HYDROLOGIC INFORMATION REPORT
SUPPORTING WATER AVAILABILITY ASSESSMENT
Appleton Study Area, WRIA 30

Prepared for: WRIA 30 Water Resource Planning & Advisory Committee

Project No. 070024-013-01 • June 30, 2011

Project funded through Ecology Grant No. G1000101

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1 Project Objectives and Report Organization

Within Water Resource Inventory Area 30 (WRIA 30), aka the Klickitat River basin, there are several areas with potential for substantial future population growth, including portions of the Swale Creek, Little Klickitat, Lower Klickitat, and Columbia Tributaries subbasins. The WRIA 30 Watershed Management Plan [Watershed Professionals Network (WPN) and Aspect Consulting, LLC (Aspect), 2004] identified data gaps that needed to be addressed in order to help determine the quantities of water available for appropriation, including:

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

The WRIA 30 Watershed Management Plan calls for conducting water availability studies and collecting data that will facilitate the processing of water rights. Washington State Department of Ecology (Ecology) provided funding (Grant No. G1000101) to conduct water availability studies in priority areas of WRIA 30, including the Dallesport area (western Columbia Tributaries subbasin), the High Prairie area (straddling western Swale Creek and eastern Lower Klickitat subbasins), and the subject of this report, the Fisher Hill/Appleton area (northwestern Lower Klickitat subbasin). Figure 1.1 provides a map of the various subbasins of WRIA 30 and the Appleton study area, covering portions of the Lower Klickitat drainage.

For previous water availability studies of the Little Klickitat and Swale Creek subbasins in WRIA 30 (Aspect, 2007), the WRIA 30 Water Resource Planning and Advisory Committee (WRIA 30 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 east of the Warwick fault. Based on these discussions, the following information was determined to be needed for the Appleton area:

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 Klickitat River and its tributaries (e.g., Skookum, Snyder, Logging Camp, and Silva Creeks), if any, and document uncertainty.
3. Obtain information about the aquifer hydraulic properties to allow assessment of interference\impairment to existing wells from the approval of new water rights.

Item 1 is related to water available for issuing new water rights. Items 2 and 3 are related to potential for impairment associated with new appropriations. However, a 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 study area.

Therefore, the objectives of this assessment for the Appleton study area include:

1. Creation of a hydrogeologic conceptual model, including the most definitive interpretation of the hydrostratigraphy and groundwater flow system to date;
2. Establishment of a groundwater level monitoring network; and
3. Creation of a study area-scale water balance, assisting in the determination of water availability for the study area.

1.1 Report Organization

The following sections of this report include:

- Water Level Monitoring;
- Conceptual Model of Hydrogeologic Conditions, including an assessment of groundwater-surface water continuity;
- Water Balance; and
- Conclusions and Recommendations.

2 Water Level Monitoring

An important element of the study is establishment of a well network in which groundwater levels can be monitored. The water level data are used to evaluate groundwater flow directions within the aquifer system and, with continued long-term measurements, document aquifer response to short-term conditions (e.g. seasonal and pumping stresses) and longer-term trends that can provide empirical information regarding sustainable levels of groundwater withdrawal. The water level monitoring activities for the study area are described below.

2.1 Establishment of Well Monitoring Network

The primary area of focus for the groundwater level monitoring network was the Appleton area, which is the northwestern portion of the Lower Klickitat subbasin defined in the WRIA 30 Level 1 Assessment (WPN and Aspect, 2004). A monitoring network of 12 wells located within the Appleton area was established in April 2010 as part of this water availability study.

The establishment of the water level monitoring network was conducted in accordance with a Quality Assurance Project Plan (QAPP) prepared for the project (Aspect, 2010a). Members of the WRIA 30 PAC and local community assisted in the effort by contacting local well owners to request permission to access their well and inform them of the study objective.

The first step for establishing the expanded water level monitoring network involved compilation of addresses of prospective wells based on well locations from Ecology's on-line well log database (http://apps.ecy.wa.gov/welllog/). Additional wells were added to the prospective water level monitoring network list based on personal contacts of local community members.

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[1] in the various basalt aquifers to allow for potential differentiation of water levels within respective hydrostratigraphic units. For wells completed in the interflow zones between the basalt units, water levels were considered to be representative of the underlying basalt 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

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[1] A well being "completed" in a specific aquifer zone(s) indicates that it is open to, thus assumed to be withdrawing groundwater from, that zone. A well that is cased across an aquifer zone is not considered to be completed within that zone.

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 or the Klickitat County Natural Resources Department (Klickitat County) called and set up a time with the respective owner in which to do so.

Personnel from Aspect performed the initial field reconnaissance and monitoring network water level measurements in April 2010. The subsequent water level monitoring events in November/December 2010 and April 2011 were conducted by Klickitat County staff.

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 had pumps installed, care was taken to avoid getting the electric water level indicator, if used, caught on pump wiring or other items in the well. Only wells for which water levels could be readily measured 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 continues to be received. Figure 2.1 displays the locations of the wells included in the monitoring network. Although well T04N/R12E-9R1 is located slightly outside of the study area, groundwater flows north, away from the axis of the Bingen anticline (see Section 3.3) in that area, thus the well was kept as part of the monitoring network. Table 2.1 summarizes the well completion information for the wells included in the monitoring network.

2.2 Well Survey

Prior to the field reconnaissance, locations and groundwater levels for wells in the study area 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 by the USGS’ Digital Elevation Model (DEM). In areas of relatively large vertical relief, this can cause significant errors in the well elevation and thus the 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 (surveyed) well locations and elevations for wells included in the water level monitoring network.

As part of the field reconnaissance, wells included in 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 at 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 study area. 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 1.0 and 0.1 foot, respectively. Table 2.1 presents the survey data for wells within the monitoring network.

2.3 Water Level Measurements

Three rounds of water level measurements were collected from the monitoring network wells during this study: April 2010 and April 2011, generally representing pre- or early-irrigation conditions; and November/December 2010, generally representing post-irrigation conditions. A summary of the water level measurements is provided in Table 2.2.

In order to provide an accurate "snapshot" of pre-irrigation and post-irrigation groundwater levels, an attempt will be made during subsequent monitoring events to collect the water level measurements for the Appleton area within a 1-week period of time, if possible.

2.3.1 Water Level Measurement Procedures

Depth-to-water measurements were conducted using either an electric water level indicator (tape) or a sonic water level indicator (sounder)[2], depending on well access. The former provides greater precision, but has the significant disadvantage of potentially becoming permanently caught on wiring or other appurtenances within the well casing. The latter has less precision but is much faster to use and, more importantly, does not have the risk of becoming caught in the well. During the initial round of water level measurements (April 2010), field personnel used both the electric tape and the well sounder for all wells which had suitable access in order to establish instrument accuracy and suitability for each well. A quality control (QC) evaluation of the sonic sounder performance, using actual data from WRIA 30 monitoring efforts, is provided in the QAPP (Aspect, 2010a).

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 magic marker, if possible, and was documented in the field form so that it can be reproduced during subsequent measurement rounds. A table of static water level measurements from the respective wells logs was carried in the field. Measurements that varied greatly from previous measurements in a given well (accounting for differences between pre- and post-irrigation) were repeated for confirmation.

Electric Water Level Indicator

When the electric water level indicator was used, each depth-to-water measurement was made to a precision of 0.01 foot. The water level indicator was lowered to contact the water in the well casing (contact determined by a light or beep on the indicator) and the reading noted. The indicator was then immediately withdrawn out of 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. If repeated water level measurements indicated the presence of rising/falling water levels due to pumping influences, it was noted as such on the respective field form. Other

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[2] Global Water WL600 or equivalent instrument.

pertinent information regarding the well or the depth-to-water measurement was also recorded in the field notes.

If an electric water level indicator was used for the depth-to-water measurement, the lower couple of feet of tape was rinsed and wiped with a clean paper towel. Any rust or other visible material on the water level indicator after a measurement was also wiped off using a clean paper towel prior to the next measurement.

Sonic Water Level Indicator

When the sonic water level indicator was used, each depth-to-water measurement was made to a precision of 0.1 ft. The sonic water level indicator was programmed with the regional monthly temperature setting suggested by the manufacturer. The sonic water level indicator was placed flush with the top of the casing, and the depth-to-water was displayed on a LCD screen. The measurement was repeated until a reproducible result was obtained. If the two readings were consistent, the reading was recorded in the field notes along with measurement date and time. If the two sonic water level readings were not consistent, or the water level appeared to be incorrect based on well construction or regional hydrologic information, then the depth-to-water was measured solely with an electric water level indicator.

3 Conceptual Model of Hydrogeologic Conditions

3.1 Hydrostratigraphy

A generalized geologic history of the WRIA 30 subbasins, including Lower Klickitat subbasin, within which the Appleton study area occurs, is provided in the WRIA 30 Level 1 watershed assessment (WPN and Aspect, 2004). Based on that information and subsequent evaluation, hydrostratigraphic units within this study area include (from youngest to oldest):

- Alluvium (Qa);
- Landslide deposits (Qls);
- Missoula Flood deposits (Qfg/Qfs);
- Balch Lake basalt (QPLvb[bl]);
- Dalles Formation(Mc[d]);
- Wanapum basalt (Priest Rapids (Mv[wpr]), Roza (Mv[wr]), and Frenchman Springs (Mv[wfs]) members); and
- Grande Ronde basalt (Mv[g]).

Both the Wanapum and the Grande Ronde basalts are formations of the Columbia River Basalt Group (CRBG), which consisted of widespread extrusion of numerous basalt flows originating from vents located in the Pasco area (Bauer and Hansen, 2000). Sedimentary interbeds deposited between the individual basalt flows are collectively referred to as the Ellensburg Formation (Mc[e]).

The surface geology and geologic structures from Washington Department of Natural Resources (WDNR) 1:100,000 scale digital mapping are shown on Figure 3.1. Detailed hydrgeologic cross sections (Figures 3.2 and 3.3) were developed to better define the depth and distribution of the local hydrostratigraphic units, the presence of geologic structures (faults and folds), and the occurrence of water-bearing zones within the study area.

The cross sections were developed using well logs from Ecology’s well log database, WDNR geologic mapping, and available information from other studies. 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 the surface elevation from the USGS DEM. Appendix A provides a summary of the well completion details from the well logs in the study area used for developing cross sections and/or groundwater elevation contour maps.

3.1.1 Groundwater Occurrence

Groundwater in the study area generally occurs within the bedrock units of the Columbia River Basalt Group (CRBG). The Balch Lake basalt, not part of the CRBG, may also provide a limited source of groundwater, but it is of limited extent and located in the extreme southern region of the study area (Figure 3.1). The overlying unconsolidated deposits, including the alluvium, landslide deposits, Missoula Flood deposits, and the Dalles Formation are not considered to be significant aquifers due to the limited extent and thickness of these deposits and the limited number of wells completed within these respective units. Therefore, for the purposes of this assessment, the unconsolidated deposits (collectively termed the unconsolidated aquifer) were not included in the water level monitoring network.

Groundwater in the CRBG occurs primarily within the tops of the individual flows (flow tops) that became vesicular (porous) as gas bubbles escaped the flows during cooling, and/or within the fractured flow bottoms (sometimes referred to as pillows). Flow tops and bottoms – collectively 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.

In addition, terrestrial sediments can be deposited between the underlying flow top and overlying flow bottom during time periods between basalt flows. These sediments are collectively considered part of the Ellensburg formation (Mc[e]) and can be either relatively permeable or impermeable; depending on composition, thickness, and lateral extent (Brown, 1979).

The lateral continuity and thickness of the water-bearing interflow zones within the study area can be highly variable. This leads to variability in the depth and productivity of the water wells throughout the study area.

3.1.2 Hydrostratigraphic Unit Descriptions

The younger hydrostratigraphic units overlying the CRBG in the study area include (Figure 3.1): alluvium (Qa), landslide deposits (Qls), Missoula Flood deposits (Qfg/Qfs), Balch Lake basalt (QPLvb[bl]), and the Dalles Formation (Mc[d]). As previously discussed, these units are not expected to be a significant source of groundwater on the scale of the study area. The following sections provide a brief description of the hydrostratigraphic units found within the study area.

Alluvium

Within the study area, the alluvium can be highly variable in composition (ranging from clay to gravel), resulting from stream-channel, side stream, overbank, fan, and lacustrine deposits (Korosec, 1987). The only notable occurrence of alluvium within the study area is along the Klickitat River, in the eastern region of the study area (Figure 3.1). Smaller occurrences of alluvium can also be found in the upper reaches of Synder Swale, Simmons Creek, and Skookum Canyon. Groundwater occurrence within the alluvium is generally limited to the coarse-grained (sand and gravel) deposits. Very few wells are known to be completed solely in this unit.

Landslide Deposits

The landslide deposits consist of a poorly sorted mixture of fine-grained sediments interspersed with gravels and boulders (Korosec, 1987). These deposits are found in areas of steep topography near river or creek canyons. In the study area, landslide deposits can be found along the northern side of Snyder Creek canyon, and along the western side of the Klickitat River canyon (Figure 3.1). Due to the localized occurrence and heterogeneous consistency of these deposits, they are not expected to be a significant source of groundwater, and no wells are known to be completed in this unit.

Missoula Flood Deposits

The Missoula Flood deposits consist of both fine-grained (Qfs) and coarse-grained (Qfg) deposits from the Missoula floods, which occurred between 15,300 and 12,700 years ago. The fine-grained deposits consist of sand, silt, and clay deposited along backwater canyons, while the coarse-grained deposits consist of gravel and coarse sand that is poorly sorted and unstratified. These deposits are found at the surface in the southern region of the study area (Figure 3.1). Based on well logs for the area, the deposits can be as much 150 feet thick. One well located in T03N/R12E-28A and completed solely in the Missoula Flood deposits had a static water level of 90 feet bgs and a yield of 15 gallons per minute (gpm) with 30 feet of drawdown after 1 hour. A second well in the same area had a static water level of 32 feet bgs and a yield of 3.5 gpm for a period of 4 hours. Well yields within the Missoula Flood deposits can be highly variable, depending on the type of deposits. In addition, due to the limited extent, these deposits are not expected to be a significant source of groundwater on the scale of the study area.

Balch Lake Basalt

The Balch Lake basalt consists of a porphyritic, olivine basalt flow that may have originated in the Simcoe Mountains volcanic field to the northeast. The basalt likely consists of a single flow that has a thickness ranging between 10 and 60 feet (Korosec, 1987). This unit is found at the surface in several small areas in the southern region of the study area, overlying the Dalles Formation (Figure 3.1). Because this unit is limited in extent and found at local topographic highs, it is not expected to be a significant source of groundwater within the study area and no wells are known to be completed in this unit.

Dalles Formation

The Dalles Formation is found in the southwestern region of the study area (Figure 3.1). This unit consists of thickly bedded, gray, volcaniclastic and sedimentary deposits (Korosec, 1987), which can be as much as 365 feet thick in the study area. Based on the available wells logs, no wells in this area appear to be completed solely in the Dalles Formation, but there are numerous wells completed across the Dalles Formation and the underlying CRBG.

The Columbia River Basalt Group (CRBG)

The CRBG units in the study area have a collective thickness of several thousand feet. Except where eroded away along several drainages (Klickitat River, Snyder Creek, and Logging Camp Canyon), the Wanapum basalt is consistently present across the study area (Figure 3.1). In the areas where the Wanapum basalt is present, its thickness ranges from 250 to 600 feet (Figures 3.2 and 3.3). The Wanapum basalt consists of three separate members (from youngest to oldest): the Priest Rapids (Mv[wpr]), Roza (Mv[wr]), and Frenchman Springs (Mv[wfs]):

- The Priest Rapids member is generally exposed at the surface in the vicinity of local topographic highs, or to the southwest of an unnamed northwest-southeast trending normal fault in the southern region of the study area (Figure 3.1). Since the Priest Rapids member is not present over much of the study area, its thickness is unknown, but where present, the thickness is expected to be less than 300 feet, based on thicknesses to the east of the Klickitat River (High Prairie area).
- The Roza member is generally exposed at the surface to the southeast of the Bingen anticline, on the slopes to the west of the Klickitat River (Figure 3.1). Where present, the Roza member can be as much as 150 feet thick, based on the cross sections on Figures 3.2 and 3.3).
- The Frenchman Springs member is generally exposed at the surface to the west of the Roza member, or in the vicinity of major drainages and their respective tributaries. However, along the Klickitat River and parts of Snyder Creek and Logging Camp Canyon, the Frenchman Springs member is absent where the underlying Grande Ronde basalt is exposed at the surface. Where present, the Frenchman Springs member generally ranges between 200 and 600 feet in thickness across the study area (Figures 3.2 and 3.3).

