Table 5), for an average of 127 gpcd.

The remaining population (179 residents) served by PWS in the subbasins was assumed to use the same average of 127 gpcd. Residential water use for each PWS was calculated by multiplying the number of residents served by 127 gpcd, and converting to an annual volume in acre-feet/year.

PWS-Supplied Non-Residential Usage

The total PWS-supplied non-residential water use is estimated to be approximately 1,236 and 72 acre-feet/year from the Little Klickitat and Swale Creek subbasins, respectively (Table 5). The majority of this water use (1,148 and 70 acre-feet/year from each subbasin) is supplied by the City of Goldendale PWS.

The DOH PWS database reports the number of residential and total connections. The difference between the total number of connections and residential connections was assumed to be the number of non-residential connections. Non-residential use water estimates tend to be more uncertain than residential use estimates since there can be far greater variability in non-residential use per non-residential connection (e.g., a spigot at a public park vs. a large industrial facility). Based on the PWS information, there are 318 non-residential connections in the Little Klickitat subbasin and two in the Swale Creek subbasin. Of those in the Little Klickitat subbasin, 240 are served by the City of Goldendale PWS.

Information on the total non-residential water use by the City of Goldendale PWS was calculated as the difference between the total volume of water produced by the system (1,783 acre-feet/year) as reported by the City, and the calculated residential water use described above. Approximately 1,218 acre-feet/year of water is produced by the City's PWS for non-residential use. Of that volume, 70 acre-feet/year was assumed to be produced from the Basse well field in the Swale Creek subbasin. The largest single non-residential water consumer from the City's PWS is the Goldendale Energy power plant operated by Puget Sounds Energy. Based on information from the City, GEI accounts for 580 acre-feet/year of non-residential use from the City's PWS.

Excluding the City of Goldendale, there are two PWS in the Little Klickitat subbasin serving more than two non-residential connections. Both of the PWS were parks so an estimate of 1.1 acre-feet/year for each non-residential connection (averaged for a year-round water use) was applied to each park. This per connection estimate was based on 2006 water use statistics from two nearby parks, Maryhill and Columbia Hills State Park, located in the Columbia Tributaries subbasin, as reported by a Washington State Parks representative.

In addition to the PWS serving more than two connections, the DOH database was queried for Group A PWS that reportedly only served one non-residential connection. The assumption in this case was that these systems are using a relatively large amount of water in order to be classified as a Group A system with only one connection. There was one such PWS in the Little Klickitat subbasin. The Goldendale Observatory State Park was the only one of these PWS. Annual water use for this PWS was estimated at 1.1 acre-feet/year (Table 5).

The methodologies outlined above provided water use estimates for 309 of the 320 non-residential PWS connections in WRIA 31. Lacking other data, water usage for the 11 remaining non-residential connections was estimated using the water use per non-residential connection that was calculated from the state park data. This approach yields 12.1 acre-feet/year for those 11 connections. Although it is a highly uncertain assumption, the non-residential water use represented by these connections is expected to be a small percentage of estimated total water use in either subbasin.

Estimated Non-Public Water System Water Use

Non-PWS water use includes water supplied by single-family domestic (permit-exempt) wells for residential use (self-supplied) and water for non-residential use that is not from a PWS. Water use estimated from each group is discussed in the following subsections.

Self-Supplied Residential Usage

The self-supplied residential population for each subbasin was estimated by projecting the self-supplied population in 2000 to 2006 using an annual population growth rate. The self-supplied population in 2000 for each subbasin was determined for the WRIA 30 Level 1 assessment (WPN and Aspect Consulting 2004). Based on the state Office of Financial Management's projected growth in unincorporated Klickitat County from 2000 to 2006 (0.8% per year), we estimate 2,795 and 110 self-supplied residents in the Little Klickitat and Swale Creek subbasins, respectively.

Annual water use estimates for the self-supplied population were calculated assuming an average consumption of 127 gpcd and converting that volume of water into acre-feet/year for a total of 414 acre-feet/year (Table 6).

While 414 acre-feet/year is the best estimate of self-supplied water use based on available information, a maximum self-supplied water use can also be estimated by assuming that each household of the self-supplied population fully uses the 5,000 gpd volume of water allowed without a water right from the state (exempt well). To estimate this water use, the self-supplied population was converted to a number of households, and each household was assumed to use 5,000 gpd.

It was assumed that each household contains an average of 2.24 persons based on the number of residents per residential connection served by PWS in the Little Klickitat and Swale Creek subbasins. Based on this assumption, the Little Klickitat and Swale Creek subbasin's self-supplied persons occupy 1,248 and 49 households, respectively. Assuming each household uses 5,000 gpd every day, year-round, these self-supplied households could use up to approximately 6,978 and 275 acre-feet/year in the Little Klickitat and Swale Creek subbasins, respectively.

However, this estimated annual volume equates to a per capita water use of over 2,200 gpd, which is an order of magnitude above estimates typically used in water use planning anywhere in the state. This maximum value could be considered as a 'worst-case scenario' in watershed planning, but is considered a far less realistic use estimate than the 414 acre-feet/year estimate presented in Table 6.

Non-PWS Non-Residential Usage

There are no known large non-PWS supplied non-residential water users in either the Little Klickitat or Swale Creek subbasins. One category of minor non-residential water use in is stock watering from exempt wells and developed springs. Groundwater withdrawal up to 5,000 gpd for stock watering is exempt from water right permitting, thus there is no readily available information to estimate such usage in the WRIA. Regardless, stock watering is considered to be a small component of total water use in the subbasins, especially relative to irrigation.

Estimated Water Use by Subbasin

Table 7 presents the water use estimates for the Little Klickitat and Swale Creek subbasins for each water use category (irrigation, residential, and non-residential). Based on the results of this assessment, a total of roughly 11,947 and 5,810 acre-feet of water is used annually in the Little Klickitat and Swale Creek subbasins. Irrigation represents the overwhelming majority of the all water use in both basins (81% in the Little Klickitat, 98% in the Swale Creek subbasin). Approximately twice as much water is used in the Little Klickitat as is used in the Swale Creek subbasin. However, on a use-per-acre basis, there is slightly higher usage in Swale Creek subbasin (0.067 and 0.072 acre-feet/year per acre in Little Klickitat and Swale Creek subbasins, respectively).

Because irrigation represents a vast majority of the total water use in each subbasin, the simplifying assumptions used when estimating residential and non-residential water use from PWS and non-PWS sources have little impact on the accuracy of the water use estimates at the subbasin-scale.

Water use includes both consumptive use and non-consumptive return flow. Return flow represents water that is used but not consumed, and thus is returned to the watershed. Ultimately, return flow is partitioned into streamflow via runoff and groundwater recharge via deep percolation. The estimation of consumptive and non-consumptive water uses is described below.

Consumptive Water Use

The portion of water use that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment is considered consumptive. Consumptive water use from each subbasin was determined based on each specific water use: irrigation, residential and non-residential.

We assume that 90% of the irrigation water used is consumed, whether transpired by crops or lost to evaporation before the crops can use it (Table 7). Irrigation is conducted in these subbasins primarily using a combination of center pivot and wheel lines. A consumptive use percentage of 90% is the average for center pivots with impact heads (95%) and wheel lines (85%), as listed in Ecology’s Guidance 1210 for calculating annual consumptive quantity. The remaining 10% of irrigation use is therefore assumed to be non-consumptive return flow.

The total consumptive irrigation water use is 8,750 and 5,120 acre-feet/year for the Little Klickitat and Swale Creek subbasins, respectively.

The remaining non-irrigation water use in each subbasin is divided between residential and non-residential use from both PWS sources and self-supplied sources. 2006 data from the City of Goldendale indicate current water system distribution leakage (up to 45 percent of production) and wastewater treatment plant discharge (42 percent of production) make up 87% of the total annual volume of water produced by the City. The remaining 13 percent of production is estimated as the average consumptive use for the system. This estimate agrees with the typical domestic use in the State of Washington of 12% consumptive (Solley, 1995).

A total consumptive demand of 13% was applied to both residential and non-residential uses from the City of Goldendale PWS. As discussed above, approximately 100 acre-feet/year is withdrawn from the Basse well field in the Swale Creek subbasin and delivered to the Little Klickitat subbasin via the City of Goldendale PWS. This cross-basin transfer is accounted for in Table 7 by assuming the entire 100 acre-feet/year (30 acre-feet residential and 70 acre-feet non-residential) is consumptive from the Swale Creek subbasin, since there is no return flow from it to the subbasin. All other PWS-supplied residential water use and self-supplied residential water use was considered 12% consumptive based on typical domestic water use numbers for the State of Washington (Solley 1995). All other non-residential water use was considered 13% consumptive. The resultant consumptive residential and non-residential water use volumes are presented in Table 7.

Non-Consumptive Return Flow

The difference between the amount of water delivered and the amount of water consumed is returned to the watershed as either groundwater recharge or streamflow. We assumed the 10% irrigation return flow was partitioned 2/3 to 1/3 between groundwater recharge and streamflow, respectively. The City of Goldendale estimates approximately 45% of their water production (802 acre-feet/year) is currently lost as leakage in their distribution system; a program to actively reduce leakage to a 10% target is in planning. This annual volume of water is applied to groundwater recharge in the Little Klickitat subbasin. Wastewater treatment plant discharge data from the City indicates 752 acre-feet of treated water (42% of production) was discharged to the Little Klickitat River in 2006. This annual volume was applied to return flow as streamflow. All return flow volumes from the City's PWS are applied to the Little Klickitat subbasin, including water pumped from the Basse wellfield in the Swale Creek subbasin.

The City of Goldendale operates the only wastewater treatment plant discharging to surface water in either the Little Klickitat or Swale Creek subbasins. We assumed all other PWS-supplied and self-supplied water users treat their effluent via septic tanks and drain fields. Therefore all other non-consumptive return flow was considered groundwater recharge.

The resultant estimated non-consumptive return flow volumes are presented in Table 7.

Monthly Distribution of Water Use

Because the subbasins' largest water use occurs during the growing season, it is useful to evaluate the monthly distribution of the estimated annual water use.

To do so, we partitioned the estimated annual irrigation water use into monthly uses assuming the monthly net irrigation requirement as a percentage of annual irrigation requirement, as listed for alfalfa in Goldendale in the Washington Irrigation Guide (WIG). This apportioned the annual irrigation use into monthly uses consistent with the WIG. For residential and non-residential uses, we assumed monthly water use is proportional to maximum monthly temperature, as measured at Goldendale.

By this methodology, the estimated monthly water use in each subbasin, for each use category, is presented in Table 8 and shown graphically on Figure 15. The figure illustrates both the dominance of irrigation use in the subbasins, and the peaking use in June through August. Water uses in all three categories peak in the summer, but the relative effects of peak residential and non-residential uses are small on the subbasin scale.

Subbasin-Scale Water Balances

One of the important objectives in this assessment is to develop supporting information to help address the question of the physical and thus legal availability of water in the subbasins. Although Ecology determines the legal availability of water for appropriation, this assessment provides the best available information regarding the physical availability of water on the subbasin scale. Understanding water availability can start with calculating a water balance for a subbasin.

Water Balance Methodology

The conventional water balance approach on the subbasin scale accounts for partitioning of precipitation into evapotranspiration (ET: water evaporated from soil, rock, or open water plus water consumed [transpired] by growing plants), runoff becoming streamflow, and groundwater recharge on an annual basis. To assess the current water balance of each subbasin, estimated volumes of consumptive water use and return flow (calculated in the previous section) were added to the water balance. The current water balance is similar to that applied in the Level 1 assessment (WPN and Aspect Consulting 2004), but incorporates additional information and the updated estimates of water use (both consumptive and return flow).

In the current condition scenario, the water balance approach for a subbasin accounts for partitioning of precipitation into groundwater recharge, runoff becoming streamflow evapotranspiration, consumptive water use and return flow on an annual basis expressed by:

Precipitation = Recharge + Streamflow + Evapotranspiration + Consumptive Water Use - Return Flow (non-consumptive use)

Each component of the water balance is described below.

Precipitation

Mean annual precipitation in the Little Klickitat and Swale Creek subbasins is estimated at 26 inches and 23 inches per year, respectively, or approximately 388,000 and 154,000 acre-feet/year (Table 9). Precipitation for each subbasin was compiled from the Parameter-Elevation Regressions on Independent Slopes Model (PRISM; Daly and others 1994) as presented in the Level 1 assessment (WPN and Aspect Consulting 2004).

Groundwater Recharge

Based on recharge estimates from the USGS, mean annual groundwater recharge in the Little Klickitat and Swale Creek subbasins is estimated at approximately 109,000 and 26,000 acre-feet/year, respectively (Table 9).

The USGS (Bauer and Vaccaro 1990) used a detailed numerical model (Deep Percolation Model) to calculate the water balance for 53 basins on the Columbia Plateau, for the purpose of estimating recharge to the basalt aquifer system. Although the USGS didn’t specifically model the Little Klickitat or Swale Creek basins, they did project recharge estimates into these basins based on nearby modeled evapotranspiration and streamflow values and a regression relationship between precipitation and those values from the basins that were modeled. The estimates of average annual recharge for each subbasin were calculated as a part of the Level 1 assessment based on the USGS recharge maps and are used here as the best available estimates.

Streamflow

The annual streamflow in the Little Klickitat subbasin was estimated from continuous record streamflow data collected by the USGS and Ecology at the mouth of the Little Klickitat River (Little Klickitat River near Wahkiaus). The USGS operated the station from 1944 to 1981, and Ecology has operated it since 2005. The mean annual flow (average of mean daily flows) at the station is 166 cfs for the period of record. This discharge volume was converted to 120,323 acre-feet/year and added to the water balance for the Little Klickitat subbasin (Table 9).