Underlying the Wanapum basalt is the Grande Ronde basalt, which is the most laterally extensive and thickest of the CRBG formations, constituting 85 to 88 percent of the total volume of the CRBG (Vaccaro, 1999). The Grande Ronde basalt is present beneath the entire study area, but is generally exposed at the surface only at the base of deeply incised drainages (Klickitat River, Snyder Creek, and Logging Camp Canyon). As the cross sections indicate (Figures 3.2 and 3.3), there are numerous wells open to and withdrawing groundwater from both the Wanapum and Grande Ronde basalts, but very few wells are completed solely in the Grande Ronde, except where it is exposed at the surface. Based on the cross sections, one well completed solely in the Grande Ronde basalt is well T04N/R12E-9R1. Based on the well log, this well has a static water level of 550 feet bgs and a yield of 8 gpm for a period of 1 hour.

Ellensburg Formation

Sediments deposited between the various basalt flows are part of the Ellensburg formation. Where the sediments are coarse-grained (sand/gravel), they may transmit groundwater in usable quantity. However, because the composition, thickness, and extent of the interbeds 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. As previously discussed, water levels from the interflow zones are considered to be representative of the underlying basalt aquifer; therefore, for the purposes of this study the interflow zone is also considered to be part of the underlying basalt aquifer.

3.2 Geologic Structures

The major geologic structures (faults and folds) in the project area, taken from WDNR 1:100,000 geologic mapping, are identified on both the geologic map (Figure 3.1) and the cross sections (Figures 3.2 and 3.3). The major geologic structures within the study area are part of the Yakima Fold belt.

The Yakima Fold Belt formed from regional north-south compression that began during the deposition of the Grand Ronde basalt approximately 16 million years ago (Reidel et al., 1989). This compression resulted in the formation of the southwest-northeast trending folds (synclines and anticlines) and the associated reverse and thrust faults (older rocks are slid upward over younger rocks) found in the region. There are a series of southwest-northeast trending synclines and anticlines as you move north through the study area. These include the Mosier syncline in the southern region of the study area, the Bingen anticline in west-central region of the study area, and an unnamed anticline that extends through the northwestern region of the study area. The individual flows of the CRBG dip away from the axes of the anticlines and towards the axes of the synclines.

Superimposed upon the major southwest-northeast trending structures within the study area are numerous northwest-southeast trending normal faults (younger rocks are slid downward over older rocks) and strike-slip faults (rocks are slid laterally past each other), likely created from a rotational component of the same north-south compression that resulted in the southwest-northeast trending structures (Reidel et al., 1989). Within the study area, this includes several normal faults and right-lateral strike-slip faults. The normal faults are located in the southern region of the study area, with the northernmost fault likely having between 100 and 300 feet of vertical displacement, based on the geologic map (Figure 3.1). The two major right-lateral strike-slip faults include the Laurel fault, which extends through the center of the study area, and the Warwick fault, located along the northeastern boundary of the study area. In addition, there are two smaller right-lateral strike-slip faults located in the western region of the study area, to the southwest of the Laurel fault and to the northeast of the northern most normal fault (Figure 3.1).

In the subsurface, folds and faults may represent partial or complete barriers to lateral groundwater flow, laterally compartmentalizing flow within the study area. Newcomb (1961 and 1969) theorized that tight anticlinal folding of basalt forms breccia (broken rock) and fine-grained 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. In addition, due to the folding and upwarping of the individual flows in the creation of the anticlinal crest, higher heads are needed for groundwater to flow over this crest. Fault gouge may also decrease the transmissivity of the basalt units in the vicinity of both normal and reverse faults. If significant displacement occurs across these faults to offset the water-bearing interflow zones, the faults may act as impermeable barriers to lateral groundwater flow.

Although there is generally no vertical offset associated with strike-slip faults, fault gouge may impede groundwater flow across these faults. Based on groundwater levels and flow directions (Aspect, 2011), the Laurel fault was shown to be a low permeability barrier to groundwater flow within the CRBG to the east of the Klickitat River (High

Prairie area). In addition, in Swale Creek subbasin, the Warwick fault was also shown to be a barrier to groundwater flow based on mounding (hundreds of feet) of groundwater behind the fault (Aspect, 2007).

Therefore, based on these other local indications of both the Laurel and Warwick faults acting as low permeability barriers, it is assumed that these faults are also acting as low permeability barriers to groundwater flow within the Appleton study area. It is also assumed that this is the case with the smaller unnamed strike-slip faults located to the southwest of the Laurel fault and the northeast of the northernmost normal faults (western region of study area).

However, because groundwater flow directions within the study area generally parallel the northwest-southeast trend of the strike-slip faults (see Section 3.3.2), the faults may not be greatly impeding regional groundwater flow within the Appleton study area. In addition, there are also circumstances where strike-slip faults have not likely acted as barriers to groundwater flow. Neither the Snipes Butte nor the Goldendale faults, which are similar strike-slip faults father east of the Warwick Fault and are oriented generally perpendicular to the regional groundwater flow direction, were shown to act as complete barriers to groundwater flow. In both of these cases, lineaments associated with nearby synclines may provide a permeable conduit for groundwater flow across the low-permeability faults (Aspect, 2010b).

3.3 Groundwater Conditions

3.3.1 Unconsolidated Aquifer

As previously discussed, the surficial units of the unconsolidated aquifer are not expected to be a significant source of groundwater. Within the study area, the only wells completed solely within this aquifer were completed in the southern region of the study area (T03N/R12E-28A), in the Missoula Flood deposits. These wells had static water levels ranging between 30 and 90 feet bgs and yields of between 3.5 and 15 gpm, based on the well logs.

Due to the limited continuity and thickness of the unconsolidated aquifer and the limited number of wells completed within this aquifer, it is not possible to accurately determine groundwater flow directions for this aquifer. The scattered occurrences of the unconsolidated aquifer wells relative to the basalt aquifer wells also do not allow for a reliable determination of vertical gradients between the unconsolidated aquifer and the underlying basalt aquifers. However, in areas where unconsolidated materials rest upon a low-permeability flow interior (not a permeable interflow zone) of the underlying CRBG, it is expected that groundwater flow in the unconsolidated material will follow the subsurface topography of the bedrock, with springs often occurring at the downgradient extents of the unconsolidated aquifer (Piper, 1932). Conversely, in areas where the immediately underlying CRBG consists of relatively permeable interflow zones, it is expected that there is a downward gradient from the unconsolidated materials into the basalt, especially during the early part of the year when there is significant precipitation. Under these circumstances, recharge from the unconsolidated aquifer to the underlying basalt aquifers is expected.

3.3.2 Basalt Aquifers

As previously discussed, the Balch Lake basalt aquifer is not expected to be a significant source of groundwater, and no wells are known to be completed solely within this aquifer. Therefore, no interpretations of groundwater flow directions within this aquifer have been made. However, as with the unconsolidated aquifer, in areas where Balch Lake basalt overlies a low-permeability flow interior of the CRBG, it is expected that groundwater flow will follow the subsurface topography of the bedrock, with springs often occurring at the downgradient extents of the Balch Lake basalt aquifer. In areas where the immediately underlying CRBG consists of relatively permeable interflow zones, it is expected that there is a downward gradient from the Balch Lake basalt into the CRBG.

Based on Vaccaro (1999), regional groundwater flow within the Grande Ronde basalt and the CRBG in the study area is inferred to be to the southeast, towards the Klickitat River. Although Vaccaro (1999) does not provide an inferred groundwater flow direction for the overlying Wanapum basalt in the study area, it is assumed to be in a similar direction. In general, local groundwater flow within the CRBG is expected to be towards major surface water bodies, away from anticlinal axes and in the direction of the regional geologic dip of the basalt flows (Steinkampf, 1989). During the formation of an anticline, the compression of the various basalt flows leads to both the folding and uplift of the respective flows. Erosion of the upper flows will later expose the lower flows at the surface, thus allowing for the areal recharge of the respective flow. For this reason, groundwater generally flows away from these relatively high points of recharge and down the geologic dip.

Of the 12 wells in the current Appleton water level monitoring network, 11 wells are completed in (open to) the Wanapum basalt and 1 well is completed in the Grande Ronde basalt (Figure 2.1). Water levels from the interflow zones between the various members and formations of the CRBG are considered to be representative of the underlying basalt aquifer. As the cross sections illustrate (Figures 3.2 and 3.3), a majority of the wells within the study area are completed across multiple members of the Wanapum basalt (Priest Rapids, Roza, and Frenchman Springs), or across both the Wanapum and the Grande Ronde basalts. A well being “completed” in a specific aquifer zone(s) indicates that it is open to, thus assumed to be withdrawing groundwater from, that zone. A well that is cased across an aquifer zone is not considered to be completed within that zone. Therefore, for the purposes of this study, one groundwater elevation contour map is presented for the Wanapum basalt as a whole (Figure 3.4). In addition, since the Grande Ronde basalt generally has significantly lower groundwater levels than the Wanapum basalt, a second groundwater elevation contour map was created for the Grande Ronde basalt (Figure 3.5).

Figures 3.4 and 3.5 present the groundwater elevation contour maps for the Wanapum and Grande Ronde basalt aquifers, respectively, developed using April 2011 water level data from the monitoring network, supplemented by well log data (water levels at time of drilling). Since the well log water levels were collected over decades of time, and multiple seasons of the year (irrigation and non-irrigation), they reflect annual and seasonal changes in groundwater levels, in addition to errors associated with the well locations and DEM elevations. Therefore, the April 2011 water level monitoring network measurements from surveyed well locations (Table 2.1) were used to verify and supplement the historical data by gathering a basin-wide “snapshot” of groundwater levels over a relatively short (5-day) period of time. The data collected for this study are reliable data upon which interpretations of groundwater conditions are primarily based.

The resulting groundwater elevation contour maps represent an aggregate interpretation of the Wanapum and Grande Ronde basalt aquifer groundwater data. Due to the disparity in accuracy between the well log water levels and the 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 and Grande Ronde basalt aquifer groundwater flow systems on a basin scale. Most importantly, establishment of the water level monitoring network also allows for future monitoring to document seasonal or longer-term changes in the groundwater flow system.

3.3.2.1 Groundwater Flow Directions

Based on the study area groundwater elevation contour maps (Figures 3.4 and 3.5), groundwater flow directions within the apparent fault-bounded blocks of the Wanapum and Grande Ronde basalt aquifers are:

- to the south-southeast (towards the Klickitat River), east of the Warwick fault;
- to the southeast (towards the Klickitat River), west of the Warwick fault and east of Laurel fault; and
- to the south-southeast (towards the Klickitat River), west of Laurel fault and the NW-SE trending unnamed normal fault in the southern portion of the study area.

Continuity of groundwater with study area streams is described in Section 3.6.

While a regional groundwater flow regime is defined from the groundwater elevation contour maps, there are numerous folds and faults within the study area (Figure 3.1), which can act as local barriers to groundwater flow (Section 3.2). In addition, the Appleton area is crosscut by numerous incised drainages (Skookum Canyon, Snyder Creek, Kuhnhausen Creek, Logging Camp Canyon, and Silva Creek) which intersect the CRBG interflow zones and likely collect groundwater discharge where the streambed elevation is lower than the groundwater elevation in the basalt aquifers. Consequently, the CRBG aquifer zones within the study area are “compartmentalized” by geologic structures and topography (incised drainages). This geologic situation can hydraulically isolate individual CRBG aquifer “blocks” from the rest of the aquifer, limiting its recharge area to within the footprint of the aquifer “block”.

Based on the groundwater elevation contour maps, the following sections provide a brief description of local groundwater flow directions within the study area, which are controlled in part by the numerous geologic structures and incised drainages.

East of Warwick Fault

East of the Warwick fault, wells are completed both in the Wanapum and the Grand Ronde basalts. Groundwater in this portion of the study area generally discharges to

Skookum and Wahkiacus Canyons, and eventually the Klickitat River. As previously mentioned in Section 3.2, due to the groundwater flow direction paralleling the trend of the Warwick fault, it is not possible to confirm that the fault is acting as a barrier to groundwater flow. However, the Warwick fault has been show to act as a barrier to groundwater flow in nearby Swale Creek subbasin (Aspect, 2007b).

There is one unique portion of the Warwick fault where a large spring discharges from the Grand Ronde basalt and was reportedly used by early settlers since the early 1900s (Brown, 1979). Klickitat springs, located near the intersection of the Warwick fault and the Klickitat River, has high dissolved solids and carbon dioxide, and has been historically used for commercial bottled water production and dry ice manufacturing. The source of this water is interpreted to be upward flow from deeper aquifer units along fault traces.

West of Warwick Fault

West of the Warwick fault, wells are again completed in both the Wanapum and the Grand Ronde basalts. Groundwater in this portion of the study area generally discharges to Snyder Creek and eventually the Klickitat River.

West of Laurel Fault

West of the Laurel fault, the Bingen anticline appears to act as a groundwater divide in both the Wanapum and the Grande Ronde basalt aquifers. Groundwater flow to the north of the Bingen anticline, in an area known locally as Timber Valley, is to the north-northeast, towards a tributary to Snyder Swale. South of the Bingen anticline, groundwater flows to the south-southeast, discharging into several incised surface water drainages (Logging Camp Canyon and Silva Creek) and ultimately the Klickitat River.

West of Unnamed Normal Fault (Southern Study Area)

In the southern portion of the study area, there is an unnamed normal fault exhibiting 100 to 300 feet of vertical displacement (Figure 3.1). The significant vertical displacement and groundwater elevation differences on the order of 200 feet across the fault suggest that it is a barrier to groundwater flow. Groundwater flow to the west of the normal fault is to the south-southeast, discharging to Silva Creek, the Klickitat River, and an unnamed surface water drainage along Canyon Road (west of Silva Creek).

3.3.2.2 Vertical Gradients

Because many of the wells within the study area are completed across multiple members of the Wanapum basalt or across both the Wanapum and the Grande Ronde basalts, it is difficult to determine exact vertical gradients between individual aquifer zones. However, the groundwater levels on the cross sections (Figures 3.2 and 3.3) generally indicate a downward vertical gradient – i.e., the groundwater levels of the wells completed in the upper flows of the CRBG are generally higher than the groundwater levels of the wells completed in the lower flows. Based on the cross sections and the groundwater elevation contour maps (Figure 3.4 and 3.5), groundwater levels are between 250 and 400 feet lower in the Grande Ronde basalt compared to the Wanapum basalt.

3.4 Aquifer Hydraulic Parameters

Table 3.1 presents a summary of both regional and local aquifer hydraulic parameters, including lateral hydraulic conductivity, transmissivity and storativity. 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), and are provided in Table 3.1. Estimates of lateral hydraulic conductivity were initially based on specific capacity data (pumping rate divided by drawdown; unit of gpm/ft) from select well logs. Values for a well's specific capacity 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)

The Q/s term is the well's specific capacity as defined above. Because drawdown increases with pumping duration, the specific capacity is typically defined for a specific pumping time.

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). A summary of these results are also provided in Table 3.1.

More localized hydraulic parameters for the Wanapum basalt aquifers within the study area were estimated based on the specific capacity data from wells within the study area. Only three well logs within the study area provide suitable pump test data (pumping rate and drawdown) for the estimation of hydraulic parameters. The aquifer transmissivity estimates from these specific capacity data are summarized in Table 3.1. The relatively limited specific capacity data indicate relatively low aquifer productivity, with transmissivities ranging between 28 and 103 ft^2/day (210 to 770 gpd/ft). However, this low productivity can be attributed to well construction (well loss) in addition to the aquifer's transmissivity. It important to note that the productivity of the basalt aquifers can be highly variable due to the presence of nearby geologic structures (folds and faults), and the nature and extent of the interflow zones.

3.5 Long-Term Water Level Trends

The measured groundwater levels over time (groundwater elevation hydrographs) for the Appleton study area are illustrated on Figure 3.6. Due to the limited number of groundwater level measurements collected to date (2 pre-irrigation and 1 post-irrigation monitoring events), no interpretations of the long-term water level trends will be made as part of this water availability study. Contingent upon continued funding, both pre-irrigation and post-irrigation water level measurements will continue to be collected, and subsequent interpretations of long-term water level trends will be included in the annual reports summarizing the water level monitoring activities.

3.5.1 Precipitation Trends

An analysis of long-term precipitations trends was performed in order to determine potential impacts on groundwater levels within the study area. Precipitation data from the National Oceanic and Atmospheric Administration (NOAA) weather observation station in Glenwood (Station No. 452184-6), was used to determine precipitation trends for the study area. Although there is a NOAA weather observation station in Appleton (Station No. 450217), the period of record for this station was from June 1959 to October 2006, and there were numerous missing readings. Therefore, based on location, elevation, and surrounding topography, the Glenwood station is assumed to be the most representative of the actual precipitation for the study area. Brown (1979) also provided a distribution of mean (average) annual precipitation for Klickitat County, which confirms this. Glenwood has a mean annual precipitation of 29.7 inches for the station’s period of record (1979 - 2010). The basin-scale water balance (Section 4) assumes an average annual precipitation of 24 inches/year for the study area as a whole, based on regional climatic modeling results; however, the regional modeling does not provide annual precipitation values over time, which is needed for the precipitation trend analyses, therefore the Glenwood data are used here.

The upper half of Figure 3.7 presents both the annual precipitation and the 29.7-inch mean annual precipitation for the period of record. In addition, a cumulative departure from the mean annual precipitation is presented in the lower half of Figure 3.7. The cumulative departure analysis adds the inches above or below the average precipitation for each year into a running total, and thereby illustrates longer-term drought or wet periods. 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.

Over the last 10 years, the annual precipitation in the Glenwood area was significantly below average (more than 5 inches) during calendar years 2005 and 2010, but significantly above average in 2006 (about 12 inches) and slightly above average in 2007 (about 1 inch). Although the precipitation has historically fluctuated significantly around the mean annual precipitation, there has not recently been a consistent period of either significantly below or above average precipitation in the area. Therefore, it seems unlikely that there would be a long-term response in groundwater levels in the Appleton area associated with precipitation trends over the past decade.

3.6 Interaction of Groundwater and Surface Waters

3.6.1 Springs and Creeks

Based on Newcomb (1969) and United States Geological Survey 1:24,000 scale topographic maps, there are several springs located along incised drainages and steep bedrock exposures within the study area (Figures 3.4 and 3.5). These springs occur where streams and rivers have incised into and exposed the basalt interflow zones at the surface. Based on the geologic map (Figure 3.1), this likely includes: the Klickitat River, Wahkiacus Canyon, Skookum Canyon, Synder Creek, Kuhnhausen Creek, Logging Camp Canyon, Silva Creek, and the unnamed surface water drainage west of Silva Creek. In addition to the mapped springs, the cross sections (Figures 3.2 and 3.3) illustrate that these drainages should have springs discharging from the deeper members of the Wanapum basalt in their upstream portions (i.e. interflow zones within the Roza and Frenchman Springs members intersect the drainages). In addition, within the deeply incised Klickitat River and the downstream portions of Snyder and Logging Camp Canyon, there may also be springs discharging from the upper flows of the Grande Ronde basalt.

Based on the above discussion, the source of water for the smaller drainages in the study area is likely a combination of precipitation runoff and groundwater discharge from the various basalt interflow zones. There is groundwater continuity with these creeks, but the quantity of spring discharge is not sufficient to maintain perennial baseflow throughout their lengths. Groundwater interactions with the Klickitat River are discussed in the following section.

3.6.2 Klickitat River

The Klickitat River forms the eastern extent of the Appleton study area (Figure 2.1). In addition to precipitation runoff, the river receives spring discharge from the deeper interflow zones of the Wanapum basalt and the upper flows of the Grande Ronde basalt. Most of this spring discharge occurs via the incised streams discussed in Section 3.6.1 (e.g., Synder Creek).

As cross sections to the east of the Klickitat River, in the High Prairie area, have illustrated (Aspect, 2011), the Klickitat River is in direct hydraulic continuity with flows lower down in the Grand Ronde basalt sequence. Based on groundwater level data from available well logs adjacent to the Klickitat River, the river appears to be a slightly losing to slightly gaining[3] stream adjacent to the study area.

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[3] A losing stream discharges water to the groundwater system, whereas a gaining stream receives water (baseflow) from groundwater.

4 Water Balance

For this assessment, we prepared a basin-scale water balance representing current conditions for the High Prairie study area, using the same general methodologies applied in the prior water availability assessments for Swale and Little Klickitat subbasins of WRIA 30 (Aspect, 2007 and 2010b) and the WRIA 31 Level 1 Watershed Assessment (Aspect and WPN, 2004). Appendix B details the water balance methods and assumptions.

Based on the proportion of water rights (certificates + permits) appropriated for the study area (as recorded in Ecology's Water Rights Tracking System [WRTS]), we estimate that approximately 95% of the total water use in the study area is supplied by groundwater, with 4% from smaller streams and 1% from the Klickitat River[4]. The accuracy and validity of the water rights information in Ecology's WRTS is not known, and the recorded water right information may overstate surface water use within the study area.

The Klickitat wastewater treatment plant treats wastewater generated within the Town of Klickitat (residential and non-residential uses), and discharges treated effluent to the Klickitat River (treated as an export from the study area). Outside of the Town of Klickitat, treatment of residential wastewater in the study area is accomplished via septic tanks, so that water that is used but not consumed (return flow) is returned to the groundwater system as artificial recharge or to surface water via runoff.

Using the water balance analysis, we estimate an average annual total water use within the study area of approximately 134 acre-feet/year; of this total use, an estimated 43 acre-feet/year (32%) consumed while the remaining 91 acre-feet/year (68%) is return flow. The return flow is estimated to provide 56 acre-feet/year of additional groundwater recharge and 35 acre-feet/year of discharge to the Klickitat River via the Klickitat wastewater treatment plant. Based on the collective information, we estimate that approximately 90% of the water use in the study area is for residential supply, with nearly half of that use being via permit-exempt private wells.

The water balance estimates that the annual consumptive groundwater use is less than 1 percent of the annual groundwater recharge from precipitation for the study area as a whole. This calculation "nets out" recharge of return flow from groundwater use, so the net water input and output for the groundwater system can be compared.

However, as is common in WRIA 30, the study area's basalt aquifers are compartmentalized, as described in Section 3, and the volume of groundwater production is not uniformly distributed across the study area. Documenting groundwater use versus recharge for localized areas would require considerable additional information and is

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[4] Several recorded Klickitat River water rights are excluded from this analysis because they are not currently in use, or are for fish rearing purposes, so are not imported and used within the study area (refer to Appendix B).

beyond the scope of this basin-scale study. Instead, a water level monitoring network has now been established for the study area, and continued monitoring of water levels, particularly in areas of greater population density and groundwater production, will provide the best indication (empirical) regarding sustainability of current pumping, and capacity to accommodate additional future withdrawals (i.e. groundwater availability for appropriation).

5 Conclusions and Recommendations

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

- The primary source of water supply for the study area is groundwater withdrawal from the Columbia River Basalt Group. Surface water is estimated to supply roughly 6 percent of the total annual water use.
- The Columbia River Basalt Group consists of the Wanapum and Grande Ronde basalt formations within the study area, which are further subdivided into individual members. Aquifer zones occur in vertically distinct interflow zones within each member. Based on the available data, groundwater levels appear to be between 250 and 400 feet deeper in the Grande Ronde basalt aquifers than in the shallower Wanapum basalt aquifers.
- The Wanapum basalt aquifers are the primary source of groundwater supply for the study area as a whole, with lesser supplies from the deeper Grande Ronde basalt.
- Where data were sufficient, groundwater elevation contour maps were created for both the Wanapum and the Grande Ronde basalt aquifers. Groundwater flow within these aquifers is generally to the southeast or south-southeast, towards the Klickitat River. Within the study area, the major geologic faults likely act as low permeability barriers to lateral groundwater flow.
- Springs discharge into the tributaries of the Klickitat River from the interflow zones of the Wanapum basalt. In areas of more deeply incised drainages (Snyder and Logging Camp Canyon), springs likely also discharge from the upper flows of the deeper Grande Ronde basalt. To better assess groundwater-surface water continuity in important tributary creeks (e.g., Skookum Canyon, Snyder, Logging Camp Canyon and Silva), we recommend installation, calibration, and long-term operation of streamflow gages on one or more of these creeks.
- Groundwater elevation monitoring has been conducted twice a year (spring and fall) since the Appleton area monitoring network was created in the Spring of 2010. Three rounds of measurements have been collected from the monitoring network to date (2 pre-irrigation and 1 post-irrigation monitoring events), so it is too early to assess groundwater level trends over time within the study area.
- On the scale of the entire study area, the annual quantity of consumptive groundwater use is less than 1 percent of the annual groundwater recharge including return flow from water use. This suggests that additional groundwater is available for appropriation and use within the study area. However, the analysis assumes uniform distribution of groundwater recharge and groundwater pumping across the entire study area; it does not account for localized pumping. In addition, potential for impairment to senior water rights may need to be determined individually for pending water right applications.

- An estimated 35 acre-feet/year of water is discharged to the Klickitat River from return flow from the Town of Klickitat via the Klickitat wastewater treatment plant (supplied by groundwater wells).
- A groundwater level 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 system of the Appleton study area. Evaluation of long-term groundwater level trends provides key empirical information regarding sustainability of groundwater production in the study area, and thus availability of additional groundwater for supply purposes. It is critical to continue monitoring to track long-term trends in water levels, particularly given the apparent compartmentalized nature of the basalt aquifers within the study area. Efforts can continue to increase well owner participation in the monitoring program to provide more complete spatial coverage of the study area.

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Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of WRIA 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.

Table 2.1 - Groundwater Level Monitoring Network

Appleton Water Availability Study
WRIA 30, Washington

Ecology Well Log Data								Well Survey Data				
Ecology Well Log ID	**Map Location**	**TRS Label**	**Well Log Date**	**Dia. (in)**	**Depth (ft)**	**Static Water Level (ft bgs)**	**Unit of Completion**	**Northing[1] (SPS 83; ft)**	**Easting[1] (SPS 83; ft)**	**Top of Casing Elevation[2] (ft MSL)**	**Casing Stick-up (ft)**	**Comments**
556413	27N1	T04/R12-27N1	8/16/08	6	310	50	Wanapum	174435.66	1437679.82	2381.92	1.9	Sonic sounder provides accurate measurement.
377246	3M2	T03/R12-3M2	7/10/95	6	425	260	Wanapum	160785.24	1437744.88	1834.54	2.5	Sonic sounder does not provide accurate measurement.
N/A	3M3	T03/R12-3M3	N/A	6	N/A	N/A	Wanapum	160906.05	1437744.90	1826.36	2.4	Sonic sounder provides accurate measurement. Well located on Tax Parcel 03120300002500. Owner reports well completed to same depth as 3M2.
143971	21G1	T04/R12-21G1	7/28/92	6	90	15	Wanapum	190010.54	1441497.08	2190.50	1.1	Sonic sounder does not provide accurate measurement.
379451	21G2	T04/R12-21G2	3/26/04	6	180	22	Wanapum	189899.01	1442101.03	2189.27	1.8	Sonic sounder does not provide accurate measurement.
141805	34B1	T04/R12-34B1	10/16/79	6	110	29	Wanapum	169614.98	1439494.94	2109.34	0.7	Sonic sounder provides accurate measurement.
407050	26C1	T04/R12-26C1	4/6/05	6	288	40	Wanapum	175447.03	1442752.65	2246.50	1.7	Sonic sounder provides accurate measurement.
413153	3Q4	T03/R12-3Q4	7/8/05	6	470	170	Grand Ronde	160917.50	1439389.34	1821.91	2.1	Sonic sounder does not provide accurate measurement.
317875	10Q4	T04/R12-10Q4	8/15/01	6	350	175	Wanapum	186199.94	1440242.20	2449.70	1.7	
369681	9R1	T04/R12-9R1	8/29/03	6	825	550	Wanapum	188578.46	1435807.67	2421.49	1.9	Sonic sounder provides accurate measurement.
452260	2A1	T03/R12-2A1	4/17/06	6	150	68	Wanapum	164321.77	1445873.21	1970.29	1.8	Sonic sounder provides an accurate measurement.
335142	3R5	T03/R12-3R5	4/16/02	6	185	8	Wanapum	159207.59	1441549.57	1695.04	1.8	Sonic sounder does not provide accurate measurement.

Notes:

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

[2] All elevations are in NAVD 1988 datum.

Table 2.2 - Monitoring Network Groundwater Level Data

Appleton Water Availability Study
WRIA 30, Washington

Ecology Well Log Data				April 2010 Measurements			November/December 2010 Measurements			April 2011 Measurements		
Ecology Well Log ID	**Map Location**	**TRS Label**	**Unit of Completion**	**Depth to Water[3] (ft bTOC)**	**GW Elevation[2] (ft MSL)**	**Comments**	**Depth to Water[3] (ft bTOC)**	**GW Elevation[2] (ft MSL)**	**Comments**	**Depth to Water[3] (ft bTOC)**	**GW Elevation[2] (ft MSL)**	**Comments**
556413	27N1	T04/R12-27N1	Wanapum	42.18	2339.74		52.6	2329.32		64.5	2317.42	
377246	3M2	T03/R12-3M2	Wanapum	165.75	1668.79	Rising water level	170.17	1664.37	Rising water level	168.1	1666.44	Rising water level
N/A	3M3	T03/R12-3M3	Wanapum	162.88	1663.48		163.43	1662.93		162.59	1663.77	
143971	21G1	T04/R12-21G1	Wanapum	5.76	2184.74		10.44	2180.06			2190.50	
379451	21G2	T04/R12-21G2	Wanapum	8.62	2180.65		7.54	2181.73			2189.27	
141805	34B1	T04/R12-34B1	Wanapum	18.93	2090.41		22.8	2086.54		18.8	2090.54	
407050	26C1	T04/R12-26C1	Wanapum	18.26	2228.24		24.6	2221.90		18.3	2228.20	
413153	3Q4	T03/R12-3Q4	Grand Ronde	125.08	1696.83	Rising water level	126.58	1695.33		122.44	1699.47	Rising water level
317875	10Q4	T04/R12-10Q4	Wanapum	-	-		68.09	2381.61		51.20	2398.50	
369681	9R1	T04/R12-9R1	Wanapum	381.98	2039.51		358.86	2062.63		368.25	2053.24	
452260	2A1	T03/R12-2A1	Wanapum	15.90	1954.39		-	-		-	-	Rising water level
335142	3R5	T03/R12-3R5	Wanapum	2.28	1692.76		6.58	1688.46		3.62	1691.42	

Notes:

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

[2] All elevations are in NAVD 1988 datum.

[3] Sonic measurements recorded to nearest 0.1 ft, electric tape measurements recorded to nearest 0.01 ft.