The annual streamflow in the Swale Creek subbasin was estimated from continuous streamflow data collected recently by the Yakama Nation at the mouth of Swale Creek. Gaging data were provided by Yakama Nation personnel (Will Conley, personal communication, June 25, 2007) from the station for the period of April 18, 2006 to May 9, 2007. The mean annual flow (average of mean daily flows) for that period was 46 cfs. Based on the streamflow record from the Little Klickitat gage, that period of record had slightly (4%) greater streamflow than average. To account for this, we reduced the measured 46 cfs average flow by 4% to 44 cfs in the water balance (Table 9). This discharge volume was converted to an annual volume of 31,855 acre-feet/year and added to the water balance for the Swale Creek subbasin (Table 9).

Evapotranspiration

There were no reliable subbasin-scale ET estimates that could be used in the water balance equations for either the Little Klickitat or Swale Creek subbasin. However, since it was the only undetermined value in the water balance for either basin, we solved the water balance equation (net balance equal to zero) to estimate ET for each subbasin. The resultant ET estimates were 153,369 and 93,120 acre-feet/year for the Little Klickitat and Swale Creek subbasins, respectively. These values represent ET for the non-irrigated vegetation/soil cover, not irrigated acreage which is accounted for in the irrigation water use values. Therefore, irrigated acres in the subbasin were subtracted from the total subbasin area before converting ET value into inches/year. The resultant ET values for the two subbasins were 10.4 and 14.2 inches/year, respectively (Table 9).

Water Use

Water use estimates, including estimated consumptive versus non-consumptive use, are described above. The proportion of actual water use supplied by surface water versus groundwater sources is not documented. Therefore, we assume for the water balance that the proportion of annual surface water use versus groundwater use is the same as the proportion of annual surface water versus groundwater rights (certificates plus permits) appropriated in each subbasin.

Water Balance Results

Table 9 provides the estimated average annual water quantities (acre-feet/year) associated with each water balance term for each subbasin.

Of interest for assessment of water availability on the subbasin scale is the comparison of total consumptive surface water use relative to total streamflow, and total consumptive groundwater use relative to groundwater recharge, and comparison of estimated actual water use compared to appropriated water rights. Table 10 summarizes that information.

Little Klickitat Subbasin

Based on the distribution of annual water rights, the proportion of surface water use to groundwater use in the Little Klickitat subbasin is approximately 44% and 56%, respectively, of total use. Based on the water balance, the estimated total consumptive use of surface water in the subbasin is 3% of annual streamflow. This consumptive use from the surface water system is partly offset by return flow (from total water use) reaching surface waters.

Based on the water balance, the estimated total consumptive use of groundwater in the subbasin is 5% of annual groundwater recharge. This consumptive use from the groundwater system is partly offset by return flow (from total water use) providing additional recharge not included in the recharge term.

The estimated total annual volume of water use in the Little Klickitat subbasin is approximately 35% of the total annual volume of water appropriated in the subbasin (Table 10).

Swale Creek Subbasin

There is very little surface water use in this subbasin consistent with the lack of reliable surface water flow year-round and lack of water storage to capture and make use of the higher winter flows. Based on the water balance, the estimated total consumptive use of surface water in the Swale Creek subbasin is 0.04% of annual streamflow.

Water use in the subbasin is nearly all supplied by groundwater sources. Based on the water balance, the estimated total consumptive use of surface water in the Swale Creek subbasin is 21% of annual groundwater recharge.

The estimated total annual volume of water use in the Swale Creek subbasin is approximately 50% of the total annual volume of water appropriated in the subbasin (Table 10).

Uncertainties in Subbasin-Scale Water Balances

The subbasin-scale water balance estimates do not accurately reflect hydrologic conditions at all locations within a subbasin, or during all years, or all seasons. They are meant to represent the generalized long-term average hydrologic conditions of each subbasin. Quantifying the level of uncertainty in the water balance in terms of +/- percent is difficult at best. However, the sources of uncertainty in calculating the annual water balance for each subbasin can be discussed in terms of the uncertainties associated with each water balance term.

As the primary input to each water balance, precipitation is the single greatest factor in determining the water balance. Fortunately, long-term precipitation monitoring and the advancement of precipitation models (e.g. PRISM) has produced a reliable record of precipitation that can be appropriately applied to the subbasin-scale water balance. However, the precipitation value represents average conditions in the past, and may not necessarily predict average conditions in the future. Year-to-year rainfall fluctuation, seasonal droughts, and the potential for long-term climate change are several factors that add uncertainty to the water balance as a tool to predict the amount of water available for future appropriation.

Groundwater recharge as modeled by the USGS also introduces some uncertainty into the subbasin-scale water balances. It was a very large scale regional model and, as discussed above, the USGS didn't specifically model the Little Klickitat or Swale Creek subbasins; rather the values were determined based on statistical relationships and precipitation in the subject subbasins. Additionally, the recharge estimates were based on a different period of record (1956-1977) than the PRISM precipitation data used in the water balance (1961-1990).

Streamflow records for the Little Klickitat subbasin represent continuous discharge over a relatively long period of time. The average annual streamflow term in the water balance for the Little Klickitat subbasin is considered representative of past watershed conditions. However, the period of record for streamflow (1944-1981, and 2005 to present) does not correspond with the period of record for either the precipitation or recharge data. The period of record for streamflow data in Swale Creek is limited to essentially the past year. An attempt was made to correlate the average streamflow from last year to an average historical value by analyzing the Little Klickitat data. Nonetheless, using only a single year of streamflow data in Swale Creek introduces some uncertainty into that term of the water balance for that subbasin.

Since ET was calculated from each water balance equation, no additional uncertainty is introduced into the water balance from attempting to estimate ET. However, uncertainties associates with the other terms are propagated into the resultant ET value for each subbasin.

Water use in each subbasin is dominated by irrigation as described above and illustrated on Figure 15. Uncertainties in the total irrigated acreage, annual average water duty, and the total consumptive versus non-consumptive water use add uncertainty to the total water use estimate for each subbasin. Based on information from the local FSA, we are confident that the number of irrigated acres and water duty are the best estimates of current conditions in each subbasin. Although the water duty is reasonable based on the crop assumption, it is likely conservatively high. Given the magnitude of irrigation water use in each subbasin, even small uncertainties in these values can influence the water use calculations.

Conclusions and Recommendations

The primary conclusions and recommendations from this assessment are as follows:

- A well monitoring network has been established that provides the opportunity, with continued landowner permission, to track future seasonal and/or long-term changes in the groundwater flow system of the Swale Creek subbasin. With the monitoring network established and the local community generally aware, it may be possible to obtain permission from additional local well owners and thus provide expanded well coverage in specific areas.

- Data from drillers logs, coupled with well elevations from the USGS DEM, provide suitably accurate information for basin-scale hydrogeologic investigation.

- Data developed and interpreted for this study help confirm the groundwater flow regime for the Swale Creek subbasin. The collective information further confirms that the Warwick Fault restricts discharge of groundwater from Swale Valley into the Swale Canyon, except in the lowest reaches of the canyon where the fault is west of it. Even without the fault barrier limiting discharge into the canyon, groundwater provides insufficient baseflow to sustain flow in that portion of the creek, whether in late spring (prior to start of irrigation pumping in Swale Valley) or in September. The limited groundwater discharge does appear to sustain isolated pools in that area during the late season, as observed during field reconnaissance in September. The lack of groundwater discharge observed year-round (i.e., prior to onset of irrigation pumping) indicates that the limited groundwater contribution to baseflow in Swale Canyon is the natural hydrogeologic condition.

- There is hydraulic continuity between groundwater in Swale Valley and the lowermost reach of Swale Creek in Swale Canyon. However, groundwater pumping in Swale Valley appears to have little effect on flows in Swale Canyon.

- A remaining hydrologic data gap is the interaction between groundwater in the Swale Valley alluvium aquifer and Swale Creek surface water, particularly in the area of the Warwick Fault near where the alluvium pinches out. The magnitude and timing of seasonal water level decline, and the reduction in creek flow resulting from that decline, remains uncertain.

- To address that data gap, we recommend that a new dedicated shallow monitoring well be installed in the alluvium aquifer upgradient (east) of the Warwick Fault. We expect that the well would need to be no deeper than about 60 feet to allow year-round water level measurements. The well should be equipped with a downhole pressure transducer/data logger to allow continuous water level monitoring. The PAC has already applied for Ecology funding to install and equip such a well.

- There is negligible hydraulic continuity between groundwater in the western half of the Swale Creek subbasin and the Little Klickitat River, because of the presence of the Horseshoe Bend Anticline groundwater divide. Farther to the east, the groundwater divide between the subbasins is not documented. Groundwater in the northeastern portion of the Swale Creek subbasin appears to flow into the Little Klickitat subbasin and toward the Little Klickitat River.

- Due to the presence of regional geologic structures forming the Columbia Hills, groundwater in the Swale Creek subbasin is not in hydraulic continuity with the Columbia River.
- The total annual use of water is a fraction of the total water in each subbasin, so that additional water can be available for appropriation in each subbasin. However, potential for impairment to senior water users and surface water bodies (including the temperature-impaired segments of Swale Creek and Little Klickitat River) would need to be determined individually for each pending water right application.

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 30 Water Resource Planning & Advisory Committee 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 1 - Groundwater Level Monitoring Well Network

WRIA 30 Water Availability Study

Ecology Well Log Data											Contact Information			Well Reconnaissance Data: Survey Coordinates			Well Reconnaissance Data: Static Water Level Measurements				
Well Log ID	Well Log Name	T	R	S	Q	QQ	Completion Date	Dia (in)	Depth (ft)	Aquifer	Well Owner	Well Address	Source	Northing[1] (SPS 83; ft)	Easting[1] (SPS 83; ft)	Altitude[2] (ft MSL)	Date	Casing Stick-up (ft)	SWL (ft bTOC)	SWE[2] (ft MSL)	Comments
141250	JAY ANDERSON	3	13	3	SE	SE	4/15/87	6	745	Wanapum	Cliff Newport	275 Hartland Road	High Prairie	159389.4	1472760.9	2147.0	6/5/07	1.65	549.49	1597.50	
140432	GORDON WOLFF	3	13	3	NE	NW	11/12/86	6	76	Wanapum	Liza Carlson	347 Hartland Road	High Prairie	162902.9	1472929.6	2011.2	6/5/07	1.02	203.63	1807.54	Uncertain well log correlation
141715	JOHN BROWN	3	13	11	SW	NW	8/31/94	6	524	Wanapum	Gary Anderson	206 Hartland Road	High Prairie	155087.0	1474093.1	2037.4	6/5/07	1.66	115.1	1922.34	Uncertain well log correlation
139955	FRED HENSCHELL	3	13	14	NE	NE	10/16/92	6	500	Wanapum	Fred Henchell	950 High Prairie Road	High Prairie	152621.1	1478289.8	2181.2	6/5/07	0.81	435.43	1745.73	
377252	NEIL A SHUSTER	3	13	14	NE	SW	7/7/95	6	500	Wanapum	Neil Schuster	896 High Prairie Road	High Prairie	151451.4	1476350.7	2086.0	6/5/07	-	195.13	1890.86	
477832	NEIL SHUSTER	3	13	14	NE	SW	2/28/07	6	458	Wanapum	Neil Schuster	896 High Prairie Road	High Prairie	151661.4	1476308.2	2082.0	6/5/07	1.54	173.2	1908.82	
335153	THEODORE MCKERCHER	3	13	22	NW	NE	5/9/02	6	225	Wanapum	Theodore McKercher	779 Centerville Hwy	High Prairie	143235.9	1470655.1	1777.5	6/6/07	1.46	162.22	1615.26	
377254	JOHN GRIM	3	13	22	SW	SE	10/19/95	6	280	Wanapum	John Grim	781 Centerville Hwy	High Prairie	144550.2	1470944.8	1763.4	6/6/07	0.79	139.52	1623.84	Unstable water level
139217	DOUG TAYLOR	3	13	23	SW	NE	5/30/81	6	449	Wanapum	Doug Taylor	876 Centerville Hwy	High Prairie	145104.1	1475387.6	1808.1	6/5/07	1.05	75.32	1732.76	Measured using airline (questionable MP)
139404	EARL WILSON	3	13	27	SE	SW	10/27/93	6	310	Wanapum	Tom Doll	120 South Prairie Road	High Prairie	138228.3	1471376.8	1996.0	6/5/07	1.79	262.31	1733.72	
139337	E. H STRUCK	3	13	28	SW	NE	12/27/72	8	90	Alluvium and Wanapum	Cal Edwards	683 Struck Road	High Prairie	141586.1	1465563.3	1498.7	6/5/07	0.88	21.41	1477.26	Rising water level
143537	MYRIN BENTZ (01001)	3	13	28	NE	NW	9/7/94	6	220	Wanapum	Myrin Bentz	6 Oda Knight Road	High Prairie	143022.4	1466216.1	1622.7	6/5/07	2.38	141.16	1481.59	
142145	KEN CHANDLER	3	14	11	SW	SW	10/16/97	6	205	Wanapum	Richards	1195 Niva Rd.	Nitrate Study	153730.0	1505374.3	2012.7	6/7/07	0.59	69.88	1942.79	
149031	JOAN BROWN	3	14	11	NW	NW	11/14/98	6	440	Wanapum	Brown	392 Harms Road	Field Recon	158400.6	1504803.3	2053.2	6/7/07	0.87	206.92	1846.27	Rising water level
136750	ARNOLD HOIKKA	3	14	14	SE	SW	10/18/79	6	200	Wanapum	Juan Randall	905 Randall Road	Field Recon	149063.4	1509276.0	1719.7	6/7/07	0.54	7.25	1712.48	
354742	ROBERT EDWARDS	3	14	18	SW	SW	5/20/97	6	695	Wanapum	Bob Edwards	10 Meadowlark Lane	High Prairie	149041.9	1484973.1	2153.7	6/5/07	1.43	516.67	1636.99	
145052	RONALD DISCH	3	14	23	NW	NW	4/17/98	6	103	Wanapum	Ron and Deborah Disch	986 Randall Road	Field Recon	147652.3	1505602.8	1697.5	6/6/07	0.47	34.56	1662.92	
257441	BILL LANCASTER	3	14	23	NW	SW	7/13/00	6	262	Wanapum	William and Donna Lancaster	650 Harms Road	Field Recon	145770.2	1505131.1	1662.1	6/7/07	2.21	76.78	1585.28	Property sold on June 1st; need permission from new owner for
-	DAVE MATTSON	3	14	25	NW	NE	-	-	80	Alluvium and Wanapum	Dave Mattson	Centerville Road (Warwick)	Swale Creek	141882.6	1512560.9	1580.8	6/6/07	-	-	-	No ecology well log; obstructed at 22.8 ft btoc
257442	LONNIE MAGNUSON	3	14	29	NE	NE	8/7/00	6	353	Wanapum	Lonnie Magnusson	Centerville Road (W. of Harms)	Swale Creek	141946.6	1494168.8	1678.3	6/7/07	2.11	63.15	1615.17	Rising water level
138310	DALE BOWDISH	3	15	10	SW	SE	6/16/94	6	143	Wanapum	Dale Bowdish	2215 Centerville Hwy	Nitrate Study	153172.6	1532826.4	1610.6	6/6/07	1.76	36.92	1573.72	
314650	GOLDENDALE ENERGY INC	3	15	12	NE	SE	11/14/01	16	679	Wanapum	City of Goldendale	2472 Centerville Hwy	Swale Creek	155984.6	1546301.3	1621.4	6/8/07	1.5	60.97	1560.46	
314651	GOLDENDALE ENERGY INC	3	15	13	NE	NW	10/31/01	16	905	Wanapum	City of Goldendale	2472 Centerville Hwy	Swale Creek	152313.6	1545722.6	1595.9	6/8/07	1.625	31.4	1564.48	
144994	RON CRAWFORD	3	15	14	NW	NW	8/7/79	6	82	Alluvium and Wanapum	Terry	510 Dalles Mountain Rd.	Field Recon	152412.8	1536954.3	1605.5	6/6/07	-	33.65	1571.90	
140705	HENRY MILLER	3	15	20	NE	SE	-	6	54	Alluvium	Jim Miller	Garner Road (N. of Bridge)	Swale Creek	145871.4	1525996.3	1574.8	6/6/07	1.34	5.45	1569.31	
137418	BRUCE CAMERON	3	15	23	NE	SE	8/2/93	6	140	Alluvium and Wanapum	Bruce Cameron	645 Cameron Rd	Nitrate Study	145638.2	1541689.0	1634.7	6/6/07	1.5	56.61	1578.05	
138800	DENNIS JAEKEL	3	15	34	SW	NW	8/21/79	6	480	Wanapum	Dennis Jaekel	End of Jaekel Road	Field Recon	132776.8	1531588.3	1940.2	6/6/07	0.7	387.38	1552.81	
411866	MARVIN NORRIS	3	16	2	NE	NE	5/18/05	6	123	Wanapum	Marvin Norris	728 Hoctor Road	Field Recon	163199.1	1572954.6	1855.2	6/7/07	-	57.81	1797.44	Located across from 728 Hoctor Road in field
139455	ED HOCTOR	3	16	4	NW	SE	2/8/81	10	512	Wanapum	Roberta Hoctor	36 Hoctor Road	Field Recon	161914.2	1559334.0	1740.3	6/6/07	1.3	80.41	1659.89	
302764	LOWELL TURNER	4	14	31	SW	NE	10/12/00	6	506	Wanapum	Bruce Buchanan	440 Schilling Road	High Prairie	167675.2	1486274.0	1785.9	6/6/07	2.94	267.11	1518.74	
138094	CLIFFORD ECKHARDT	4	14	35	SW	SW	7/28/94	6	300	Wanapum	Erick and Mary Jean Risheim	280 Harms Road	Field Recon	164498.8	1505579.5	1914.5	6/6/07	1.83	135.22	1779.27	
191874	JESSIE CASSWELL	4	15	26	NE	SE	5/25/99	6	395	Wanapum	Stan and Josie Casswell	356 Largent Rd.	Field Recon	172446.7	1541300.9	1567.9	6/7/07	1.5	34.35	1533.57	Rising water level
302767	GARY BURGESS	4	15	29	SE	SW	12/11/00	6	240	Wanapum	Gary Burgess	Horseshoe Bend Rd.	Field Recon	169640.1	1524932.9	1720.3	6/7/07	1.5	138.87	1581.39	
417943	RAYMOND MANNING	4	15	29	SW	NW	7/25/05	6	500	Wanapum	Raymond Manning	Mustang Dr. & Morgan Ct.	Field Recon	171181.3	1521711.9	1689.3	6/7/07	2.29	294.9	1394.42	
-	REGAN EBERHART	4	15	32	NW	SE	2/3/07	6	416	Wanapum	Regan Eberhart	Appaloosa Court	Field Recon	167372.0	1522129.5	1801.8	6/7/07	3.27	177.87	1623.98	
303003	ROBERT & BONNIE BUTLER	4	16	31	SW	NW	8/26/00	6	103	Wanapum	Robert and Bonnie Butler	181 Van Hoy Road	Field Recon	163668.5	1548245.4	1662.2	6/6/07	1.17	22.28	1639.93	
136513	AGRI CHEM	4	16	32	SE	NE	5/25/82	6	67	Alluvium and Wanapum	JP Enderby	3517 S. Columbus Ave.	Field Recon	165643.7	1557437.9	1733.9	6/8/07	0.81	61.96	1671.91	
296593	MARVIN NORRIS	4	16	34	NE	SE	10/12/71	6	500	Wanapum	Karl Enyert	Clyde Story Road (S. of Gravel Pit)	Swale Creek	167237.9	1567894.2	1804.2	6/6/07	0.49	52.74	1751.50	
146522	WAYNE HOCTOR	4	17	29	NW	NW	4/4/91	6	108	Wanapum	Wayne Hoctor	138 Willis Road	Nitrate Study	171742.5	1584907.1	1999.1	6/7/07	0.58	63.53	1935.60	
146520	WAYNE HOCTOR	4	17	30	NE	NE	9/28/73	6	430	Wanapum	Wayne Hoctor	488 #4 Road	Nitrate Study	173572.1	1583929.0	1997.6	6/7/07	-	277.35	1720.21	Rising water level
139632	EMMETT HOCTON	4	17	32	SW	SE	4/29/70	8	228	Alluvium and Wanapum	Dennis Hoctor	250 Willis Rd.	Field Recon	165764.2	1585021.8	1914.5	6/7/07	-	59.37	1855.16	

Notes:

[1] Northing and Easting coordinates are in Washington South State Plane coordinate system (NAD 1983 datum)

[2] Elevation is in NAVD 1988 datum

Table 2 - Comparison of Well Log Data vs. Surveyed Data

WRIA 30 Water Availability Study

Well Location						Difference (feet) between Ecology Well Log Database and 2007 Survey Data			
T	R	S	Q	QQ	Well Address	Horizontal Location	Well Elevation	Depth to Groundwater	Calculated Groundwater Elevation
4	16	34	NE		Clyde Story Road	643	13	4	9
3	16	4	NW	SE	36 Hoctor Road	796	13	30	17
4	14	35	SW	SW	280 Harms Road	122	7	0	7
3	14	11	SW	SW	1195 Niva Road	243	8	12	20
3	14	11	NW	NW	392 Harms Road	819	13	15	2
3	14	23	NW	SW	650 Harms Road	486	11	14	25
3	15	12	NE	SE	2472 Centerville Hwy	524	1	1	0
					Average Difference	**519**	**9**	**11**	**12**

Table 3 - Hydraulic Parameter Estimates for Alluvium and Basalt Aquifers

WRIA 30 Water Availability Study

Combined Alluvium and Wanapum Basalt

Hydraulic Conductivity (ft/day)			Transmissivity (ft^2/day)			Storativity (Dimensionless)			Location	Model/Aquifer Test	Source
Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean			
-	-	-	-	-	631	-	-	-	T03N/R13E-28 E.H. Struck Well Log	Specific Capacity	Department of Ecology Well Log Database
-	-	-	-	-	536	-	-	-	T03N/R15E-14 Ron Crawford Well Log	Specific Capacity	Department of Ecology Well Log Database
-	-	-	-	-	447	-	-	-	T04N/R16E-32 Agri Chem Well Log	Specific Capacity	Department of Ecology Well Log Database
-	-	-	-	-	532	-	-	-	-	-	Geometric Mean of Values

Wanapum Basalt

Hydraulic Conductivity (ft/day)			Transmissivity (ft^2/day)			Storativity (Dimensionless)			Location	Model/Aquifer Test	Source
Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean			
0.09	8	3	4	9331	1339	2.E-06	1.E-04	-	Columbia Plateau Aquifer System	Model	Vacarro, 1999; Whiteman et. al, 1994
0.86	3	-	-	-	-	-	-	-	Swale Creek and Little Klickitat River Subbasins	Model	Hansen, Vacarro and Bauer, 1994
0.01	5244	66	-	-	-	-	-	-	Columbia Plateau Aquifer System	Specific Capacity	Vacarro, 1999
-	-	-	670	2680	-	9.E-05	2.E-04		Basse Wells #1 and #2	Pumping Test	Aspect Consulting, 2002
-	-	-	-	-	9277				T04N/R16E-34 Marvin Norris Well Log	Specific Capacity	Department of Ecology Well Log Database
0.1	52	15	54	5001	3525	1.E-05	1.E-04	-	-	-	Geometric Mean of Values

Upper Grande Ronde Basalt

Hydraulic Conductivity (ft/day)			Transmissivity (ft^2/day)			Storativity (Dimensionless)			Location	Model/Aquifer Test	Source
Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean			
0.13	9	2	41	15,898	3672	6.E-06	1.E-03	-	Columbia Plateau Aquifer System	Model	Vacarro, 1999; Whiteman et. al, 1994
0.09	2	-	-	-	-	-	-	-	Swale Creek and Little Klickitat River Subbasins	Model	Hansen, Vacarro and Bauer, 1994
0.005	2523	50	-	-	-	-	-	-	Columbia Plateau Aquifer System	Specific Capacity	Vacarro, 1999
0.04	33	11	41	15,898	3672	6.E-06	1.E-03	-	-	-	Geometric Mean of Values

Table 4 - Estimated Irrigation Water Use

WRIA 30 Water Availability Study

			Estimated Annual Water Use in Acre-Feet/Year		
Subbasin	**Irrigated Acres[a]**	**Alfalfa Water Duty in Feet/Year[b]**	**Total Irrigation Use**	**Annual Consumptive Quantity[c]**	**Annual Return Flow Quantity[c]**
Little Klickitat	2,860	3.4	9,720	8,750	970
Swale Creek	1,674	3.4	5,690	5,120	570

Notes:

[a] From Farm Service Agency, Goldendale Office (June 2007 personal communications).

[b] Assumes alfalfa water duty from 1987 Little Klickitat River Water Rights Adjudication, 40.8 in/year.

[c] Assumes 90% consumptive use, 10% nonconsumptive return flow (refer to text).

Table 5 - Estimated Public Water System (PWS) Use
WRIA 30 Water Availability Study

PWS ID	PWS Name	Group	Resid. Population Served	No. Total Connects	No. Resid. Connects	No. Non-Resid. Connects	Estimated Annual Water Use in Acre-Feet/Year: Residential	Non-Residential	Total
Little Klickitat Subbasin									
28450	GOLDENDALE, CITY OF (w/o Basse wellfield)	A	3760	1902	1662	240	534.9	1148.1	1683.1
15571	PONDEROSA PARK WATER SYSTEM	A	225	125	125	0	25.4	0.0	25.4
72472	RIMROCK WATER ASSOCIATION	A	56	25	25	0	9.6	0.0	9.6
06400	MT VIEW ACRES	B	20	4	4	0	2.8	0.0	2.8
29479	FOSTER ROAD WATER ASSOCIATION_	B	15	8	8	0	2.1	0.0	2.1
08154	ST JOHN S MONASTERY	B	10	2	2	0	1.4	0.0	1.4
FW012	GOLDENDALE FISH HATCHERY	B	8	3	2	1	1.1	1.1	2.3
05029	LANE WATER SYSTEM	B	8	3	3	0	1.1	0.0	1.1
40964	CANYON BREAKS	B	8	4	4	0	1.1	0.0	1.1
02087	OLSON, LEO WATER SYSTEM	B	7	3	3	0	1.0	0.0	1.0
03568	LINK, JAMES H. WATER SYSTEM	B	7	2	2	0	1.0	0.0	1.0
02089	OLSON, WILLIAM WTR SYSTEM	B	6	2	2	0	0.9	0.0	0.9
02091	WEDGWOOD WATER SYSTEM	B	6	2	2	0	0.9	0.0	0.9
07708	WEST MEADOW WATER SYSTEM	B	6	2	2	0	0.9	0.0	0.9
02090	MATULA, FLOYD H. WTR SYSTEM	B	5	2	2	0	0.7	0.0	0.7
03707	RED CEDAR WATER SYSTEM	B	5	3	3	0	0.7	0.0	0.7
05869	CLARK, DONALD & IDA	B	5	2	2	0	0.7	0.0	0.7
20096	BRONG S COMMUNITY WATER ASSN.	B	5	2	2	0	0.7	0.0	0.7
SP120	BROOKS MEMORIAL SP ADMIN	A	4	58	2	56	0.6	63.3	63.8
03635	ESHELMAN WATER SYSTEM	B	4	2	2	0	0.6	0.0	0.6
04122	HODGES & JUNG-HODGES	B	4	2	2	0	0.6	0.0	0.6
05877	STORKEL WATER SYSTEM	B	4	2	2	0	0.6	0.0	0.6
05879	PAYNE LANE WATER ASSOCIATES	B	4	2	2	0	0.6	0.0	0.6
27311	HILMAN	B	4	2	2	0	0.6	0.0	0.6
34701	SCHRODER, LAURENCE E.	B	4	2	2	0	0.6	0.0	0.6
05880	LOUGHBOROUGH WATER SYSTEM	B	3	2	2	0	0.4	0.0	0.4
AA311	KCC CHURCH RETREAT	B	3	1	1	0	0.4	0.0	0.4
26866	PINE SPRINGS RESORT	B	2	13	1	12	0.3	13.6	13.8
21140	ROADHOUSE 97	B	2	3	2	1	0.3	1.1	1.4
11611	OLD AMERICAN WAY	B	2	1	1	0	0.3	0.0	0.3
23251	THREE CREEKS RESORT	B	2	1	1	0	0.3	0.0	0.3
21955	WSP - GOLDENDALE WEIGH STATION #75	B	1	2	1	1	0.1	1.1	1.3
SP318	GOLDENDALE OBSERVATORY STATE PARK	A	0	1	0	1	0.0	1.1	1.1
38636	GOLDENDALE S.D.A. SCHOOL	B	0	2	0	2	0.0	2.3	2.3
FW018	KLICKITAT WILDLIFE AREA	B	0	2		2	0.0	2.3	2.3
HD006	SATUS PASS MAINTENANCE SITE	B	0	2	0	2	0.0	2.3	2.3
	Subbasin Totals		**4,205**	**2,196**	**1,878**	**318**	**593**	**1,236**	**1,830**
Swale Creek Subbasin									
05881	BARTLETT WATER SYSTEM	B	10	2	2	0	1.4		1.4
08403	HARVEST GOLD BOTTLED WATER	B	5	2	1	1	0.7	1.1	1.8
21127	CENTERVILLE GRADE SCHOOL	A	0	1	0	1	0.0	1.1	1.1
28450	GOLDENDALE, CITY OF (Basse wellfield)	A *	*	*	*		30.0	70.0	100.0
	Subbasin Totals		**15**	**5**	**3**	**2**	**32**	**72**	**104**