Table 3.1 - Hydraulic Parameter Estimates for Basalt Aquifers

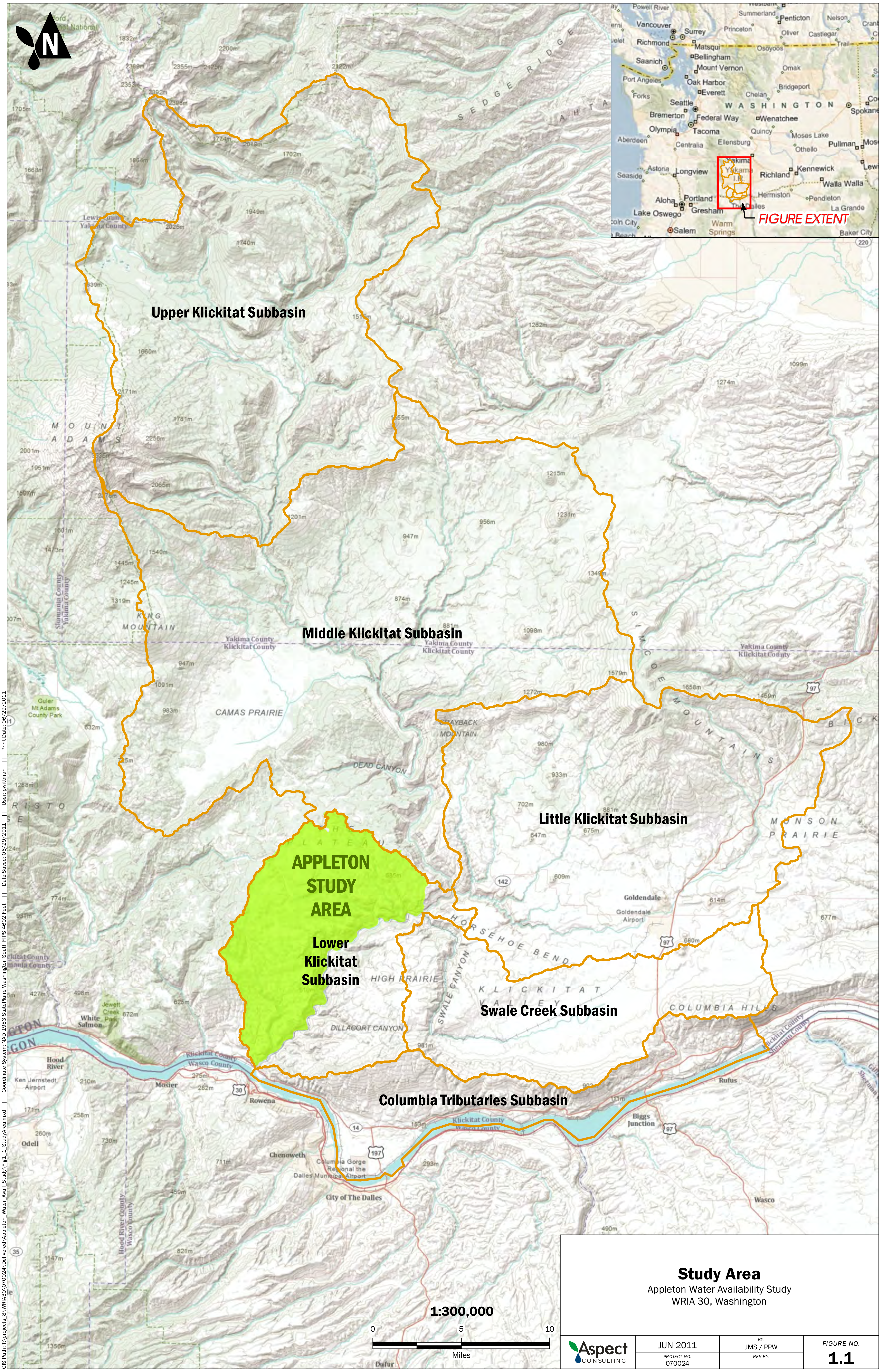
Appleton Water Availability Study
WRIA 30, Washington

Wanapum Basalt

Hydraulic Conductivity (ft/day)			Transmissivity (ft^2/day)			Storativity (Dimensionless)			Location	Ecology Well ID	Aquifer	Data Type	Source
Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean					
0.087	8	3	4	9331	1339	2.E-06	1.E-04	3.E-05	Columbia Plateau Aquifer System	-	-	Model	Vacarro, 1999; Whiteman et. al, 1994
0.007	5244	66	-	-	-	-	-	-	Columbia Plateau Aquifer System	-	-	Specific Capacity	Vacarro, 1999
0.864	3	-	-	-	-	-	-	-	Appleton Area	-	-	Model	Hansen, Vacarro and Bauer, 1994
-	-	-	-	-	102	-	-	-	T03/R12-10P	452301	Wanapum (Frenchman Springs)	Specific Capacity (Well Log)	Department of Ecology Well Log Database
-	-	-	-	-	28	-	-	-	T03/R12-10N	149034	Wanapum (Frenchman Springs)	Specific Capacity (Well Log)	Department of Ecology Well Log Database
-	-	-	-	-	103	-	-	-	T03/R12-4E	146427	Wanapum (Frenchman Springs)	Specific Capacity (Well Log)	Department of Ecology Well Log Database

Upper Grande Ronde Basalt

Hydraulic Conductivity (ft/day)			Transmissivity (ft^2/day)			Storativity (Dimensionless)			Location	Ecology Well ID	Aquifer	Data Type	Source
Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean					
0.130	9	2	41	15898	3672	6.E-06	1.E-03	2.E-04	Columbia Plateau Aquifer System	-	-	Model	Vacarro, 1999; Whiteman et. al, 1994
0.005	2523	50	-	-	-	-	-	-	Columbia Plateau Aquifer System	-	-	Specific Capacity	Vacarro, 1999
0.864	2	-	-	-	-	-	-	-	Appleton Area	-	-	Model	Hansen, Vacarro and Bauer, 1994

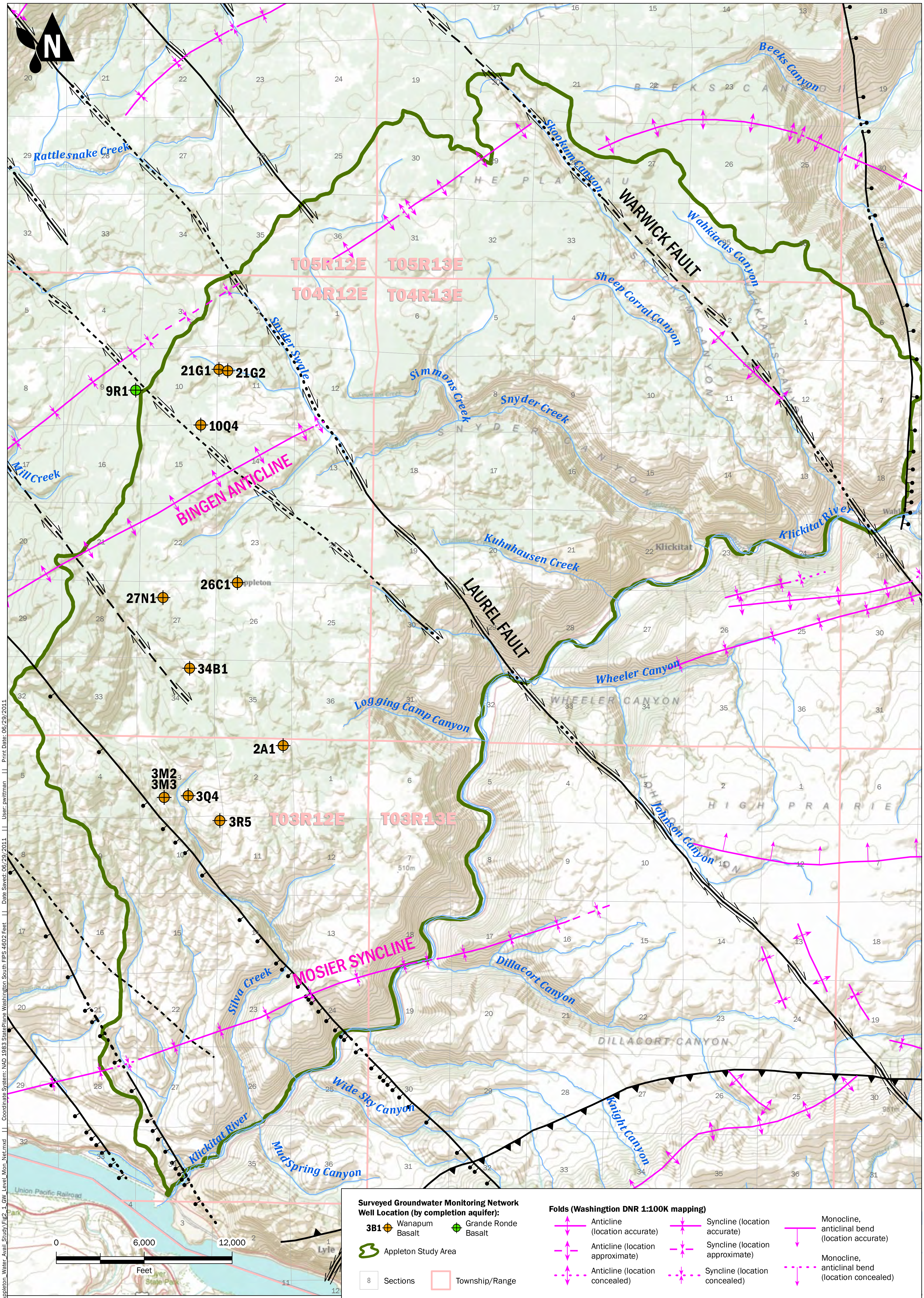


Study Area

Appleton Water Availability Study
WRIA 30, Washington

Aspect CONSULTING	JUN-2011	BY: JMS / PPW	FIGURE NO.
	PROJECT NO. 070024	REV BY: - - -	1.1

GIS Path: T:\projects_8\WRIA30\070024\Delivered\Appleton_Water_Avail_Study\Fig1_1_StudyArea.mxd || Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet || Date Saved: 06/29/2011 || User: pwittman || Print Date: 06/29/2011



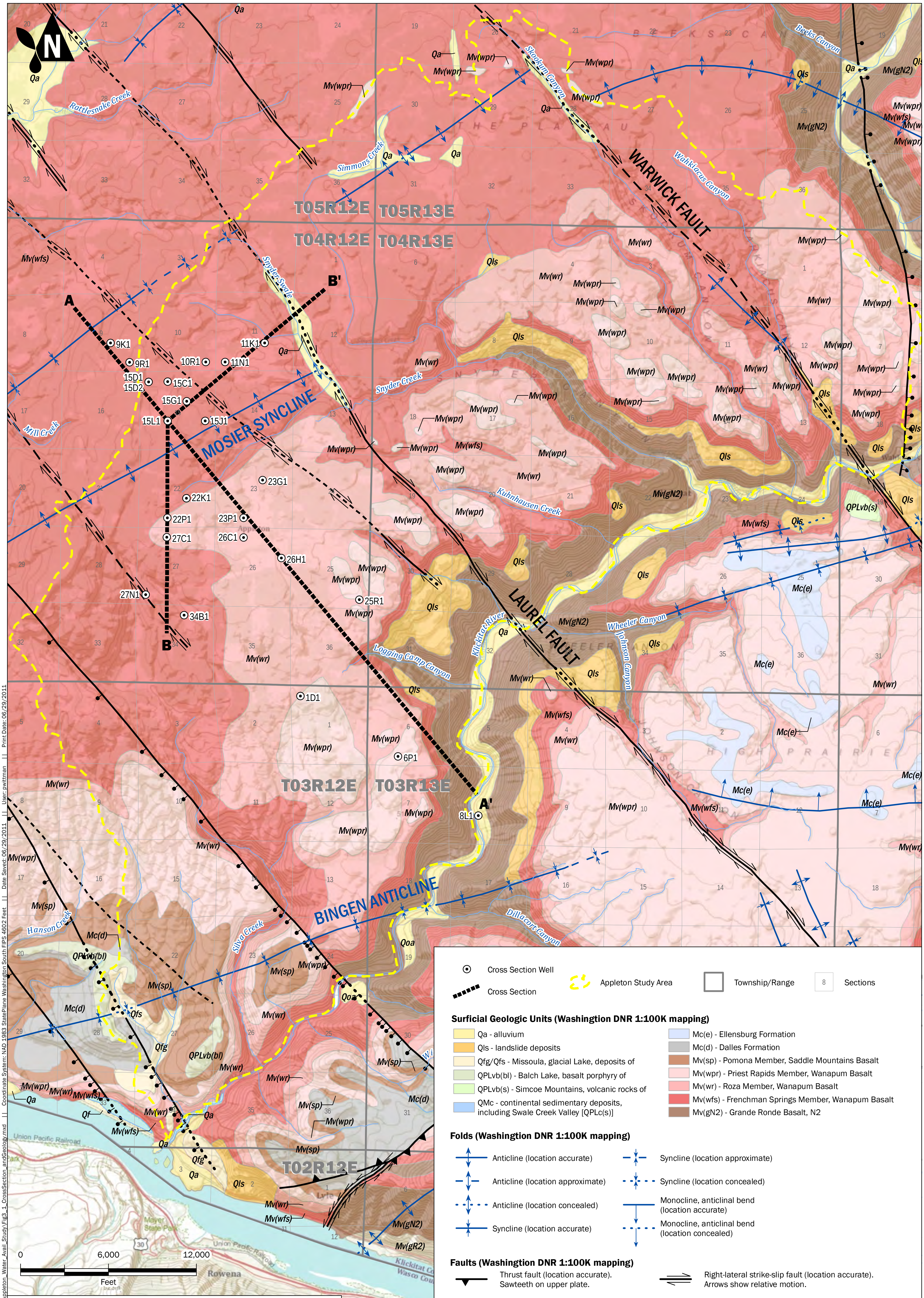
Groundwater Level Monitoring Network

Appleton Water Availability Study
WRIA 30, Washington

Aspect CONSULTING

JUN-2011	BY: DFR/PPW	FIGURE NO. 2.1
PROJECT NO. 070024	REV BY: - - -	

GIS Path: T:\projects_8\WRIA30\070024\Delivered\Appleton_Water_Avail_Study\Fig2_1_GW_Level_Mon_Net.mxd || Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet || Date Saved: 06/29/2011 || User: pwittman || Print Date: 06/29/2011



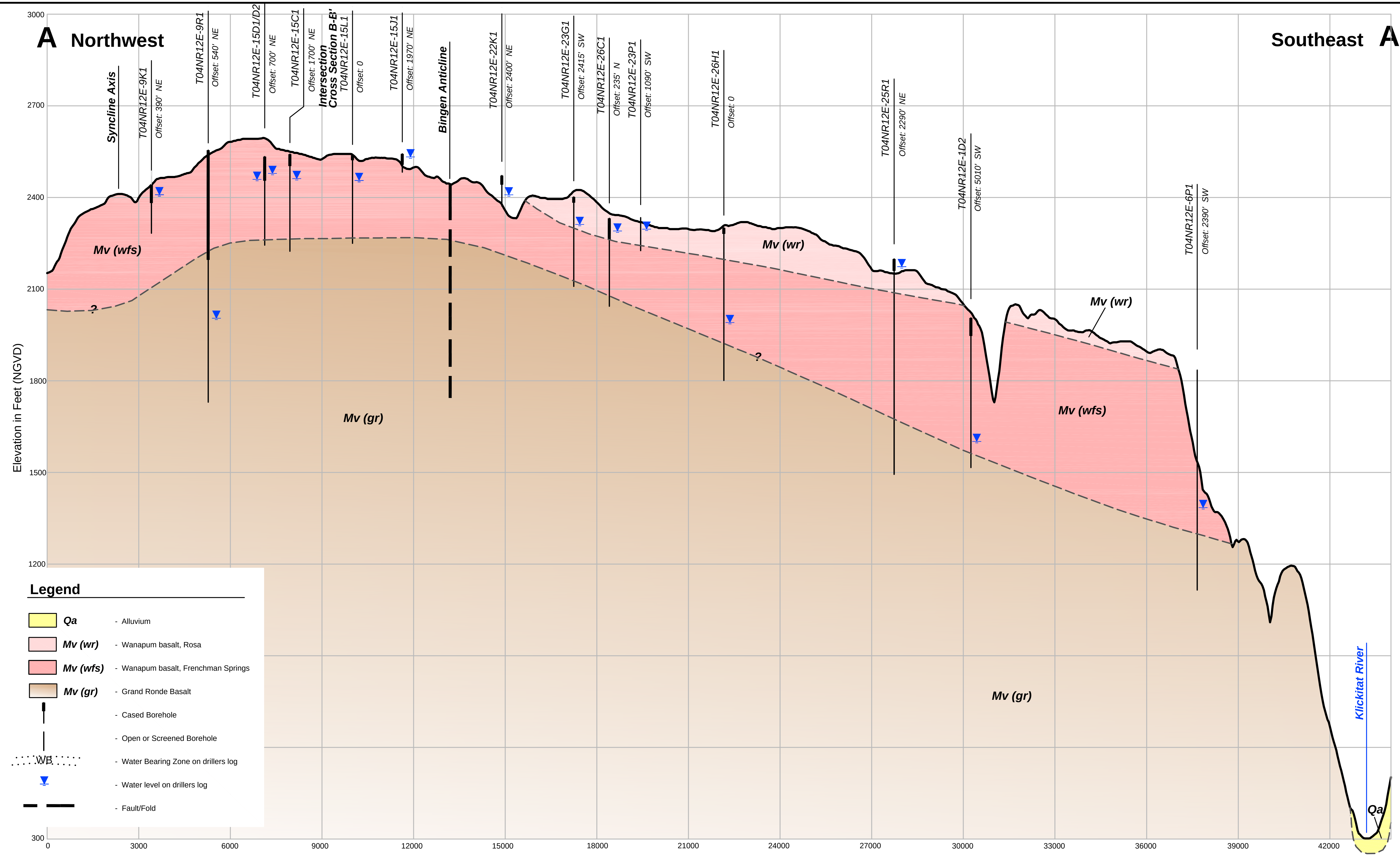
Cross Section Location and Geologic Map

Appleton Water Availability Study
WRIA 30, Washington

Aspect CONSULTING

JUN-2011	BY: DFR/PPW	FIGURE NO.
PROJECT NO. 070024	REV BY: - - -	3.1

GIS Path: T:\projects_8\WRIA30\070024\Delivered\Appleton_Water_Avail_Study\Fig3_1_CrossSection_andGeology.mxd || Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet || Date Saved: 06/29/2011 || User: pwittman || Print Date: 06/29/2011