Table 6 - Estimated Self-Supplied Residential Water Use

WRIA 30 Water Availability Study

Subbasin	Estimated Self-Supplied Population in 2000[a]	Unincorporated Population Growth Rate Per Year[b]	Projected Self-Supplied Population in 2006	Self-Supplied Water Use in gpd	Self-Supplied Water Use in Acre-Feet/Year
Little Klickitat	2,660	0.8%	2,795	354,965	398
Swale Creek	105	0.8%	110	13,970	16
Total	2,765	0.8%	2,905		414

Notes:

[a] From Table 6-13 of WRIA 30 Level 1 Assessment.

[b] Statistics for Klickitat County from Office of Financial Management.

Table 7- Subbasin-Scale Annual Water Use Summary
WRIA 30 Water Availability Study

Little Klickitat Subbasin

Subbasin	Irrigation	PWS-Supplied Residential	Self-Supplied Residential	PWS-Supplied Non-Residential	Total Use in Acre-Feet/Year
	Water Use in Acre/Feet/Year by Category				
Total Use	9,720	593	398	1,236	**11,947**
Consumptive Use	8,748	77	48	161	9,033
Total Return Flow [1]	(972)	(543)	(350)	(1,136)	(3,001)
Return Flow to Groundwater	*(648)*	*(306)*	*(350)*	*(625)*	*(1,928)*
Return Flow to Surface Water	*(324)*	*(237)*	*0*	*(512)*	*(1,073)*

Swale Creek Subbasin

Subbasin	Irrigation	PWS-Supplied Residential	Self-Supplied Residential	PWS-Supplied Non-Residential	Total Use in Acre-Feet/Year
	Water Use in Acre/Feet/Year by Category				
Total Use	5,690	32	16	72	**5,810**
Consumptive Use	5,121	30	2	70	5,223
Total Return Flow	(569)	(2)	(14)	(2)	(587)
Return Flow to Groundwater	*(379)*	*(2)*	*(14)*	*(2)*	*(397)*
Return Flow to Surface Water	*(190)*	*0*	*0*	*0*	*(190)*

Notes:
PWS: Public water system.
[1] Includes return flow from use of water pumped from Goldendale's Basse wellfield (Swale Creek subbasin) and imported into Little Klickitat subbasin. That water is not included in the use calculations for Swale Creek subbasin since it is not put to use there; it does factor into the subbasin-scale water balances for both subbasins.

Table 8 - Monthly Distribution of Estimated Water Use

WRIA 30 Water Availability Study

Little Klickitat Subbasin

	Estimated Total Water Use in Acre/Feet/Year by Category				
Month	**Irrigation**	**PWS-Supplied Residential**	**Self-Supplied Residential**	**PWS-Supplied Non-Residential**	**Total Monthly Use in Acre-Feet/Year**
January	0	30	20	63	113
February	0	36	24	75	135
March	0	42	28	88	158
April	0	49	33	102	184
May	209	56	37	117	419
June	1,751	61	41	127	1,980
July	3,389	69	46	143	3,647
August	2,519	68	45	141	2,773
September	1,835	62	41	129	2,066
October	17	51	34	106	208
November	0	38	26	80	144
December	0	32	21	66	119
Annual Total	**9,720**	**593**	**398**	**1,236**	**11,947**

Swale Creek Subbasin

	Estimated Total Water Use in Acre/Feet/Year by Category				
Month	**Irrigation**	**PWS-Supplied Residential**	**Self-Supplied Residential**	**PWS-Supplied Non-Residential**	**Total Monthly Use in Acre-Feet/Year**
January	0	2	1	4	6
February	0	2	1	4	7
March	0	2	1	5	9
April	0	3	1	6	10
May	123	3	1	7	134
June	1,025	3	2	7	1,037
July	1,984	4	2	8	1,998
August	1,475	4	2	8	1,488
September	1,074	3	2	8	1,087
October	10	3	1	6	20
November	0	2	1	5	8
December	0	2	1	4	6
Annual Total	**5,690**	**32**	**16**	**72**	**5,810**

Table 9 - Subbasin-Scale Annual Water Balances

WRIA 30 Water Availability Study

Little Klickitat Subbasin

	Inputs		Outputs						
Area	Precipitation		ET (non-irrigation)		Recharge	Streamflow		Consumptive Use	Return Flow
in ac	in inches [1]	in ac-ft [2]	in inches [3]	in ac-ft [4]	in ac-ft [5]	in cfs [6]	in ac-ft [7]	in ac-ft[9]	in ac-ft[9]
179,195	26	388,256	10.4	152,571	109,330	166	120,323	9,033	-3,001

Swale Creek Subbasin

	Inputs		Outputs						
Area	Precipitation		ET (non-irrigation)		Recharge	Streamflow		Consumptive Use	Return Flow
in ac	in inches [1]	in ac-ft [2]	in inches [3]	in ac-ft [4]	in ac-ft [5]	in cfs[10]	in ac-ft [8]	in ac-ft[9]	in ac-ft[9]
80,490	23	154,273	14.1	92,551	25,230	44	31,855	5,223	-587

Notes:

1) Source: Subbasin average from PRISM Precipitation model, as reported in WRIA 30 Level 1 Assessment (WPN)
2) Source: Calculated from value in inches
3) Source: Calculated from ET value in ac-ft
4) Source: Calculated as unknown value in Little Klickitat water balance
5) Source: USGS deep percolation model (Bauer and Vaccaro 1990), as reported in WRIA 30 Level 1 Assessment
6) Source: Mean daily flow based period of record flow data for the mouth of Little Klickitat River, both USGS and Ecology data.
7) Source: Mean daily flow based on period of record flow data for the mouth of Swale Creek, Yakima Nation data
8) Source: Calculated from value in cfs
9) Consumptive use and return flow account for pumping Goldendale's Basse wellfield in Swale Creek subbasin with import into Little Klickitat subbasin..
10) Mean annual flow measured at mouth of Swale Creek by Yakama Nation Fisheries, adjusted for mean annual precipitation (refer to text).

Table 10 - Subbasin-Scale Annual Water Balances with Comparison to Appropriated and Estimated Actual Water Uses
WRIA 30 Water Availability Study

Little Klickitat Subbasin

Water Balance Component	Average Annual Value in Acre-Feet/Year
Precipitation	388,256
Evapotranspiration (non-irrigation)	152,571
Streamflow	120,323
Groundwater Recharge	109,330
Surface Water Use (consumptive)	4,016
Return Flow to Surface Water	1,073
Groundwater Use (consumptive)	5,017
Return Flow to Groundwater	1,928
Balance:	*0*

Total consumptive surface water use as % of streamflow:	3%
Total consumptive groundwater use as % of groundwater recharge:	5%

Total Appropriated Water Rights and Water Claims	Acre-Feet/Year
Surface water certificates + permits	15,136
Groundwater certificates + permits	18,910
Water claims (groundwater+surface water)	1,536

Total annual water rights	34,046
Estimated total annual water use	12,034
Use as % of Appropriation	35%

Swale Creek Subbasin

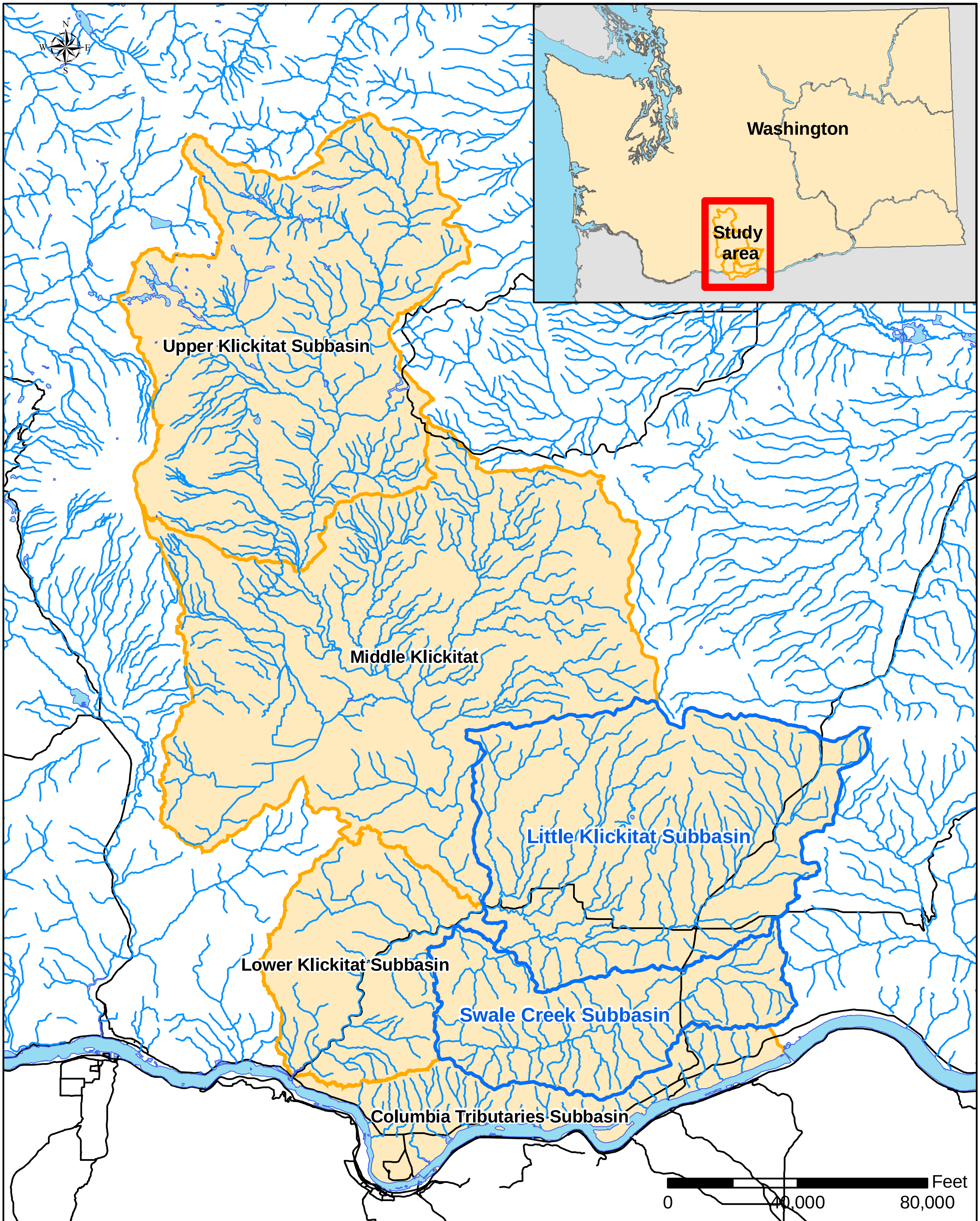
Water Balance Component	Average Annual Value in Acre-Feet/Year
Precipitation	154,273
Evapotranspiration (non-irrigation)	92,551
Streamflow	31,855
Groundwater Recharge	25,230
Surface Water Use (consumptive)	12
Return Flow to Surface Water	190
Groundwater Use (consumptive)	5,211
Return Flow to Groundwater	397
Balance:	*0*

Total consumptive surface water use as % of streamflow:	0.04%
Total consumptive groundwater use as % of groundwater recharge:	21%

Total Appropriated Water Rights and Water Claims	Acre-Feet/Year
Surface water certificates + permits	27
Groundwater certificates + permits	11,632
Water claims (groundwater+surface water)	15

Total annual water rights	11,659
Estimated total annual water use	5,810
Use as % of Appropriation	50%

Notes:
Assumes distribution of % groundwater vs. surface water annual use is equivalent to % groundwater vs. surface water annual rights (certs + permits) appropriated.