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

0 3,000 6,000
Feet

Aspect CONSULTING

Cross Section A-A'
Appleton Area

WRIA 30 Water Availability Study

Klickitat County, Washington

DATE: June 2011
DESIGNED BY: AAE/JMS/DHR
DRAWN BY: PMB
REVISED BY:

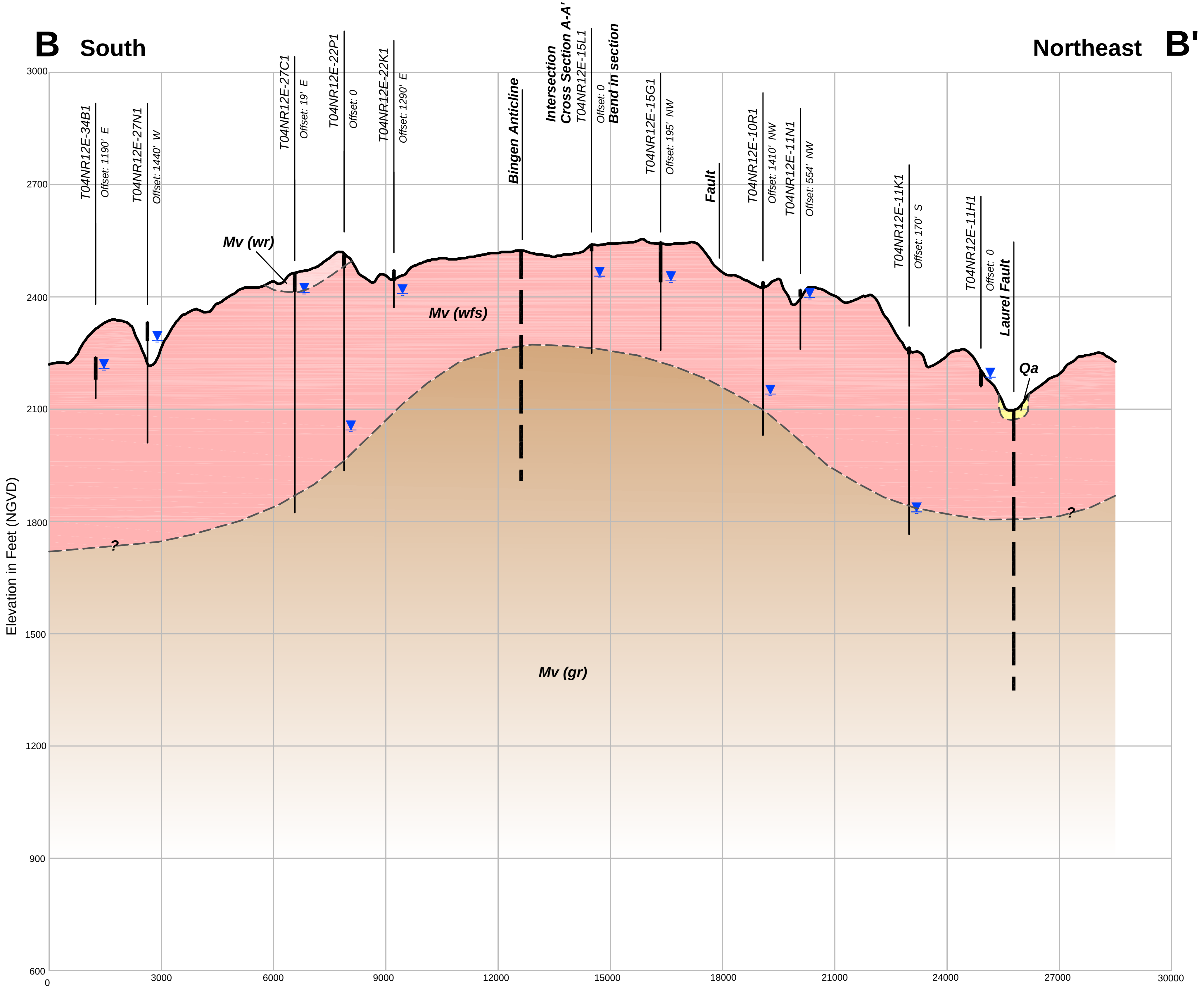
PROJECT NO. 070024

FIGURE NO. 3.2

Q:\WRIA\070024 WRIA 30\2011-06 Appleton\070024-AA.dwg

Legend

- 🟨 **Qa** - Alluvium
- ▭ **Mv (wr)** - Wanapum basalt, Rosa
- 🟥 **Mv (wfs)** - Wanapum basalt, Frenchman Springs
- 🟫 **Mv (g)** - 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

Cross Section B-B'
Appleton Area

WRIA 30 Water Availability Study

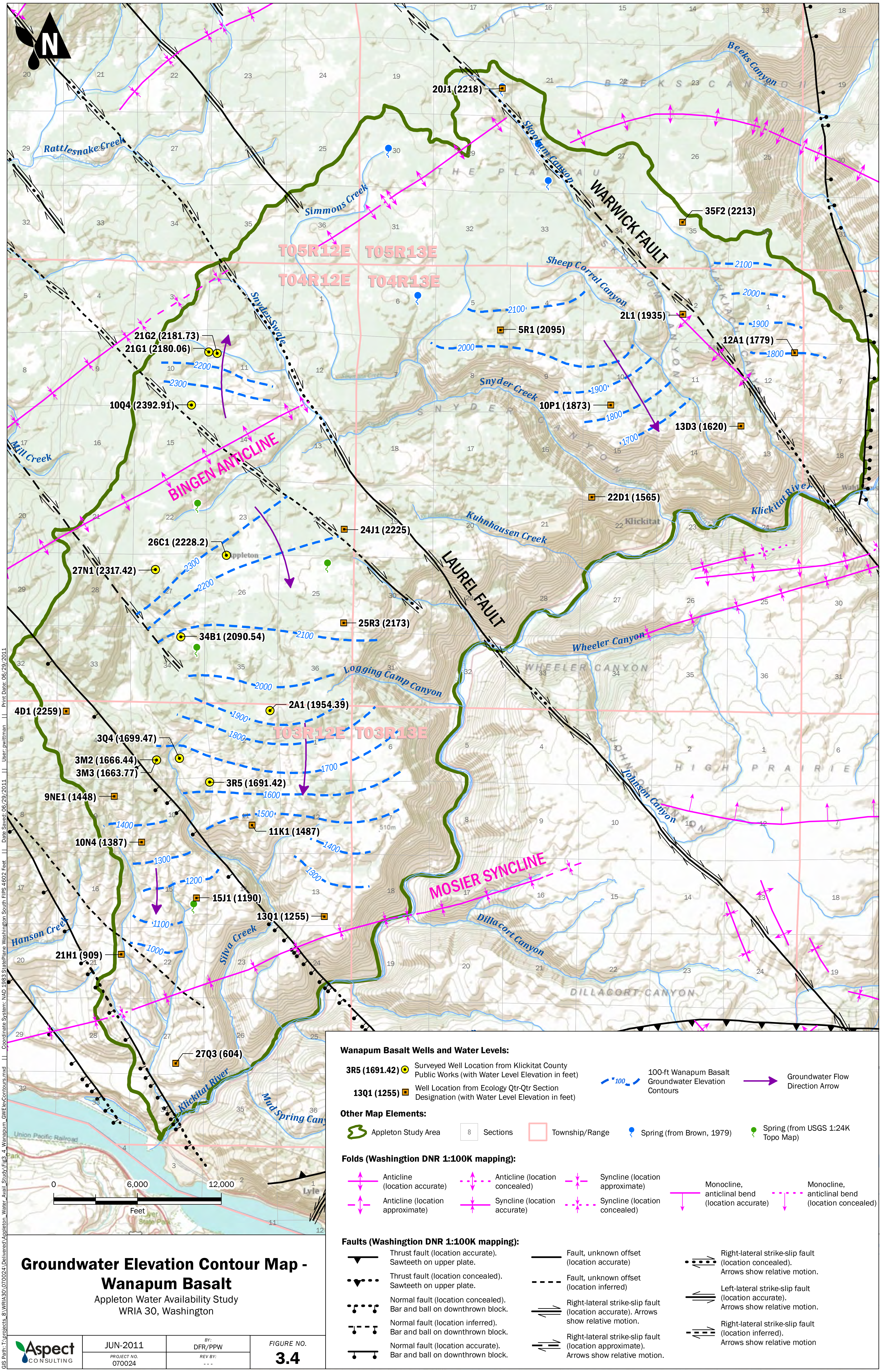
Klickitat County, Washington

DATE:	June 2011
DESIGNED BY:	AAE/JMS/DHR
DRAWN BY:	PMB
REVISED BY:	

PROJECT NO.
070024

FIGURE NO.
3.3

Q:\WRIA\070024 WRIA 30\2011-06 Appleton\070024-BB.dwg



Groundwater Elevation Contour Map - Wanapum Basalt

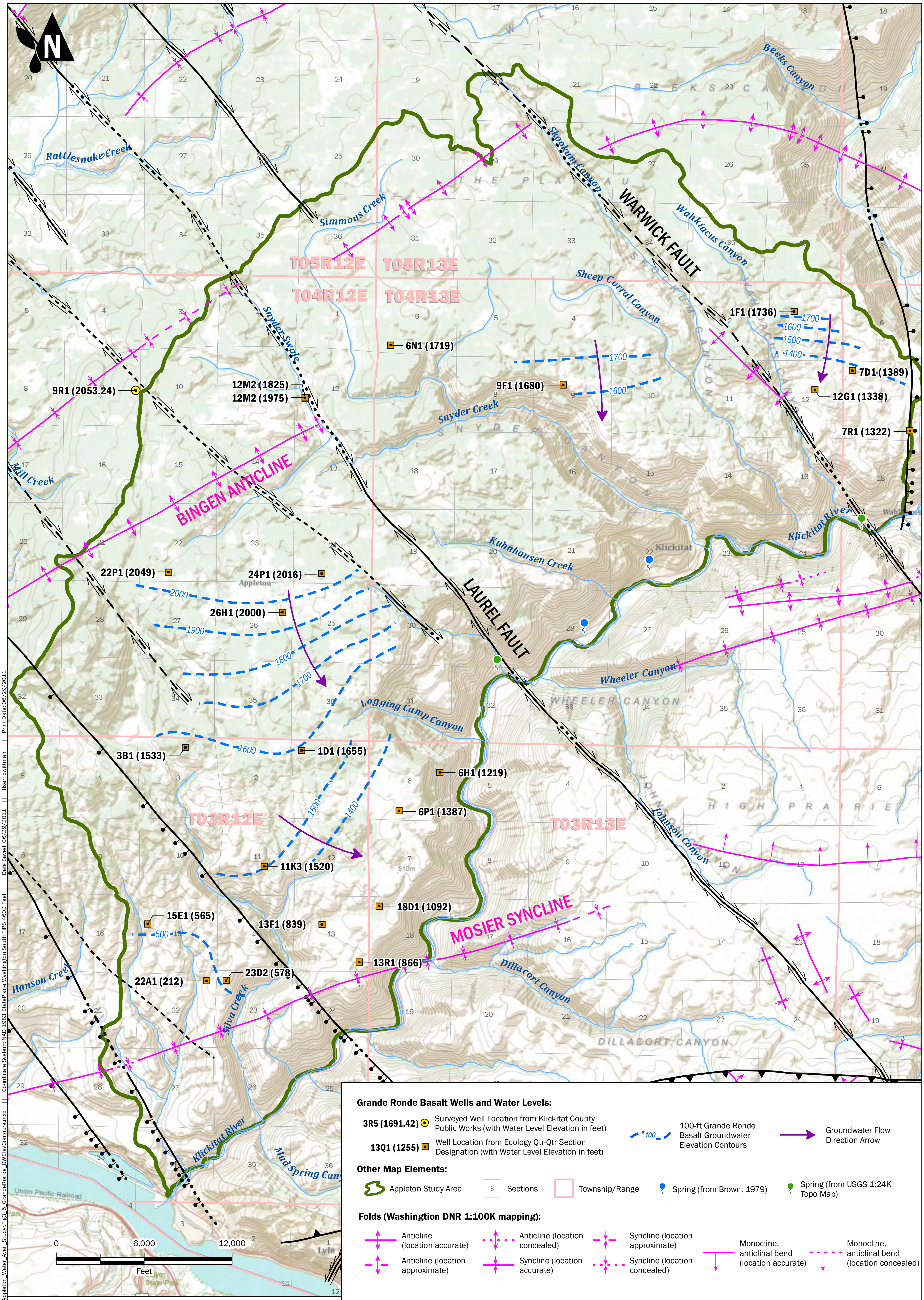
Appleton Water Availability Study
WRIA 30, Washington

Aspect CONSULTING

JUN-2011
PROJECT NO. 070024

BY: DFR/PPW
REV BY: - - -

FIGURE NO. 3.4



Grande Ronde Basalt Wells and Water Levels:

3R5 (1691.42) ● Surveyed Well Location from Klickitat County Public Works (with Water Level Elevation in feet)

13Q1 (1255) ▣ Well Location from Ecology Qtr-Qtr Section Designation (with Water Level Elevation in feet)

100-ft Grande Ronde Basalt Groundwater Elevation Contours

Groundwater Flow Direction Arrow

Other Map Elements:

Appleton Study Area

Sections

Township/Range

Spring (from Brown, 1979)

Spring (from USGS 1:24K Topo Map)

Folds (Washington DNR 1:100K mapping):

Anticline (location accurate)

Anticline (location approximate)

Anticline (location concealed)

Syncline (location accurate)

Syncline (location approximate)

Syncline (location concealed)

Monocline, anticlinal bend (location accurate)

Monocline, anticlinal bend (location concealed)

Faults (Washington DNR 1:100K mapping):

Thrust fault (location accurate). Sawteeth on upper plate.

Thrust fault (location concealed). Sawteeth on upper plate.

Normal fault (location concealed). Bar and ball on downthrown block.

Normal fault (location inferred). Bar and ball on downthrown block.

Normal fault (location accurate). Bar and ball on downthrown block.

Fault, unknown offset (location accurate)

Fault, unknown offset (location inferred)

Right-lateral strike-slip fault (location accurate). Arrows show relative motion.

Right-lateral strike-slip fault (location approximate). Arrows show relative motion.

Right-lateral strike-slip fault (location concealed). Arrows show relative motion.

Left-lateral strike-slip fault (location concealed). Arrows show relative motion.