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	**Swale Creek and Little Klickitat Subbasins, WRIA 30** Swale Creek and Little Klickitat River Subbasins WRIA 30 Water Availability Study	DATE: June 2007 DESIGNED BY: SJG DRAWN BY: ACM REVISED BY: ACM	PROJECT NO. 070024 FIGURE NO. 1

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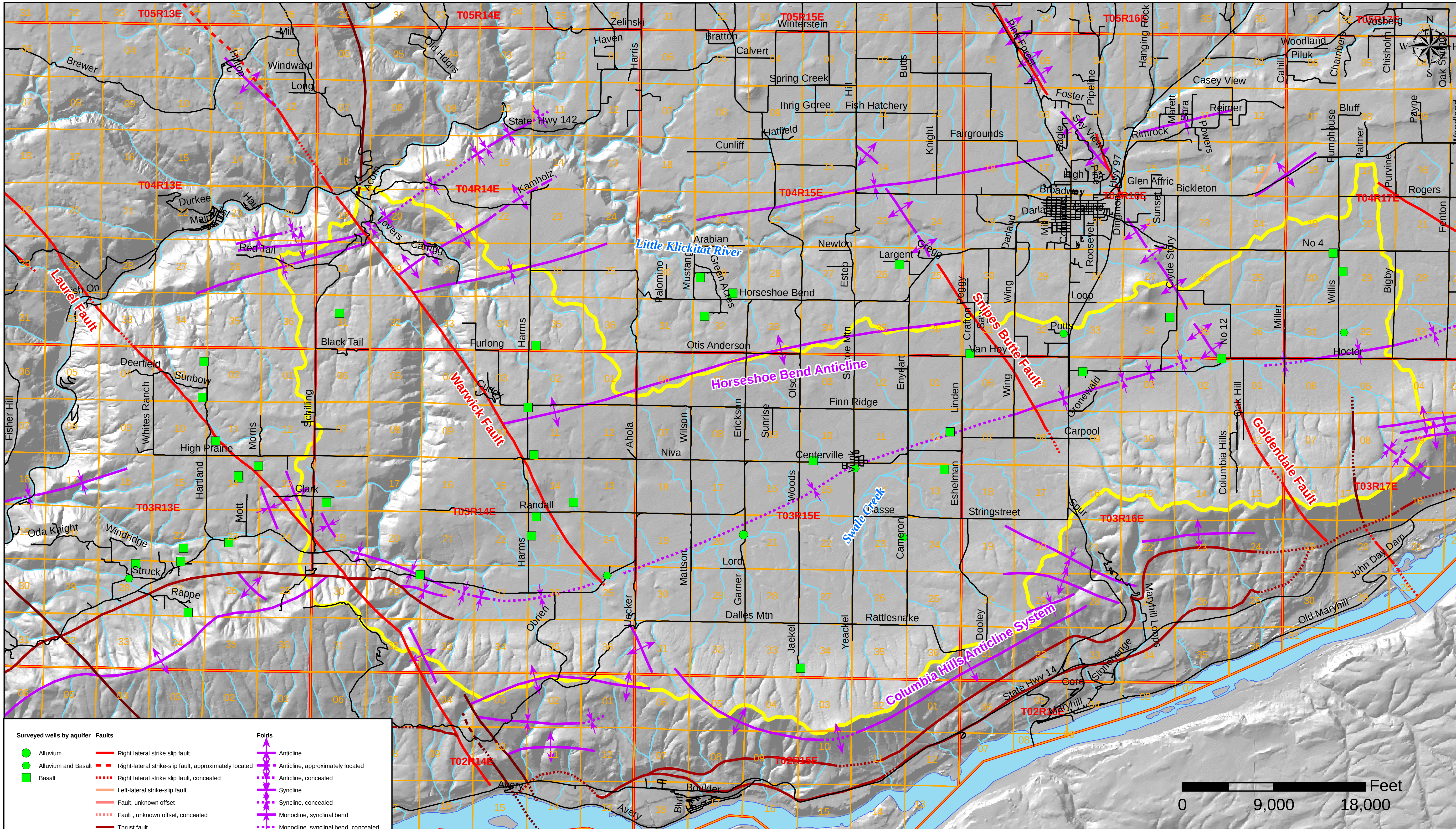

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Groundwater Level Monitoring Network, June 2007
Swale Creek and Little Klickitat River Subbasins
WRIA 30 Water Availability Study

DATE: June 2007	PROJECT NO. 070024
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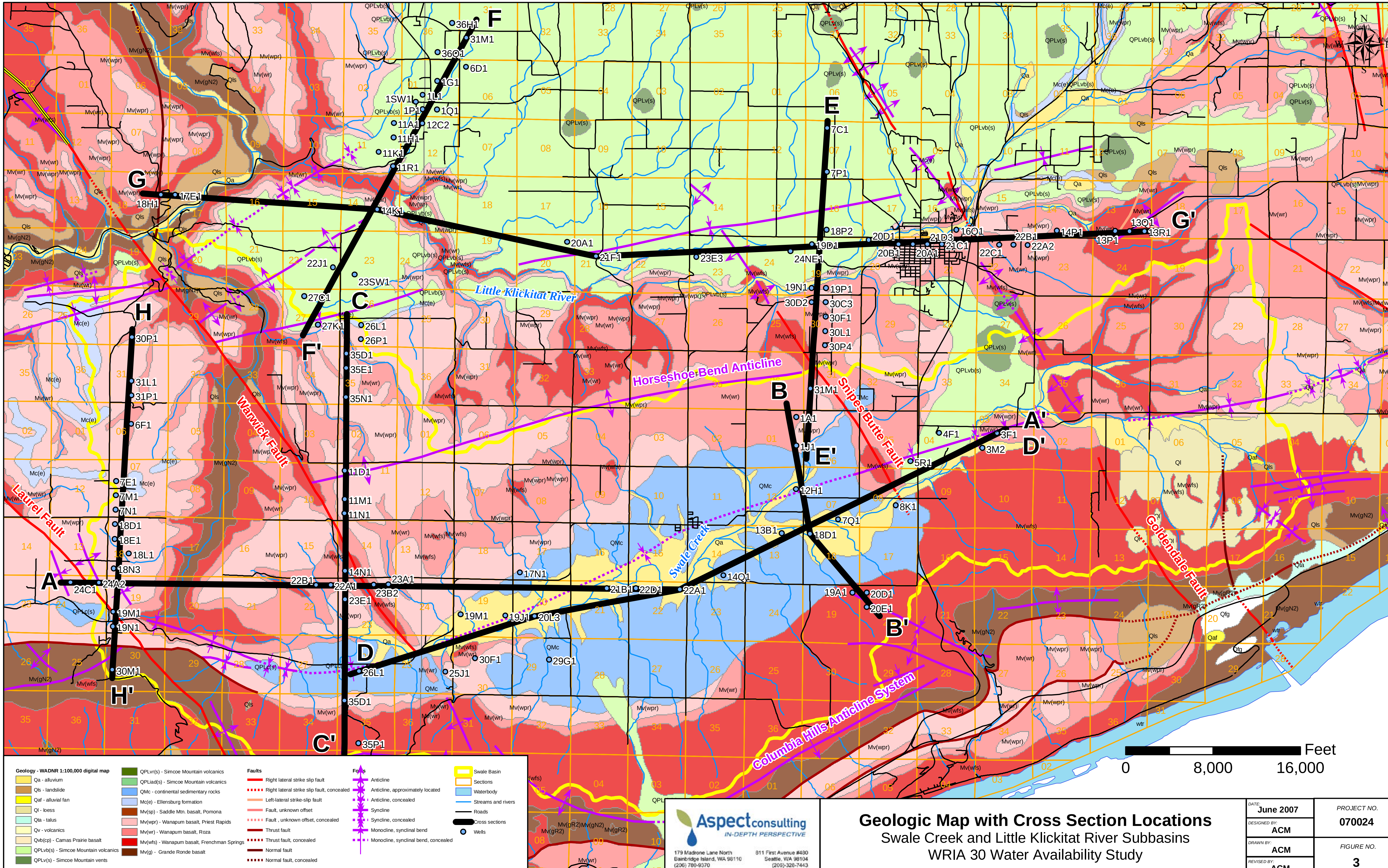
REVISED BY: ACM	



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Geologic Map with Cross Section Locations

Swale Creek and Little Klickitat River Subbasins

WRIA 30 Water Availability Study

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Cross Section A-A'

Swale Creek Subbasin
WRIA 30 Water Availability Study

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DFR	
PMB	FIGURE NO. 4
LAL	

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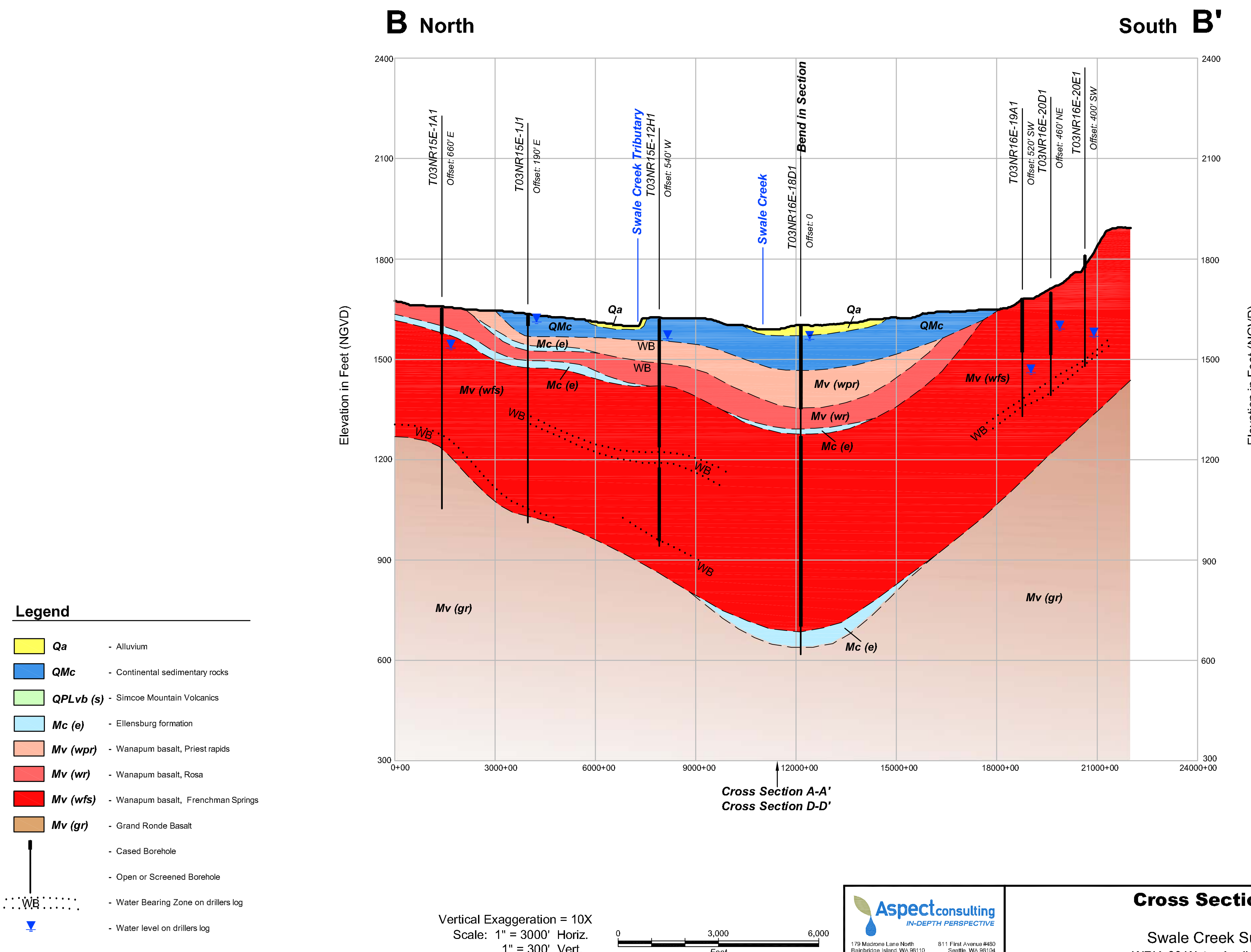

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Seattle, WA 98104
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Cross Section B-B'