Right-lateral strike-slip fault (location inferred). Arrows show relative motion

Groundwater Elevation Contour Map - Grande Ronde Basalt

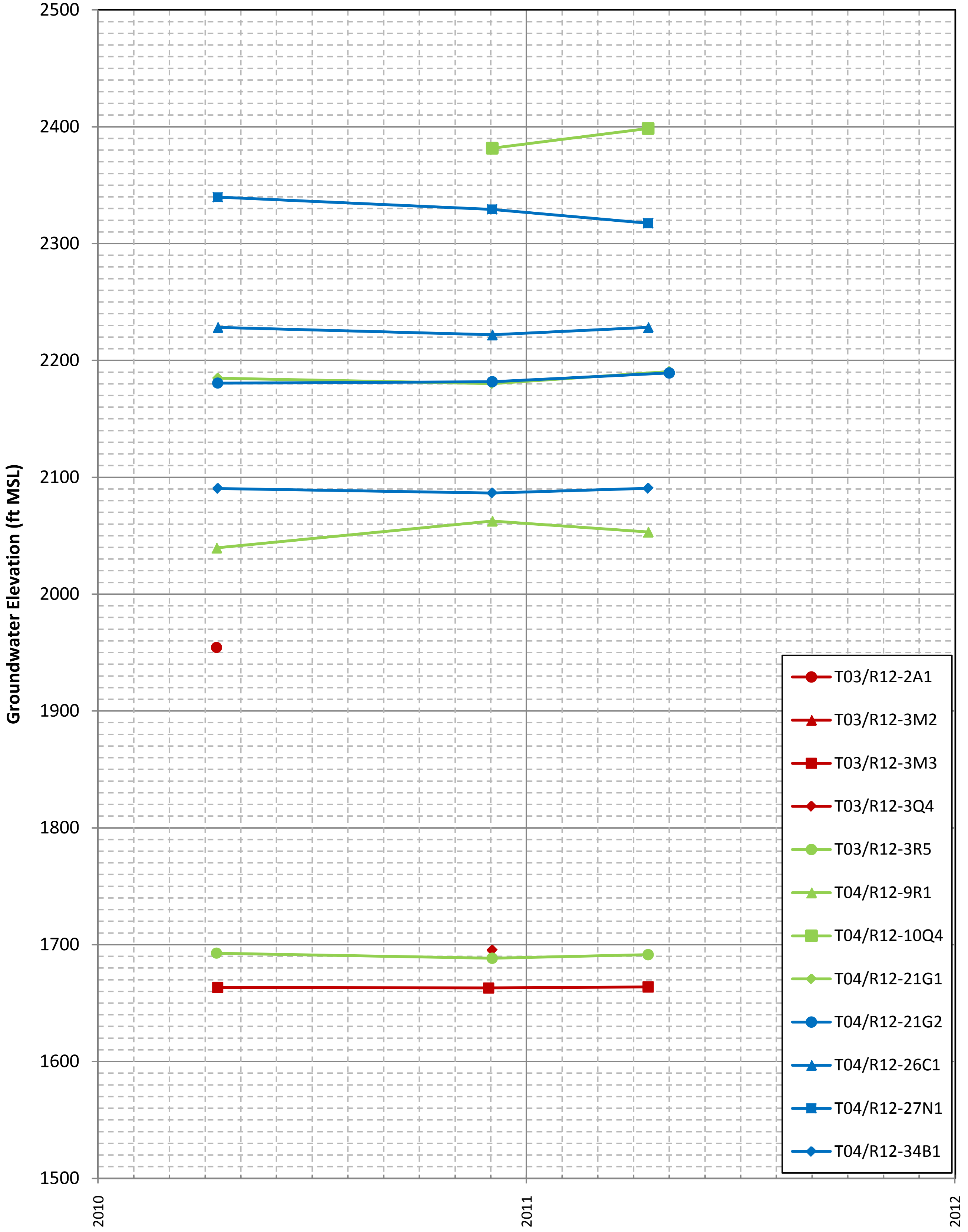
Appleton Water Availability Study
WRIA 30, Washington

Aspect CONSULTING

JUN-2011	BY: DFR/PPW	FIGURE NO.
PROJECT NO. 070024	REV BY: - - -	3.5

GIS Path: T:\projects_8\WRIA30\070024\Delivered\Appleton_Water_Avail_Study\Fig3_5_GrandeRonde_GWElevContours.mxd || Coordinate System: NAD 1983 StatePlane Washington South FIPS 4602 Feet || Date Saved: 06/29/2011 || User: pwittman || Print Date: 06/29/2011

Notes:
Any depth-to-water measurements from Table 2.2 which had non-static water levels were not included in the hydrographs.



Aspect Consulting
6/30/2011
V:\070024 WRIA 30 Phase 4\Deliverables\013 Appleton\Final\Tables 2.1 2.2 Figure 3.6

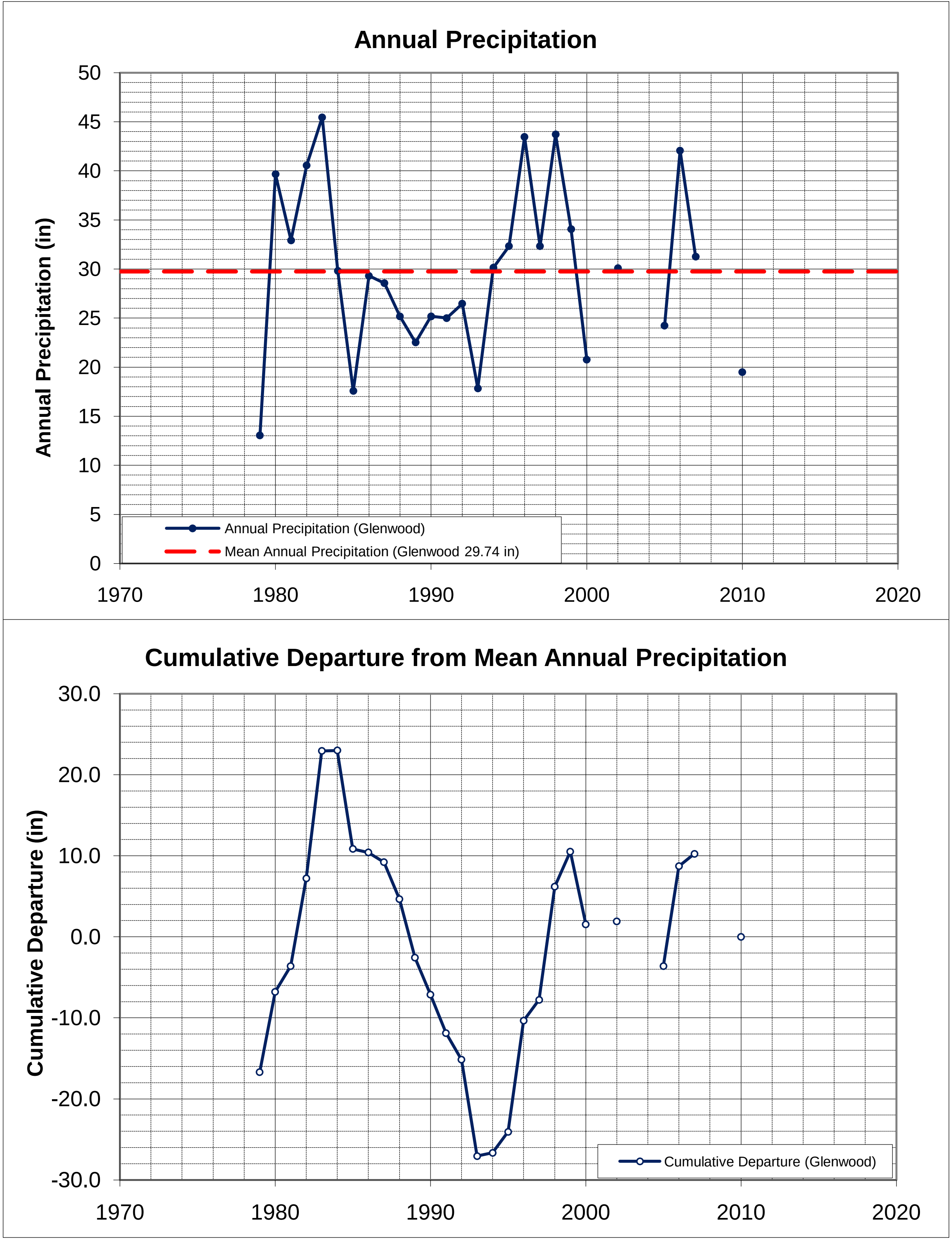
Figure 3.6 - Groundwater Hydrographs

Appleton Water Availability Study
WRIA 30, Washington

Notes:

Appleton annual precipitation data from GLENWOOD 2 Station (NWS COOP 452184-6)

Individual months with more than 5 days of missing data were not used for either monthly or annual statistics.



Aspect Consulting
6/30/2011
V:\070024 WRIA 30 Phase 4\Deliverables\013 Appleton\Final\F3.7 Precip

Figure 3.7
Long-Term Precipitation Trends

Appleton Water Availability Study
WRIA 30, Washington

APPENDIX A

Well Completion Summary Table for the Appleton Study Area

Appendix A - Well Completion Summary Table for the Appleton Study Area

Appleton Water Availability Study
WRIA 30, Washington

Well Log ID	Well Dia. (in)	Well Depth (ft)	Date	TRS Identifier	Easting (SPS NAD 83)	Northing (SPS NAD 83)
139759	6	490	12/19/1985	T03N/R12E-1D1	1447125	164021
139760	6	717	11/8/1985	T03N/R12E-1D2	1447125	164021
141941	6	375	11/14/1974	T03N/R12E-1N1	1447254	160022
141942	6	100	10/13/1972	T03N/R12E-1N2	1447254	160022
136731	6	100	7/15/1983	T03N/R12E-1N3	1447254	160022
499057	6	1125	9/26/2007	T03N/R12E-1N4	1447254	160022
417936	6	270	8/1/2005	T03N/R12E-1N5	1447254	160022
144845	6	130	9/13/1973	T03N/R12E-01-1	1449139	162032
452260	6	150	4/17/2006	T03N/R12E-2A1	1445822	163918
136489	6	260	6/30/1998	T03N/R12E-2K1	1444589	161309
411871	6	300	5/2/2005	T03N/R12E-2L1	1443271	161257
380950	6	400	5/4/2004	T03N/R12E-2N1	1441978	160116
380952	6	400	5/5/2004	T03N/R12E-2N2	1441978	160116
302694	6	725	10/9/2000	T03N/R12E-2N3	1441978	160116
144992	6	340	10/10/1997	T03N/R12E-2N4	1441978	160116
144993	6	500	10/17/1997	T03N/R12E-2N5	1441978	160116
142254	6	520	8/30/1977	T03N/R12E-2N6	1441978	160116
140055	6	620	8/9/1982	T03N/R12E-2N7	1441978	160116
257429	6	105	5/12/2000	T03N/R12E-2P1	1443314	160082
411873	6	190	4/26/2005	T03N/R12E-2P2	1443314	160082
137011	6	703	6/1/1978	T03N/R12E-3B1	1439210	164225
413152	6	710	7/15/2005	T03N/R12E-3D1	1436531	164258
302695	6	223	4/2/2001	T03N/R12E-3F1	1437914	162897
257430	6	195	6/27/2000	T03N/R12E-3F2	1437914	162897
257431	6	820	8/1/2000	T03N/R12E-3F3	1437914	162897
475810	6	117	4/10/2007	T03N/R12E-3F4	1437914	162897
141727	6	340	9/21/1977	T03N/R12E-3G1	1439247	162891
147281	10	346	2/14/1998	T03N/R12E-3J1	1440616	161560
142678	6	240	9/9/1996	T03N/R12E-3K1	1439286	161556
141441	6	140	11/8/1979	T03N/R12E-3K2	1439286	161556
138234	6	540	8/30/1993	T03N/R12E-3K3	1439286	161556
475808	6	80	4/14/2007	T03N/R12E-3K4	1439286	161556
543278	6	125	8/4/2008	T03N/R12E-3K5	1439286	161556
192033	6	430	8/24/1999	T03N/R12E-3L1	1437955	161557
384135	6	187	7/8/2004	T03N/R12E-3L2	1437955	161557
377245	6	165	6/19/1995	T03N/R12E-3L3	1437955	161557
452281	6	180	5/12/2006	T03N/R12E-3L4	1437955	161557
377246	6	425	7/10/1995	T03N/R12E-3M1	1436621	161555
487087	6	163	6/13/2007	T03N/R12E-3M2	1436621	161555
362172	6	130	5/22/2003	T03N/R12E-3M3	1436621	161555
365781	6	63	6/12/1984	T03N/R12E-3N1	1436668	160200
382341	6	790	6/11/2004	T03N/R12E-3N2	1436668	160200
141244	6	115	6/18/1997	T03N/R12E-3P1	1437994	160214
141245	6	135	10/2/1997	T03N/R12E-3P2	1437994	160214
352386	6	370	11/29/2002	T03N/R12E-3Q1	1439322	160225
420414	6	744	10/13/2005	T03N/R12E-3Q2	1439322	160225
145610	6	595	7/4/1976	T03N/R12E-3Q3	1439322	160225
384136	6	741	7/12/2004	T03N/R12E-3Q4	1439322	160225
413153	6	470	7/8/2005	T03N/R12E-3Q5	1439322	160225
380954	6	70	5/6/2004	T03N/R12E-3R1	1440650	160237
191938	10	182	6/18/1999	T03N/R12E-3R2	1440650	160237
335142	6	185	4/16/2002	T03N/R12E-3R3	1440650	160237
144104	6	500	9/1/1977	T03N/R12E-3R4	1440650	160237
136756	6	407	5/5/1991	T03N/R12E-3R5	1440650	160237
257432	6	415	6/26/2000	T03N/R12E-3R6	1440650	160237

Appendix A - Well Completion Summary Table for the Appleton Study Area

Appleton Water Availability Study
WRIA 30, Washington

Well Log ID	Well Dia. (in)	Well Depth (ft)	Date	TRS Identifier	Easting (SPS NAD 83)	Northing (SPS NAD 83)
499059	6	269	10/2/2007	T03N/R12E-3R7	1440650	160237
474101	6	843	8/19/2006	T03N/R12E-3R8	1440650	160237
137650	6	280	1/25/1973	T03N/R12E-3SE1	1439965	160896
380945	6	206	4/28/2004	T03N/R12E-4D1	1431301	164282
352382	6	125	9/25/2002	T03N/R12E-4D2	1431301	164282
146427	8	298	8/28/1981	T03N/R12E-4E1	1431349	162906
141504	6	105	8/11/1997	T03N/R12E-4N1	1431447	160151
487100	6	120	5/16/2007	T03N/R12E-4N2	1431447	160151
504589	6	330	5/18/2007	T03N/R12E-4N3	1431447	160151
146724	6	85	9/4/1997	T03N/R12E-5B1	1428667	164306
144641	6	70	2/4/1977	T03N/R12E-5B2	1428667	164306
137167	6	100	4/22/1991	T03N/R12E-5B3	1428667	164306
141924	6	430	7/7/1980	T03N/R12E-9D1	1431472	158811
140651	6	170	4/19/1995	T03N/R12E-9D2	1431472	158811
145744	6	620	7/26/1992	T03N/R12E-9F1	1432777	157520
139761	6	605	10/18/1988	T03N/R12E-9F2	1432777	157520
142339	6	625	6/14/1991	T03N/R12E-9NE1	1434733	158186
144097	6	315	8/12/1998	T03N/R12E-9P1	1432785	154910
143204	6	120	7/30/1981	T03N/R12E-9R1	1435395	154904
140658	6	450	7/15/1991	T03N/R12E-9R2	1435395	154904
192032	6	750	8/19/1999	T03N/R12E-10A1	1440644	158903
452299	6	721	5/5/2006	T03N/R12E-10A2	1440644	158903
499061	6	130	9/26/2007	T03N/R12E-10A3	1440644	158903
499062	6	270	9/24/2007	T03N/R12E-10A4	1440644	158903
499064	6	435	7/9/2007	T03N/R12E-10A5	1440644	158903
142403	6	680	7/7/1976	T03N/R12E-10B1	1439328	158891
142404	6	710	1/3/1977	T03N/R12E-10B2	1439328	158891
142405	6	785	1/7/1977	T03N/R12E-10B3	1439328	158891
139112	6	200		T03N/R12E-10B4	1439328	158891
139113	6	370	9/27/1976	T03N/R12E-10B5	1439328	158891
139968	6	300	8/23/1977	T03N/R12E-10C1	1438009	158877
137584	0	-	6/10/1997	T03N/R12E-10C2	1438009	158877
372475	6	645	11/14/2003	T03N/R12E-10D1	1436691	158861
145588	6	680	8/1/1979	T03N/R12E-10F1	1437994	157548
370571	6	164	10/8/2003	T03N/R12E-10M1	1436686	156221
380955	6	383	5/14/2004	T03N/R12E-10N1	1436684	154900
149032	6	203	12/12/1998	T03N/R12E-10N2	1436684	154900
149033	6	460	12/17/1998	T03N/R12E-10N3	1436684	154900
149034	6	445	12/9/1998	T03N/R12E-10N4	1436684	154900
136518	6	121	5/2/1997	T03N/R12E-10N5	1436684	154900
136519	6	182	5/4/1997	T03N/R12E-10N6	1436684	154900
455787	6	127	8/12/2006	T03N/R12E-10N7	1436684	154900
362169	6	250	5/7/2003	T03N/R12E-10N8	1436684	154900
138596	6	98	8/10/1991	T03N/R12E-10P1	1437962	154892
138597	6	430	10/3/1989	T03N/R12E-10P2	1437962	154892
138598	8	105	8/16/1991	T03N/R12E-10P3	1437962	154892
452301	6	640	4/28/2006	T03N/R12E-10P4	1437962	154892
452303	6	700	5/3/2006	T03N/R12E-10P5	1437962	154892
143343	6	146	7/8/1990	T03N/R12E-10Q1	1439239	154884
141606	6	138	2/4/1997	T03N/R12E-10Q2	1439239	154884
138460	6	830	6/17/1997	T03N/R12E-10Q3	1439239	154884
254791	6	610	10/4/1999	T03N/R12E-10Q4	1439239	154884
254792	6	595	11/11/1998	T03N/R12E-11C1	1443303	158830
254793	6	830	11/6/1998	T03N/R12E-11C2	1443303	158830
477834	6	637	4/15/2007	T03N/R12E-11C3	1443303	158830

Appendix A - Well Completion Summary Table for the Appleton Study Area

Appleton Water Availability Study
WRIA 30, Washington

Well Log ID	Well Dia. (in)	Well Depth (ft)	Date	TRS Identifier	Easting (SPS NAD 83)	Northing (SPS NAD 83)
499065	6	68	9/27/2007	T03N/R12E-11D1	1441970	158884
351595	6	745	8/30/1995	T03N/R12E-11F1	1443273	157498
257433	6	925	5/4/2000	T03N/R12E-11F2	1443273	157498
405753	6	560	3/14/2005	T03N/R12E-11J1	1445962	156096
302697	6	180	10/4/2000	T03N/R12E-11K1	1444601	156130
146451	6	175	9/26/1979	T03N/R12E-11K2	1444601	156130
146452	6	660	10/2/1979	T03N/R12E-11K3	1444601	156130
146453	6	125	4/3/1980	T03N/R12E-11L1	1443244	156166
146454	6	300	10/20/1977	T03N/R12E-11L2	1443244	156166
147279	6	405	8/23/1994	T03N/R12E-11M1	1441883	156198
142290	6	440	6/22/1998	T03N/R12E-11M2	1441883	156198
137578	6	785	9/26/1991	T03N/R12E-11M3	1441883	156198
390594	6	150	10/12/2004	T03N/R12E-11M4	1441883	156198
476467	6	945	4/11/2007	T03N/R12E-11M5	1441883	156198
556405	6	960	9/18/2008	T03N/R12E-11M6	1441883	156198
543334	6	180	7/8/2008	T03N/R12E-11M7	1441883	156198
351594	6	665	8/3/1995	T03N/R12E-11R1	1445957	154781
465582	6	945	8/14/2006	T03N/R12E-11R2	1445957	154781
397812	6	600	12/27/2004	T03N/R12E-12M1	1447281	156075
141096	0	-	10/25/1975	T03N/R12E-13A1	1451102	153423
335147	6	300	4/17/2002	T03N/R12E-13B1	1449824	153435
534975	6	730	5/28/2008	T03N/R12E-13F1	1448529	152158
142236	6	460	5/16/1992	T03N/R12E-13G1	1449810	152150
144936	6	320	1/31/1989	T03N/R12E-13H1	1451090	152142
141109	6	120	9/16/1977	T03N/R12E-13H2	1451090	152142
377247	6	380	9/23/1995	T03N/R12E-13H3	1451090	152142
141108	6	200	9/21/1973	T03N/R12E-13NE1	1450455	152787
138213	6	155	6/25/1998	T03N/R12E-13Q1	1449778	149578
137265	6	205	9/17/1973	T03N/R12E-13Q2	1449778	149578
137266	6	250	9/19/1973	T03N/R12E-13Q3	1449778	149578
257434	6	540	5/10/2000	T03N/R12E-13R1	1451068	149579
142371	6	420	5/23/1986	T03N/R12E-14M1	1441937	150931
146798	6	420	3/13/1976	T03N/R12E-14N1	1441988	149626
317845	6	340	8/31/2001	T03N/R12E-15A1	1440513	153541
417919	6	580	8/26/2005	T03N/R12E-15A2	1440513	153541
143881	6	740	10/23/1989	T03N/R12E-15E1	1436639	152191
141195	6	220	4/17/1978	T03N/R12E-15G1	1439257	152218
139805	6	85	9/20/1969	T03N/R12E-15G2	1439257	152218
335151	6	710	4/18/2002	T03N/R12E-15H1	1440561	152227
142991	6	500	6/17/1997	T03N/R12E-15H2	1440561	152227
142613	6	143	9/25/1976	T03N/R12E-15J1	1440604	150912
141194	6	350	10/8/1977	T03N/R12E-15J2	1440604	150912
141337	6	145	11/20/1990	T03N/R12E-15K1	1439275	150887
140818	6	150	6/18/1998	T03N/R12E-15K2	1439275	150887
314805	6	482	10/26/2001	T03N/R12E-15NE1	1439885	152875
417930	6	423	8/24/2005	T03N/R12E-15R1	1440657	149604
145780	6	200	12/8/1980	T03N/R12E-16H1	1435340	152202
146710	6	270	7/11/1985	T03N/R12E-21A1	1435242	148155
144473	6	170	9/2/1992	T03N/R12E-21A2	1435242	148155
137148	6	224	5/11/1983	T03N/R12E-21A3	1435242	148155
146448	6	179	7/9/1977	T03N/R12E-21B1	1433949	148217
145364	6	190	9/22/1976	T03N/R12E-21B2	1433949	148217
143135	6	195		T03N/R12E-21G1	1433938	146927
141413	6	300	7/21/1975	T03N/R12E-21G2	1433938	146927
141414	6	528	7/1/1974	T03N/R12E-21G3	1433938	146927

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Well Log ID	Well Dia. (in)	Well Depth (ft)	Date	TRS Identifier	Easting (SPS NAD 83)	Northing (SPS NAD 83)
140053	6	280	4/15/1988	T03N/R12E-21G4	1433938	146927
139486	6	175	7/30/1974	T03N/R12E-21H1	1435241	146878
137543	6	270	10/26/1977	T03N/R12E-21H2	1435241	146878
465583	6	358	11/15/2006	T03N/R12E-21H3	1435241	146878
146762	6	280	4/13/1982	T03N/R12E-21K1	1433927	145635
144988	6	315	10/24/1977	T03N/R12E-21K2	1433927	145635
144989	6	240	5/6/1998	T03N/R12E-21K3	1433927	145635
143615	6	960	5/4/1990	T03N/R12E-21K4	1433927	145635
139149	6	400	8/22/1978	T03N/R12E-21K5	1433927	145635
137165	6	270	9/1/1987	T03N/R12E-21K6	1433927	145635
137166	6	505	8/25/1987	T03N/R12E-21K7	1433927	145635
136469	6	343	5/17/1983	T03N/R12E-21K8	1433927	145635
254794	6	275	5/21/1996	T03N/R12E-21K9	1433927	145635
139506	6	175	7/30/1974	T03N/R12E-21NE1	1434589	147541
141546	6	235	4/19/1975	T03N/R12E-21P1	1432594	144370
138286	6	403	5/4/1982	T03N/R12E-21P2	1432594	144370
146753	6	-	10/14/1980	T03N/R12E-21R1	1435238	144325
146754	6	460	6/24/1978	T03N/R12E-21R2	1435238	144325
138704	6	205	3/4/1983	T03N/R12E-21R3	1435238	144325
455739	6	1030	7/7/2006	T03N/R12E-22A1	1440654	148302
138669	6	700	6/4/1998	T03N/R12E-23D1	1441985	148319
452280	6	995	5/17/2006	T03N/R12E-23D2	1441985	148319
377248	6	430	7/17/1995	T03N/R12E-23D3	1441985	148319
136624	6	125	6/30/1975	T03N/R12E-27E1	1436531	141684
143378	6	340	8/30/1990	T03N/R12E-27G1	1439139	141734
137113	6	260	12/9/1986	T03N/R12E-27J1	1440442	140427
142390	6	260	7/29/1985	T03N/R12E-27K1	1439133	140402
556397	6	680	10/7/2008	T03N/R12E-27L1	1437825	140374
138764	6	428	6/16/1994	T03N/R12E-27M1	1436517	140346
143279	6	280	8/3/1994	T03N/R12E-27N1	1436502	139008
142526	6	111	3/5/1968	T03N/R12E-27N2	1436502	139008
142172	6	210	12/7/1989	T03N/R12E-27N3	1436502	139008
145810	6	170	9/29/1976	T03N/R12E-27Q1	1439128	139069
137241	6	190	5/18/1981	T03N/R12E-27Q2	1439128	139069
137242	6	310	5/20/1981	T03N/R12E-27Q3	1439128	139069
142153	6	109	9/28/1976	T03N/R12E-27R1	1440442	139098
142154	6	407	9/7/1981	T03N/R12E-27R2	1440442	139098
137414	6	72	12/16/1974	T03N/R12E-27R3	1440442	139098
141820	6	143	5/26/1979	T03N/R12E-28A1	1435231	143017
377249	6	80	10/19/1995	T03N/R12E-28A2	1435231	143017
145732	6	470	5/6/1982	T03N/R12E-28B1	1433906	143036
137255	6	185	5/10/1991	T03N/R12E-28B2	1433906	143036
146739	6	325	7/20/1975	T03N/R12E-28G1	1433892	141707
141688	6	440	8/23/1979	T03N/R12E-28G2	1433892	141707
136799	6	500	11/19/1993	T03N/R12E-28G3	1433892	141707
257435	6	420	7/24/2000	T03N/R12E-28G4	1433892	141707
314801	6	625	11/8/2001	T03N/R12E-28H1	1435215	141682
139653	6	283	6/22/1990	T03N/R12E-28H2	1435215	141682
142494	6	130	9/11/1976	T03N/R12E-28R1	1435186	139010
452278	6	640	5/15/2006	T03N/R12E-28R2	1435186	139010
580764	6	205	2/20/2009	T03N/R12E-28R3	1435186	139010
590549	6	110	3/5/1968	T03N/R12E-28SE1	1434534	139695
335150	6	675	4/4/2002	T03N/R12E-33A1	1435171	137705
145597	6	180	7/12/1979	T03N/R12E-33A2	1435171	137705
145598	6	600	7/11/1979	T03N/R12E-33A3	1435171	137705

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Well Log ID	Well Dia. (in)	Well Depth (ft)	Date	TRS Identifier	Easting (SPS NAD 83)	Northing (SPS NAD 83)
145112	6	195	8/4/1981	T03N/R12E-33A4	1435171	137705
144890	6	675	6/17/1983	T03N/R12E-33A5	1435171	137705
144363	6	240	12/15/1978	T03N/R12E-33A6	1435171	137705
142645	6	680	12/2/1992	T03N/R12E-33A7	1435171	137705
142646	6	180	4/1/1983	T03N/R12E-33A8	1435171	137705
136522	6	200	12/13/1978	T03N/R12E-33A9	1435171	137705
482868	6	260	5/15/2007	T03N/R12E-34D1	1436491	137701
560630	6	145	6/18/1976	T03N/R12E-34D2	1436491	137701
138348	6	355	8/28/1980	T03N/R12E-34M1	1436473	135152
191879	6	350	6/9/1999	T03N/R12E-34P1	1437787	133866
191836	6	210	4/28/1999	T03N/R13E-5F1	1459276	162478
137599	6	165	6/30/1992	T03N/R13E-5F2	1459276	162478
137176	6	85	6/30/1996	T03N/R13E-5F3	1459276	162478
257437	6	160	7/5/2000	T03N/R13E-5M1	1457923	161149
534979	6	83	5/27/2008	T03N/R13E-5F1	1459276	162478
145362	6	720	6/8/1994	T03N/R13E-6P1	1453790	159918
137203	6	280	1/5/1988	T03N/R13E-6P2	1453790	159918
377251	6	210	9/28/1995	T03N/R13E-6H1	1456574	162526
142433	6	210	4/26/1983	T03N/R13E-8L1	1459269	155861
139123	6	140	6/3/1988	T03N/R13E-8L2	1459269	155861
143591	6	220	7/23/1998	T03N/R13E-18Q1	1455177	149426
138646	6	322	7/21/1998	T03N/R13E-18Q2	1455177	149426
138091	6	360	5/7/1979	T03N/R13E-18G1	1455193	152028
487080	6	545	4/16/2007	T03N/R13E-18D1	1452434	153401
372476	6	145	11/17/2003	T03N/R13E-19L1	1453779	145537
139354	6	324	7/30/1992	T04N/R12E-9R1	1435478	186802
377541	6	390	8/29/1995	T04N/R12E-9J1	1435482	188110
369681	6	825	8/29/2003	T04N/R12E-9R1	1435478	186802
465609	6	917	9/22/2006	T04N/R12E-9J1	1435482	188110
318661	5.5	320	7/18/1995	T04N/R12E-10K1	1439395	188166
302513	6	100	6/13/2001	T04N/R12E-10M1	1436789	188112
302775	6	400	9/5/2000	T04N/R12E-10Q1	1439385	186824
191940	6	480	6/19/1999	T04N/R12E-10Q2	1439385	186824
146712	6	100	9/16/1974	T04N/R12E-10L1	1438090	188137
146338	6	270	7/30/1977	T04N/R12E-10K1	1439395	188166
144917	6	145	8/2/1972	T04N/R12E-10-1	1438765	188823
143370	6	300	6/2/1981	T04N/R12E-10Q1	1439385	186824
143493	6	260	9/30/1974	T04N/R12E-10P1	1438084	186810
143502	6	100	9/26/1974	T04N/R12E-10R1	1440682	186835
143503	6	410	9/11/1994	T04N/R12E-10R2	1440682	186835
143039	6	55	6/11/1973	T04N/R12E-10-1	1438765	188823
142541	6	270	9/11/1979	T04N/R12E-10R1	1440682	186835
141896	6	135	5/22/1990	T04N/R12E-10K1	1439395	188166
141107	6	95	7/27/1977	T04N/R12E-10L1	1438090	188137
140304	6	80	9/13/1974	T04N/R12E-10G1	1439404	189506
140522	6	90	6/12/1973	T04N/R12E-10-1	1438765	188823
139819	6	285	7/20/1973	T04N/R12E-10-2	1438765	188823
140051	6	90	6/28/1985	T04N/R12E-10N1	1436783	186799
139731	6	300	9/22/1974	T04N/R12E-10J1	1440698	188192
139056	6	280	4/23/1992	T04N/R12E-10N1	1436783	186799
139076	6	112	6/27/1985	T04N/R12E-10N2	1436783	186799
138362	6	180	8/15/1973	T04N/R12E-10-1	1438765	188823
136526	6	85	6/15/1973	T04N/R12E-10-2	1438765	188823
136565	6	150	7/28/1977	T04N/R12E-10K1	1439395	188166
136767	6	175		T04N/R12E-10-1	1438765	188823