Swale Creek Subbasin
WRIA 30 Water Availability Study

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DESIGNED BY: DFR	
DRAWN BY: PMB	FIGURE NO. 5
REVISED BY: LAL	

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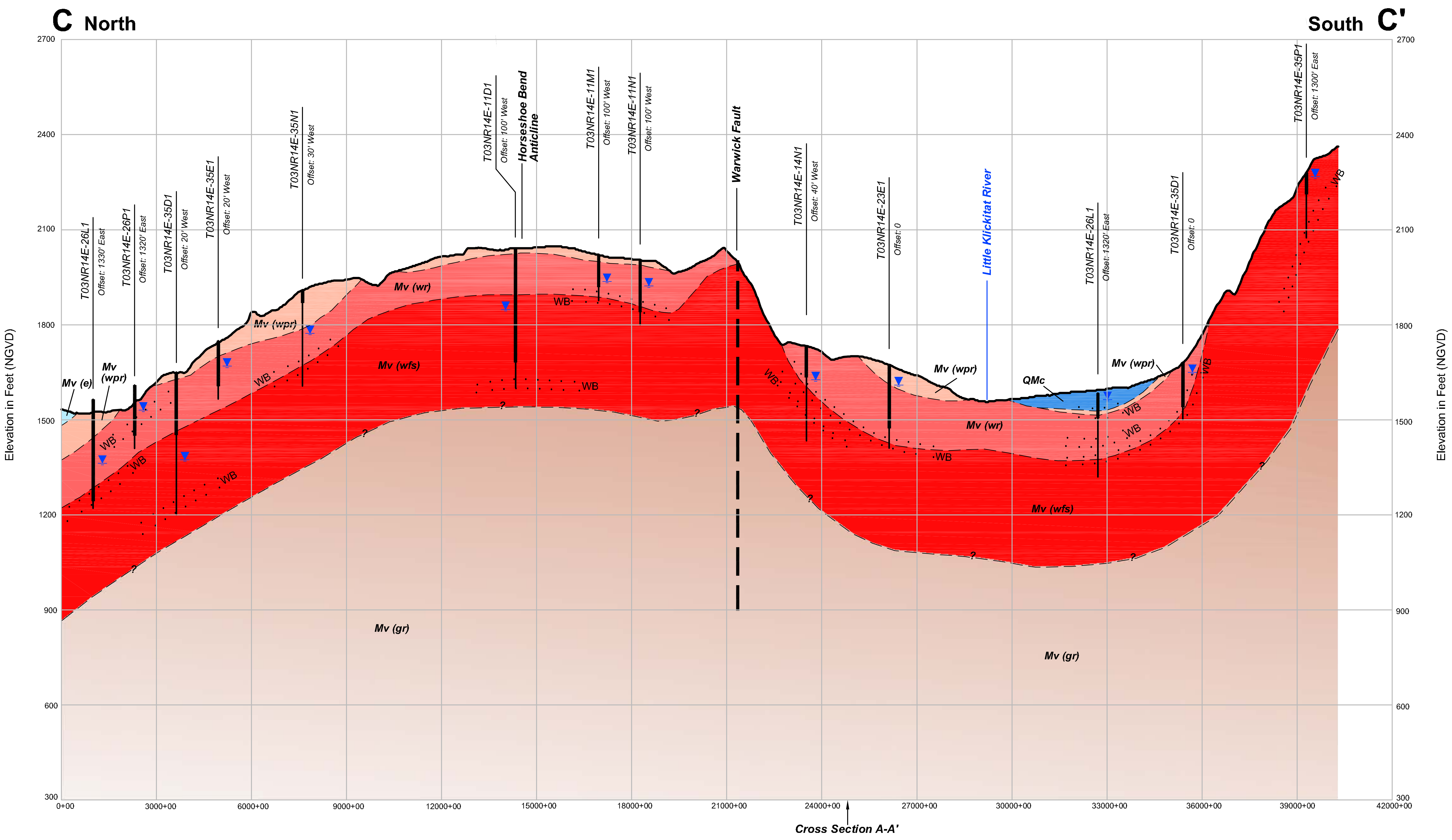

Legend

Qa	- Alluvium
QMc	- Continental sedimentary rocks
QPLvb (s)	- Simcoe Mountain Volcanics
Mc (e)	- Ellensburg formation
Mv (wpr)	- Wanapum basalt, Priest rapids
Mv (wr)	- Wanapum basalt, Rosa
Mv (wfs)	- Wanapum basalt, Frenchman Springs
Mv (gr)	- Grand Ronde Basalt
	- Cased Borehole
	- Open or Screened Borehole
WB	- Water Bearing Zone on drillers log
	- Water level on drillers log
	- Fault/Fold

Vertical Exaggeration = 10X
Scale: 1" = 3000' Horiz.
1" = 300' Vert.

0 3,000 6,000
Feet

Aspect consulting
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Cross Section C-C'

Swale Creek Subbasin
WRIA 30 Water Availability Study

DATE: June 2007
DESIGNED BY: DFR
DRAWN BY: PMB
REVISED BY: LAL
PROJECT NO. 070024
FIGURE NO. 6

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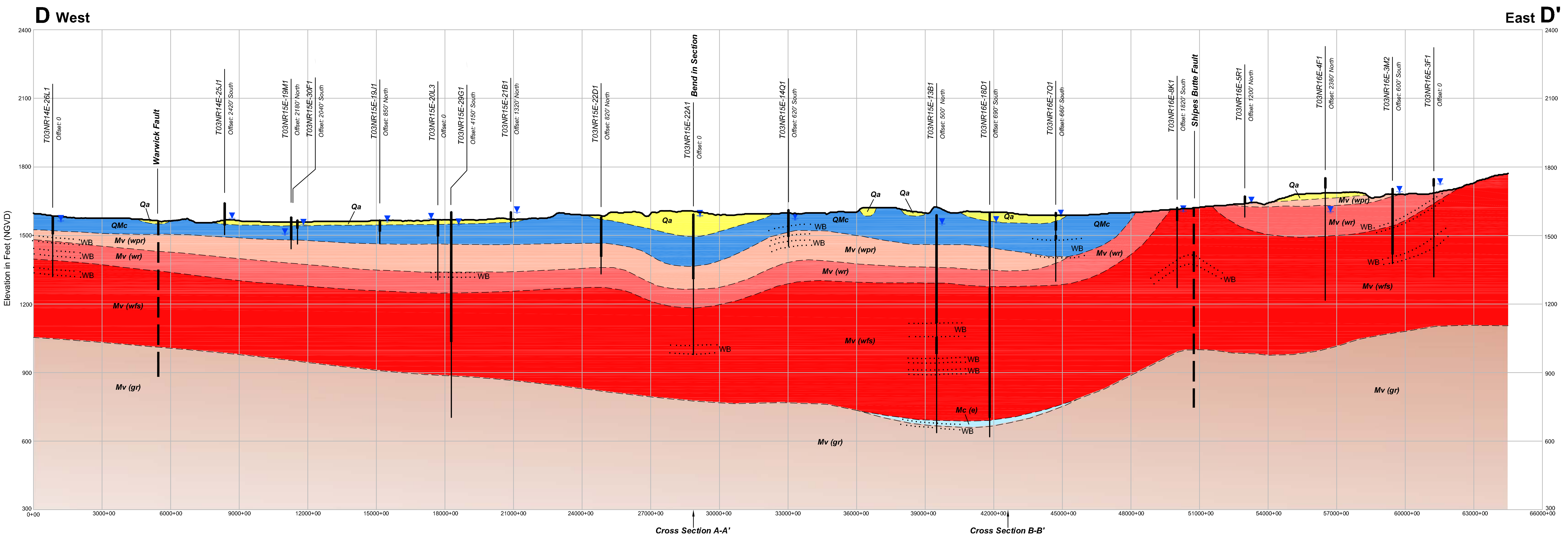

Legend

- **Qa** - Alluvium
- **QMc** - Continental sedimentary rocks
- **QPLvb (s)** - Simcoe Mountain Volcanics
- **Mc (e)** - Ellensburg formation
- **Mv (wpr)** - Wanapum basalt, Priest rapids
- **Mv (wr)** - Wanapum basalt, Rosa
- **Mv (wfs)** - Wanapum basalt, Frenchman Springs
- **Mv (gr)** - Grand Ronde Basalt
- Cased Borehole
- Open or Screened Borehole
- WB - Water Bearing Zone on drillers log
- Water level on drillers log
- Fault/Fold

Vertical Exaggeration = 10X
Scale: 1" = 3000' Horiz.
1" = 300' Vert.

0 3,000 6,000
Feet

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Seattle, WA 98104
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Cross Section D-D'

Swale Creek Subbasin
WRIA 30 Water Availability Study

DATE	June 2007
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DRAWN BY	PMB
REVISED BY	LAL
PROJECT NO.	070024
FIGURE NO.	7

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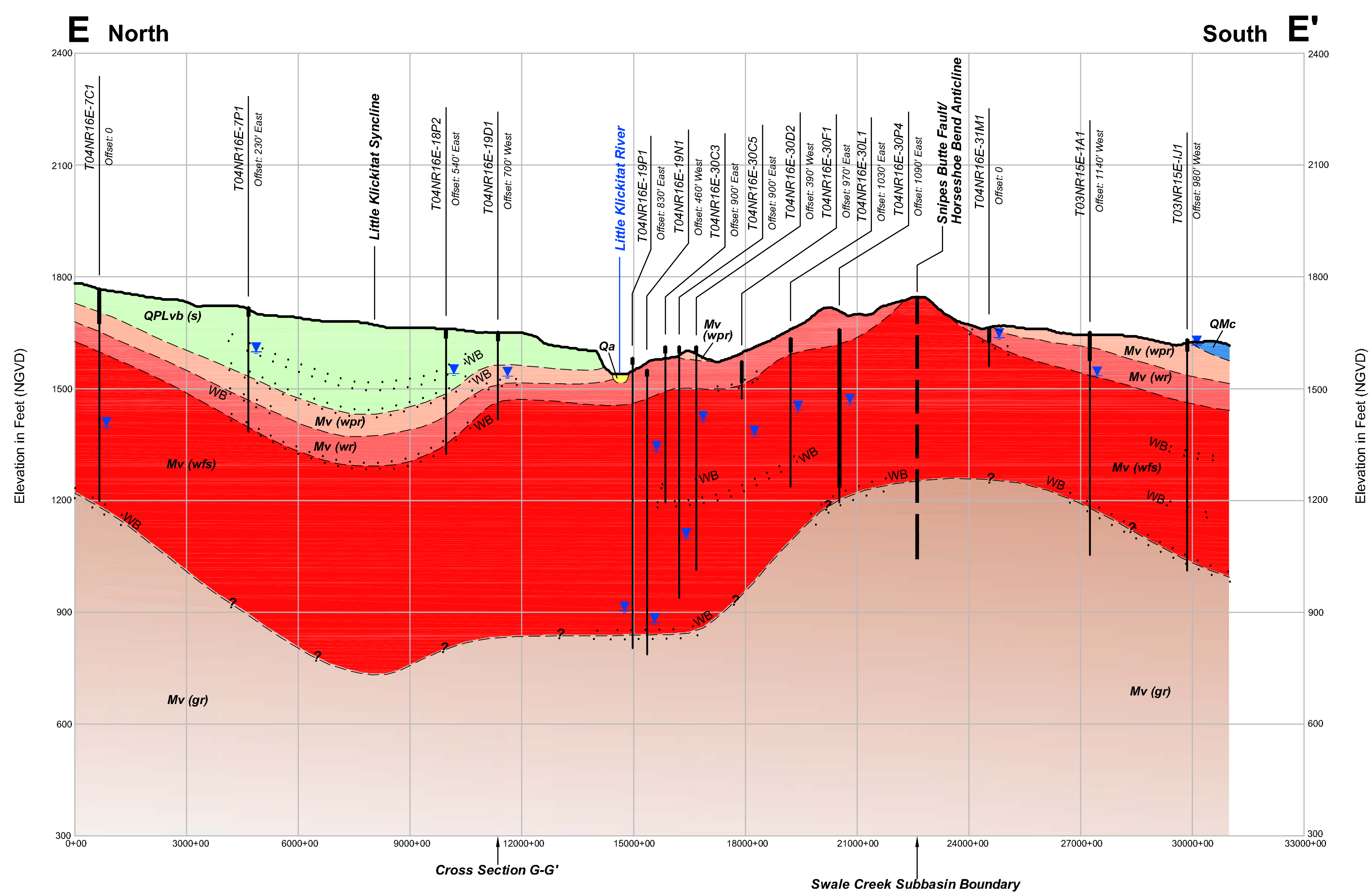

Legend

Qa	-	Alluvium
QMc	-	Continental sedimentary rocks
QPLvb (s)	-	Simcoe Mountain Volcanics
Mc (e)	-	Ellensburg formation
Mv (wpr)	-	Wanapum basalt, Priest rapids
Mv (wr)	-	Wanapum basalt, Rosa
Mv (wfs)	-	Wanapum basalt, Frenchman Springs
Mv (gr)	-	Grand Ronde Basalt
	-	Cased Borehole
	-	Open or Screened Borehole
WB	-	Water Bearing Zone on drillers log
	-	Water level on drillers log
	-	Fault/Fold

Vertical Exaggeration = 10X
Scale: 1" = 3000' Horiz.
1" = 300' Vert.

0 3,000 6,000
Feet

Aspect consulting
IN-DEPTH PERSPECTIVE
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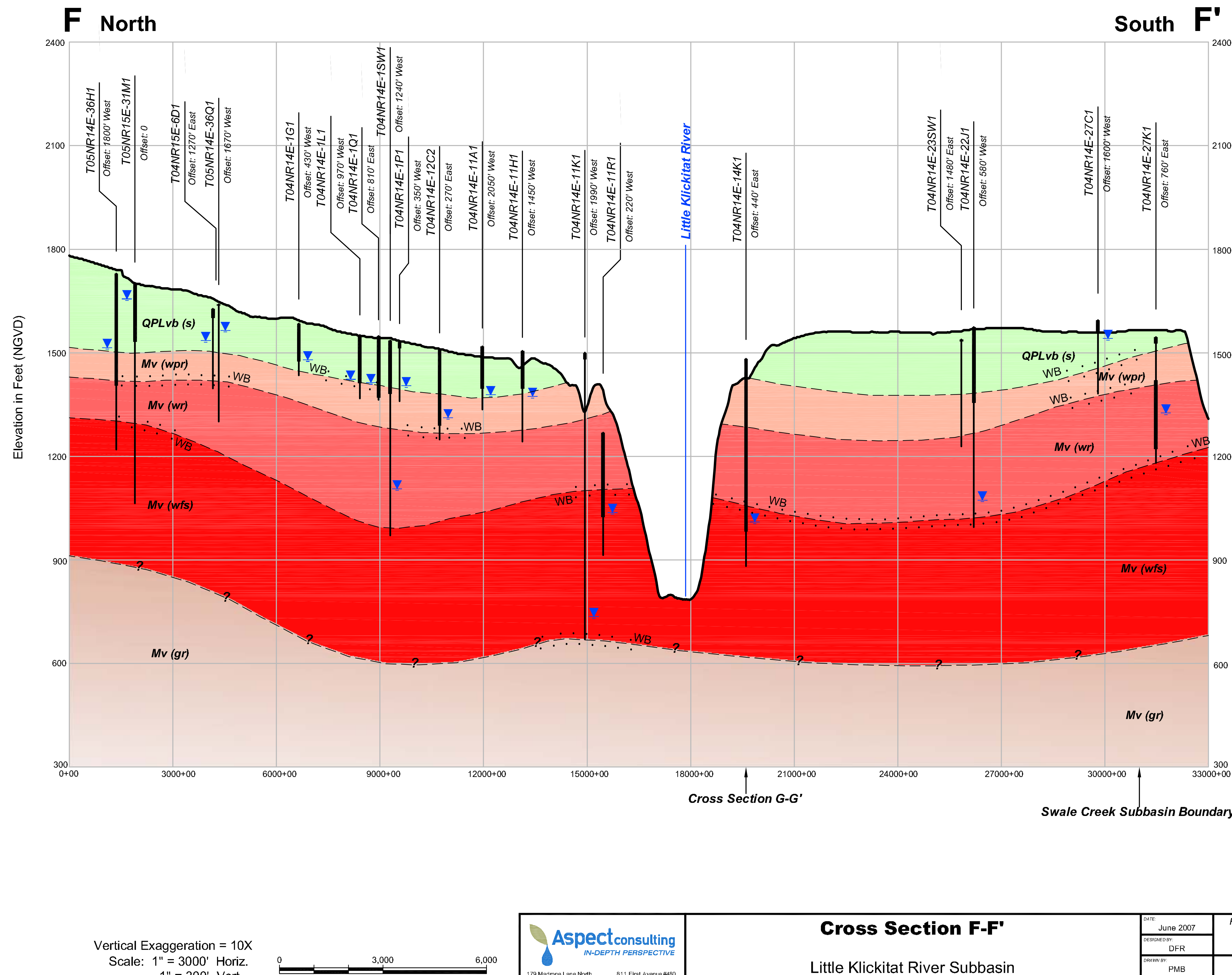
811 First Avenue #480, Seattle, WA 98104, (206) 328-7443

Cross Section E-E'

Swale Creek and Little Klickitat River Subbasins
WRIA 30 Water Availability Study

DATE:	June 2007
DESIGNED BY:	DFR
DRAWN BY:	PMB
REVISED BY:	LAL
PROJECT NO.	070024
FIGURE NO.	8



Vertical Exaggeration = 10X
Scale: 1" = 3000' Horiz.
1" = 300' Vert.

0 3,000 6,000
Feet

Aspect consulting
IN-DEPTH PERSPECTIVE
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Cross Section F-F'

Little Klickitat River Subbasin
WRIA 30 Water Availability Study

DATE: June 2007
DESIGNED BY: DFR
DRAWN BY: PMB
REVISED BY: LAL

PROJECT NO. 070024
FIGURE NO. 9

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Cross Section G-G'

Little Klickitat River Subbasin
WRIA 30 Water Availability Study

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June 2007 | DFR | PMB | LAL

PROJECT NO. 070024

FIGURE NO. 10

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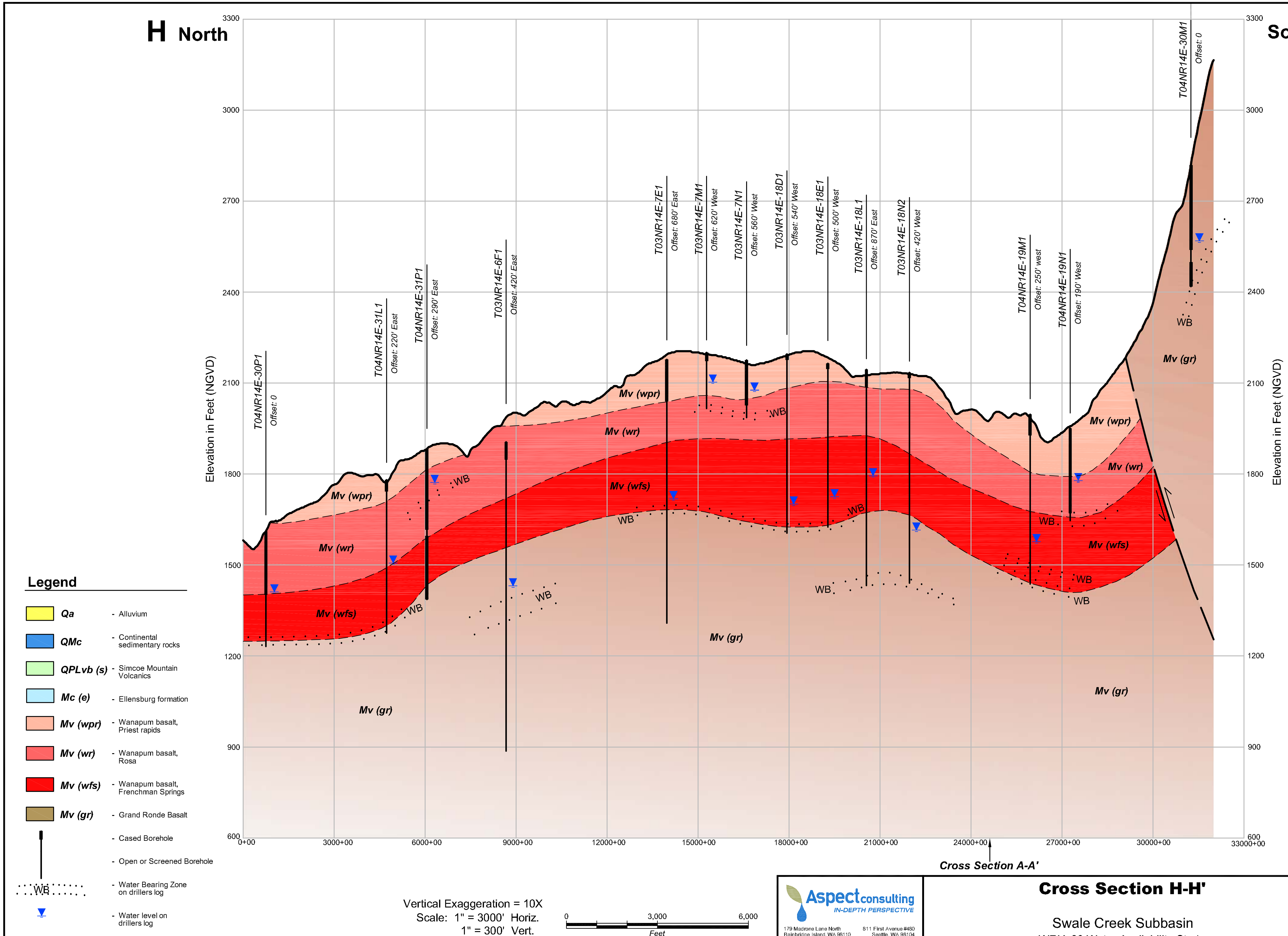

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Seattle, WA 98104
(206) 328-7443

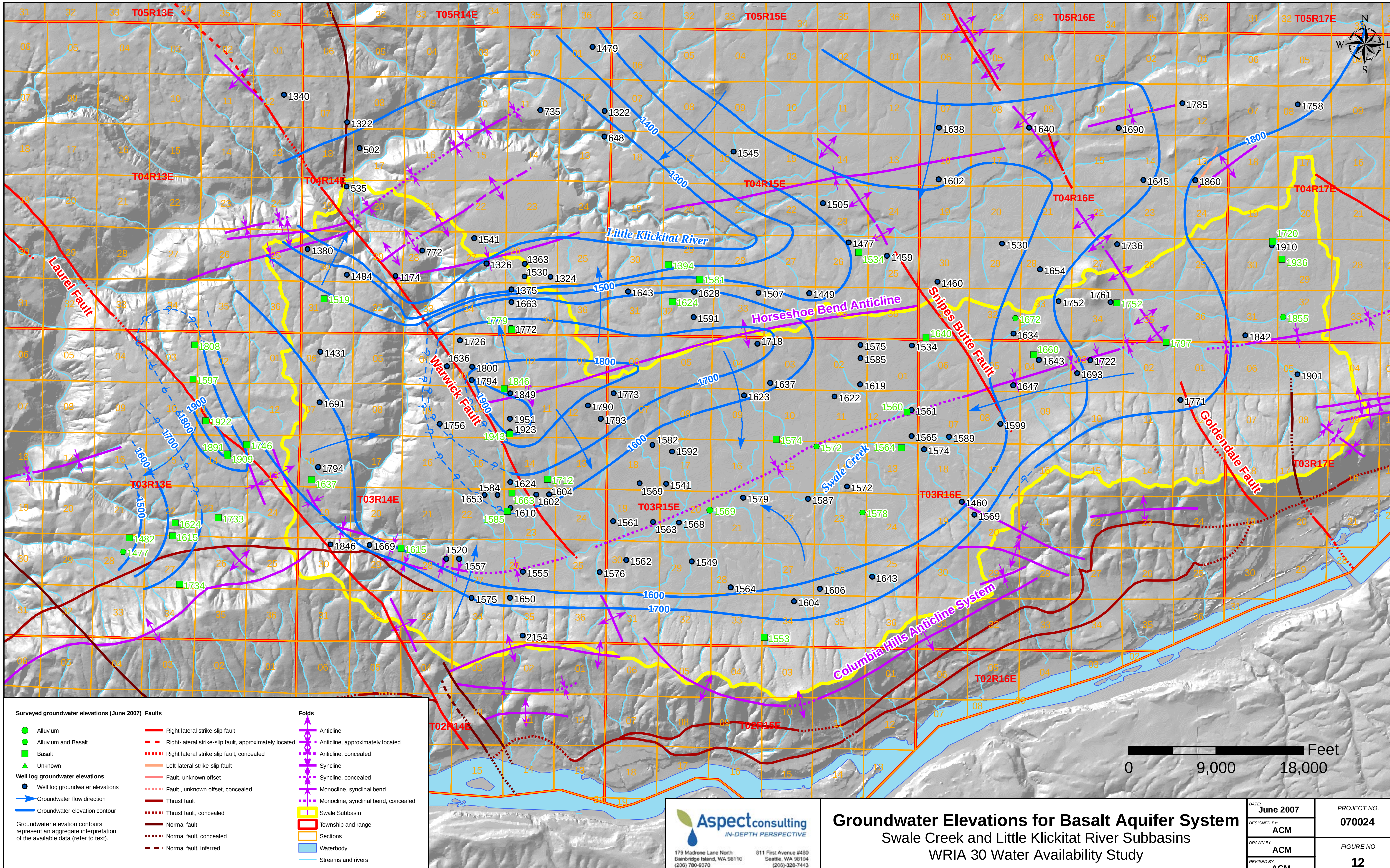
Cross Section H-H'

Swale Creek Subbasin

WRIA 30 Water Availability Study

DATE: June 2007	PROJECT NO. 070024
DESIGNED BY: DFR	
DRAWN BY: PMB	FIGURE NO. 11
REVISED BY: LAL	

Q:\WRIA\070024 WRIA 30\2007-04\070024-HH.dwg



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Groundwater Elevations for Basalt Aquifer System
Swale Creek and Little Klickitat River Subbasins
WRIA 30 Water Availability Study

DATE: June 2007	PROJECT NO. 070024
DESIGNED BY: ACM	
DRAWN BY: ACM	FIGURE NO. 12
REVISED BY: ACM	

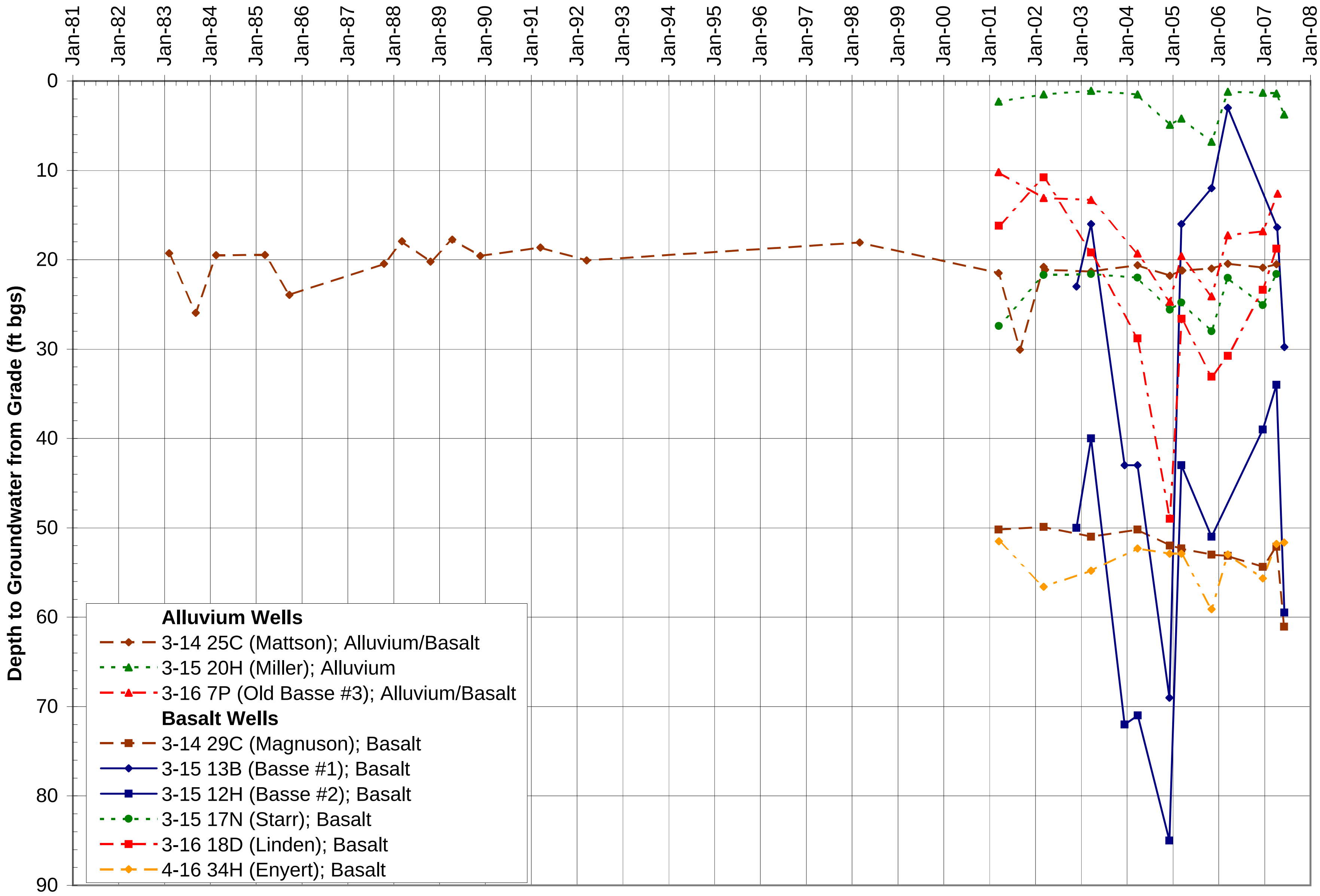

Figure 13
Swale Creek Subbasin Long-term Groundwater Level Monitoring
WRIA 30 Water Availability Study

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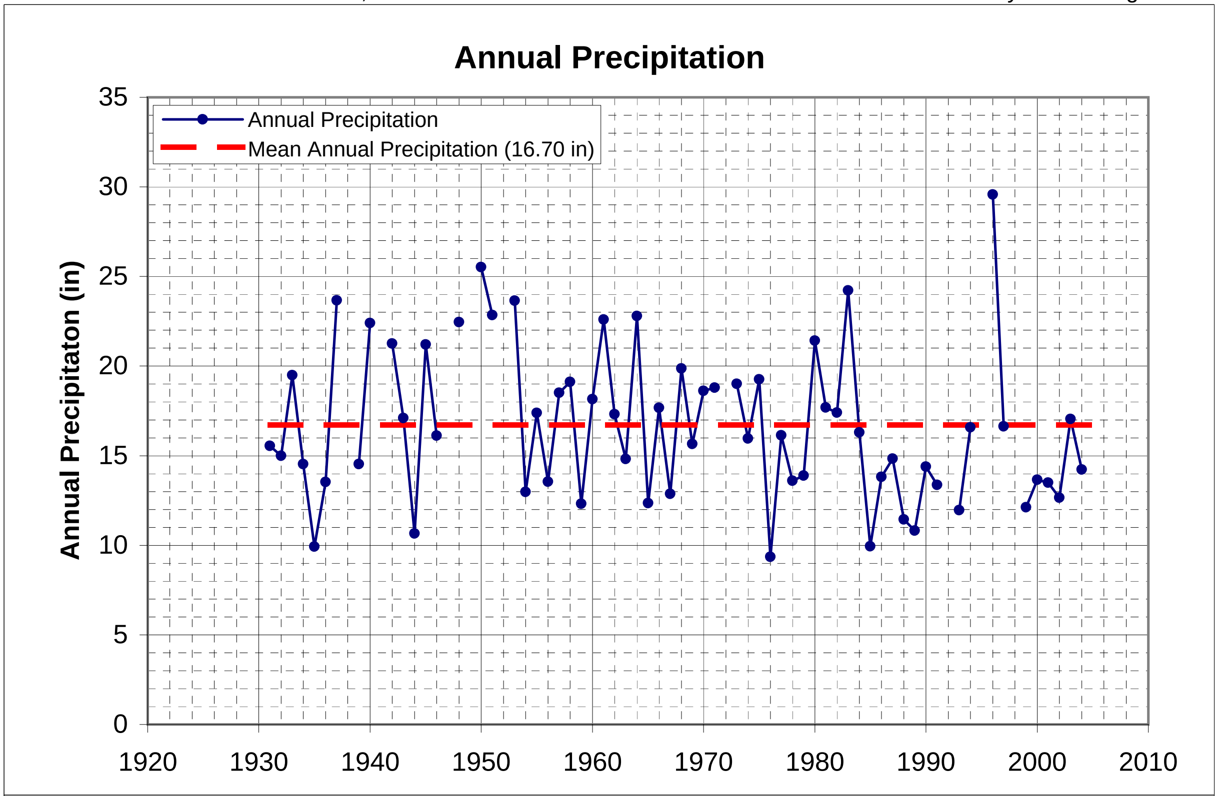
W:\070024 WRIA 30\Deliverables\Water Availability Study\Figure 13 Hydrographs

Notes:
Annual precipitation data from Goldendale (NOAA Station #453222) and Goldendale 2E (NOAA Station #453226).
Individual months with more than 5 days of missing data were not used for monthly or annual statistics.
Period of record is from 1931-2007; both 2006 and 2007 had individual months with more than 5 days of missing data.



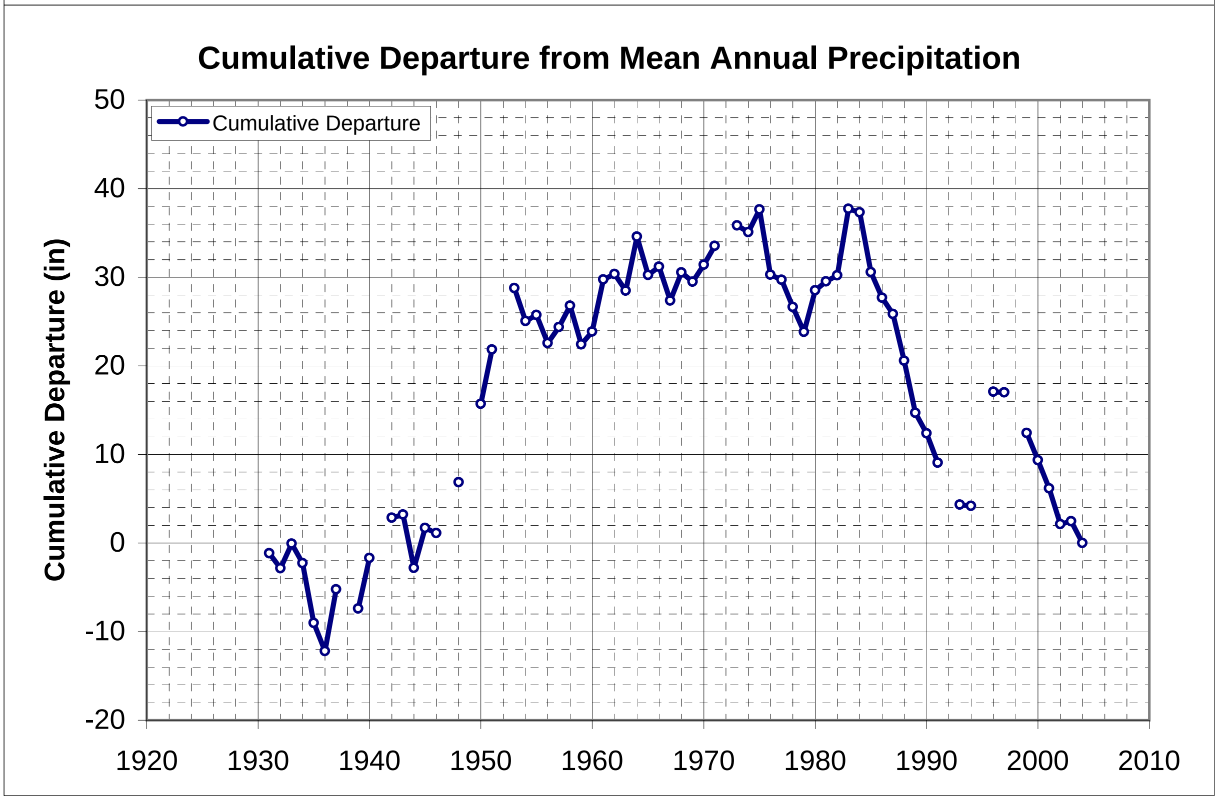
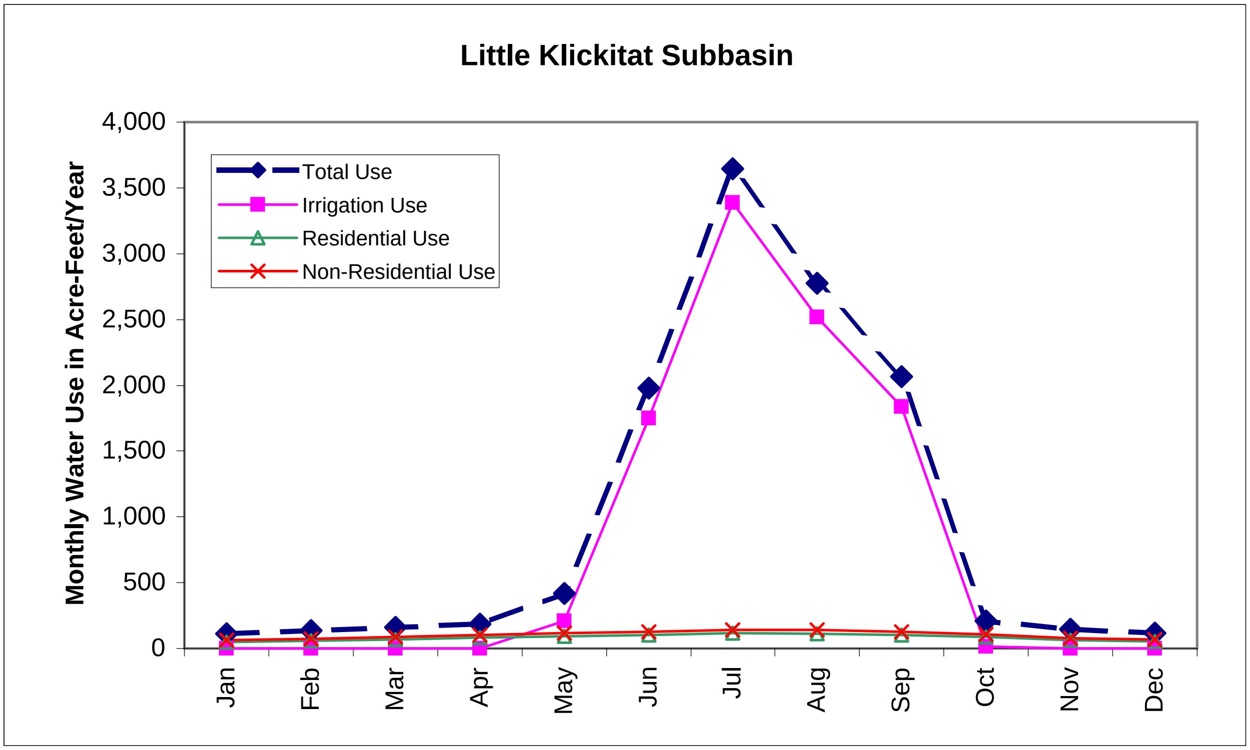
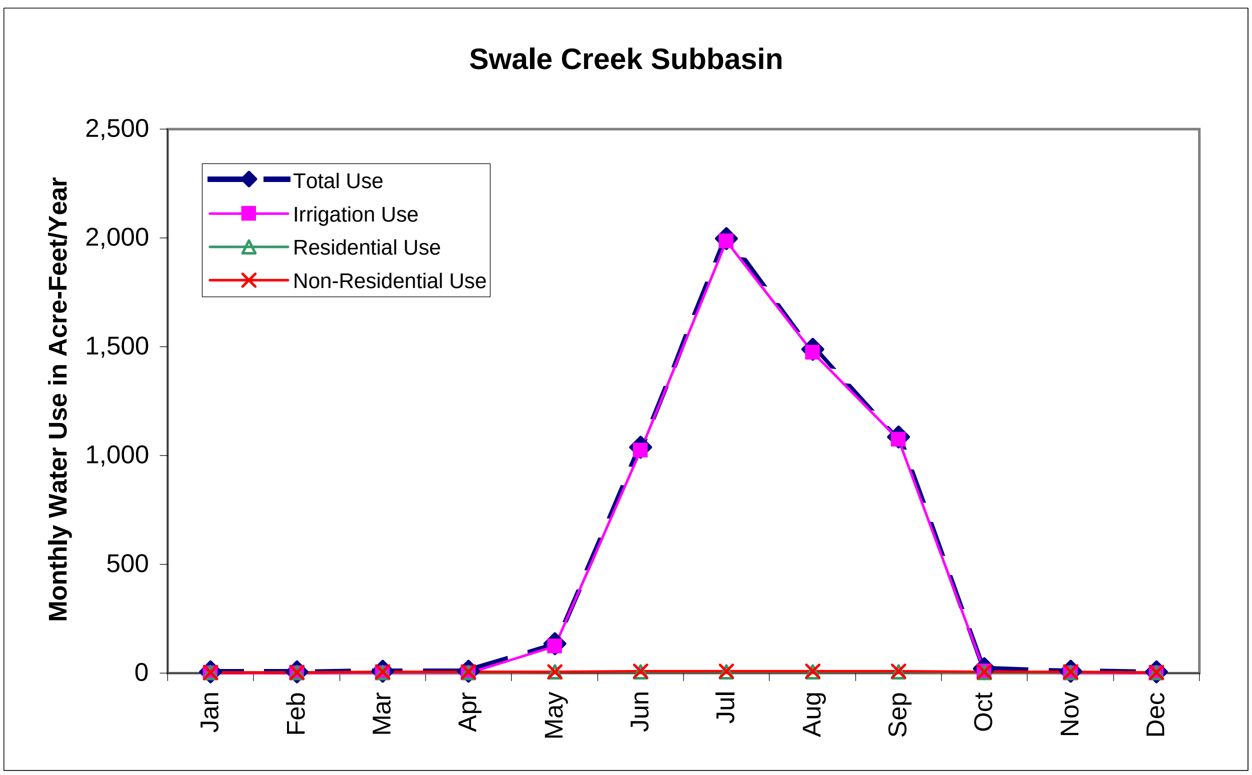


Figure 14
Long-Term Precipitation Analysis
WRIA 30 Water Availability Study





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W:\070024 WRIA 30\Deliverables\Water Availability Study\Tables 4-10 & Fig 15

Figure 15
Estimated Monthly Water Use
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