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Well Log ID	Well Dia. (in)	Well Depth (ft)	Date	TRS Identifier	Easting (SPS NAD 83)	Northing (SPS NAD 83)
317875	6	350	8/15/2001	T04N/R12E-10Q1	1439385	186824
377542	6	280	9/3/1995	T04N/R12E-10Q2	1439385	186824
407051	6	280	4/21/2005	T04N/R12E-10R1	1440682	186835
367340	6	700	7/15/2003	T04N/R12E-10M1	1436789	188112
405755	6	365	3/24/2005	T04N/R12E-10M2	1436789	188112
543274	6	200	7/31/2008	T04N/R12E-10R1	1440682	186835
380946	6	160	4/30/2004	T04N/R12E-11N1	1441997	186821
297010	6	-		T04N/R12E-11N2	1441997	186821
192123	6	500	7/22/1999	T04N/R12E-11K1	1444687	188135
145876	6	140	8/22/1977	T04N/R12E-11L1	1443351	188162
143899	6	145	5/8/1995	T04N/R12E-11F1	1443375	189536
143328	6	345	7/1/1981	T04N/R12E-11M1	1442016	188189
143329	6	605	6/23/1981	T04N/R12E-11M2	1442016	188189
143490	6	100	9/20/1974	T04N/R12E-11F1	1443375	189536
141656	6	42	5/30/1988	T04N/R12E-11H1	1446053	189495
140177	6	108	10/21/1994	T04N/R12E-11G1	1444712	189515
139039	6	80	5/14/1995	T04N/R12E-11E1	1442035	189557
137234	6	228	7/17/1991	T04N/R12E-11K1	1444687	188135
254812	6	100	8/25/1999	T04N/R12E-11L1	1443351	188162
317876	6	540	8/17/2001	T04N/R12E-11E1	1442035	189557
377543	6	455	7/12/1995	T04N/R12E-11-1	1444041	188842
377544	6	125	9/5/1995	T04N/R12E-11J1	1446022	188107
487084	6	167	5/14/2007	T04N/R12E-11D1	1442053	190922
367342	6	125	7/16/2003	T04N/R12E-11E1	1442035	189557
362170	6	170	5/8/2003	T04N/R12E-11K1	1444687	188135
604490	6	190	8/31/2009	T04N/R12E-11C1	1443398	190910
604491	6	99	9/3/2009	T04N/R12E-11G1	1444712	189515
146286	6	430	7/19/1987	T04N/R12E-12M1	1447377	188064
145119	6	330	7/22/1987	T04N/R12E-12M2	1447377	188064
143038	6	110	2/2/1977	T04N/R12E-12M3	1447377	188064
139024	6	160	5/29/1998	T04N/R12E-12NW1	1448073	190098
144911	6	288	10/5/1990	T04N/R12E-13R1	1451299	181181
142978	6	282	4/20/1987	T04N/R12E-13R2	1451299	181181
139610	6	410	4/26/1993	T04N/R12E-13G1	1450054	183900
144541	6	180	7/10/1986	T04N/R12E-14D1	1441977	185471
296089	6	83		T04N/R12E-15J1	1440635	182816
296090	6	83		T04N/R12E-15J2	1440635	182816
145816	6	140	8/10/1989	T04N/R12E-15B1	1439372	185484
144943	6	323	5/10/1993	T04N/R12E-15E1	1436791	184146
145137	6	115		T04N/R12E-15D1	1436783	185476
144757	6	300	6/3/1981	T04N/R12E-15G1	1439364	184149
143784	6	170	3/27/1982	T04N/R12E-15F1	1438079	184148
143789	6	318	4/24/1992	T04N/R12E-15C1	1438078	185479
142576	6	292	8/9/1992	T04N/R12E-15G1	1439364	184149
142163	6	170	4/28/1993	T04N/R12E-15C1	1438078	185479
142164	6	293	7/1/1994	T04N/R12E-15C2	1438078	185479
141445	6	100	8/10/1989	T04N/R12E-15C3	1438078	185479
140928	6	290	5/16/1984	T04N/R12E-15L1	1438075	182815
140527	6	140	7/18/1977	T04N/R12E-15A1	1440667	185487
139299	6	92	4/30/1992	T04N/R12E-15D1	1436783	185476
137933	6	290	5/28/1996	T04N/R12E-15D2	1436783	185476
137429	6	60	9/22/1978	T04N/R12E-15J1	1440635	182816
137678	6	290	9/5/1996	T04N/R12E-15NW1	1437434	184814
136580	0	85	6/15/1973	T04N/R12E-15-1	1438720	183492
375236	6	350	12/14/2003	T04N/R12E-15E1	1436791	184146

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Well Log ID	Well Dia. (in)	Well Depth (ft)	Date	TRS Identifier	Easting (SPS NAD 83)	Northing (SPS NAD 83)
455722	6	210	7/26/2006	T04N/R12E-15D1	1436783	185476
352359	6	110	11/22/2002	T04N/R12E-15D2	1436783	185476
580757	6	210	12/1/2008	T04N/R12E-15A1	1440667	185487
379451	6	180	3/26/2004	T04N/R12E-21G1	1434127	178885
143971	6	90	7/28/1992	T04N/R12E-21G2	1434127	178885
142745	6	205	6/2/1975	T04N/R12E-21Q1	1434096	176230
316097	6	580	10/5/2001	T04N/R12E-22P1	1438045	176198
146747	6	80	10/2/1974	T04N/R12E-22R1	1440647	176214
141491	6	81	5/13/1992	T04N/R12E-22Q1	1439345	176206
140518	6	400	7/15/1977	T04N/R12E-22P1	1438045	176198
136698	6	100	2/22/1979	T04N/R12E-22K1	1439345	177522
296603	6	-		T04N/R12E-23P1	1443257	176186
145097	6	-	11/8/1991	T04N/R12E-23P2	1443257	176186
145098	6	65	11/12/1991	T04N/R12E-23P3	1443257	176186
144434	6	90	3/22/1987	T04N/R12E-23A1	1445873	180046
143619	6	293	10/19/1988	T04N/R12E-23G1	1444555	178772
141655	6	310	5/27/1988	T04N/R12E-23R1	1445868	176139
302760	6	500	8/18/2000	T04N/R12E-24P1	1448511	176081
144832	6	100	6/24/1986	T04N/R12E-24Q1	1449840	176048
142988	6	160	5/29/1996	T04N/R12E-24K1	1449860	177337
139451	6	160	9/19/1977	T04N/R12E-24P1	1448511	176081
139513	6	216	4/21/1975	T04N/R12E-24P2	1448511	176081
377545	6	100	9/6/1995	T04N/R12E-24K1	1449860	177337
377546	6	82	10/12/1995	T04N/R12E-24K2	1449860	177337
386420	6	500	8/31/2004	T04N/R12E-24K3	1449860	177337
361583	6	160	5/9/2003	T04N/R12E-24P1	1448511	176081
352357	6	300	9/18/2002	T04N/R12E-24J1	1451194	177300
146662	6	170	10/19/1994	T04N/R12E-25D1	1447170	174781
146663	6	610	10/17/1994	T04N/R12E-25D2	1447170	174781
142303	6	218	7/1/1994	T04N/R12E-25D3	1447170	174781
504600	6	405	9/6/2007	T04N/R12E-25R1	1451147	170613
504602	6	140	9/13/2007	T04N/R12E-25R2	1451147	170613
499081	6	705	8/20/2007	T04N/R12E-25R3	1451147	170613
191919	6	185	5/19/1999	T04N/R12E-26F1	1443219	173501
146645	6	520	10/20/1998	T04N/R12E-26H1	1445826	173450
143892	6	285	10/6/1997	T04N/R12E-26C1	1443248	174853
143488	6	500	10/3/1977	T04N/R12E-26H1	1445826	173450
140731	6	380	5/26/1994	T04N/R12E-26F1	1443219	173501
140732	6	840	6/2/1994	T04N/R12E-26A1	1445855	174808
140733	6	165	6/13/1994	T04N/R12E-26G1	1444523	173475
140163	6	140	7/20/1977	T04N/R12E-26D1	1441945	174875
140037	0	-	7/17/1954	T04N/R12E-26H1	1445826	173450
254813	6	360	12/19/1999	T04N/R12E-26G1	1444523	173475
254814	6	243	10/4/1998	T04N/R12E-26H1	1445826	173450
317877	6	105	9/19/2001	T04N/R12E-26G1	1444523	173475
407050	6	288	4/6/2005	T04N/R12E-26C1	1443248	174853
191885	6	171	7/28/1999	T04N/R12E-27B1	1439330	174880
142606	6	183	5/5/1993	T04N/R12E-27C1	1438020	174878
137430	6	640	7/24/1978	T04N/R12E-27C2	1438020	174878
137159	6	58	11/9/1991	T04N/R12E-27B1	1439330	174880
137294	6	163	5/5/1993	T04N/R12E-27C1	1438020	174878
257450	6	200	6/24/2000	T04N/R12E-27C2	1438020	174878
411864	6	240	5/14/2005	T04N/R12E-27D1	1436713	174874
534976	6	150	6/3/2008	T04N/R12E-27N1	1436578	170951
483456	6	138	5/23/2007	T04N/R12E-27D1	1436713	174874

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Well Log ID	Well Dia. (in)	Well Depth (ft)	Date	TRS Identifier	Easting (SPS NAD 83)	Northing (SPS NAD 83)
556413	6	310	8/16/2008	T04N/R12E-27N1	1436578	170951
141805	6	110	10/16/1979	T04N/R12E-34B1	1439201	169553
372471	6	400	11/12/2003	T04N/R13E-1K1	1482113	192623
146768	6	610	4/15/1994	T04N/R13E-1C1	1480687	195287
146219	6	360	7/11/1983	T04N/R13E-1D1	1479345	195314
146381	6	640	6/14/1993	T04N/R13E-1D2	1479345	195314
139803	6	495	8/26/1979	T04N/R13E-1G1	1482068	193939
139157	6	360	4/16/1994	T04N/R13E-1D1	1479345	195314
138507	6	425	6/15/1993	T04N/R13E-1D2	1479345	195314
136770	6	187		T04N/R13E-1P1	1480862	191337
487132	6	610	6/26/2007	T04N/R13E-1F1	1480749	193969
359627	6	440	4/16/2003	T04N/R13E-1K1	1482113	192623
499083	6	470	9/12/2007	T04N/R13E-1F1	1480749	193969
499085	6	630	8/9/2007	T04N/R13E-1F2	1480749	193969
556398	6	645	10/13/2008	T04N/R13E-1H1	1483390	193910
191889	6	335	5/26/1999	T04N/R13E-2H2	1478051	193992
140982	6	183	7/14/1983	T04N/R13E-2L1	1475436	192706
371227	6	150	10/20/2003	T04N/R13E-2L2	1475436	192706
141943	6	290	5/29/1994	T04N/R13E-5R1	1462369	191596
139528	6	660	3/26/1981	T04N/R13E-6N1	1453207	191677
139529	6	490	1/27/1977	T04N/R13E-6N2	1453207	191677
145529	6	175	6/5/1984	T04N/R13E-9P1	1464953	186334
141240	6	500	9/18/1996	T04N/R13E-9F1	1464982	188941
465613	6	130	10/26/2006	T04N/R13E-10P1	1470268	186206
191846	6	178	8/9/1999	T04N/R13E-12B1	1482169	189951
146188	6	190	1/18/1977	T04N/R13E-12D1	1479626	189967
146220	6	370	1/20/1977	T04N/R13E-12D2	1479626	189967
145601	6	230	8/10/1972	T04N/R13E-12A1	1483441	189944
145602	6	576	9/13/1977	T04N/R13E-12A2	1483441	189944
143671	6	568	10/5/1977	T04N/R13E-12A3	1483441	189944
142845	6	180	8/9/1972	T04N/R13E-12C1	1480898	189960
141184	6	145	5/31/1995	T04N/R13E-12B1	1482169	189951
141294	6	560	5/14/1996	T04N/R13E-12G1	1482165	188631
137286	6	217		T04N/R13E-12B1	1482169	189951
136812	6	100	11/11/1989	T04N/R13E-12B2	1482169	189951
352353	6	600	9/5/2002	T04N/R13E-12A1	1483441	189944
543327	6	460	8/11/2008	T04N/R13E-12D1	1479626	189967
543332	6	400	8/14/2008	T04N/R13E-12D2	1479626	189967
140305	6	110	5/6/1992	T04N/R13E-13D3	1479586	184702
416748	8	150	8/15/1988	T04N/R13E-22R1	1472748	175541
143518	6	96	7/24/1964	T04N/R13E-22P1	1470159	175564
143202	6	130		T04N/R13E-22N1	1468865	175571
142302	6	210	8/29/1997	T04N/R13E-22P1	1470159	175564
141915	6	370		T04N/R13E-22Q1	1471455	175553
416745	8	125	8/29/1988	T04N/R13E-22R1	1472748	175541
141113	6	145	8/13/1991	T04N/R13E-22Q1	1471455	175553
139515	6	80	8/10/1994	T04N/R13E-22SW1	1469521	176241
382337	6	275	6/17/2004	T04N/R13E-22D1	1468911	179609
636547	8	125	8/29/1988	T04N/R13E-22R1	1472748	175541
192121	6	85	7/15/1999	T04N/R13E-23M1	1474113	176850
146511	6	80	3/30/1981	T04N/R13E-23M2	1474113	176850
144755	6	85	11/4/1994	T04N/R13E-23G1	1476785	178156
144504	6	115	3/24/1981	T04N/R13E-23M1	1474113	176850
140320	6	143	1/31/1977	T04N/R13E-23H1	1478092	178148
140105	6	145	5/7/1993	T04N/R13E-23G1	1476785	178156

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Appleton Water Availability Study
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Well Log ID	Well Dia. (in)	Well Depth (ft)	Date	TRS Identifier	Easting (SPS NAD 83)	Northing (SPS NAD 83)
139512	6	50	4/14/1976	T04N/R13E-23N1	1474056	175531
138042	6	130	11/10/1994	T04N/R13E-23G1	1476785	178156
137390	6	130	6/22/1993	T04N/R13E-23G2	1476785	178156
590553	6	102	3/13/1968	T04N/R13E-23G3	1476785	178156
138895	6	390	8/21/1981	T04N/R13E-24E1	1479400	178139
142819	6	110	10/10/1983	T04N/R13E-27D1	1468834	174247
145811	6	53	12/27/1967	T04N/R13E-28-1	1465445	172291
144179	6	-	4/14/1966	T04N/R13E-28SE1	1466745	170931
142204	6	133	10/15/1964	T04N/R13E-28G1	1466148	172950
141723	6	70	8/1/1989	T04N/R13E-28SE1	1466745	170931
140842	6	20	10/11/1974	T04N/R13E-28F1	1464825	172964
140258	6	70	9/7/1977	T04N/R13E-28H1	1467471	172933
139908	6	125	2/26/1981	T04N/R13E-28G1	1466148	172950
139956	6	165		T04N/R13E-28P1	1464779	170221
139534	6	65	10/19/1990	T04N/R13E-28H1	1467471	172933
139096	6	122	3/11/1980	T04N/R13E-28G1	1466148	172950
137135	6	140	5/29/1981	T04N/R13E-28G2	1466148	172950
136467	6	75	9/6/1977	T04N/R13E-28H1	1467471	172933
432413	6	80	2/17/2006	T04N/R13E-28NE1	1466825	173613
452347	6	150	6/28/2006	T04N/R13E-28L1	1464801	171597
428317	6	135	11/23/2005	T04N/R13E-28N1	1463481	170192
590552	6	96	7/24/1964	T04N/R13E-28NE1	1466825	173613
302761	6	105	4/19/2001	T04N/R13E-32N1	1457963	165185
302762	6	145	4/16/2001	T04N/R13E-32N2	1457963	165185
146057	6	165	8/11/1994	T04N/R13E-32N3	1457963	165185
142585	6	42	4/20/1973	T04N/R13E-32A1	1461956	168902
140009	6	60	7/19/1984	T04N/R13E-32B1	1460635	168986
139251	6	159	9/10/1997	T04N/R13E-32F1	1459310	167761
138370	6	200	8/9/1994	T04N/R13E-32A1	1461956	168902
377547	6	180	8/31/1995	T04N/R13E-32L1	1459304	166456
452305	6	100	4/1/2006	T04N/R13E-32F1	1459310	167761
452376	6	83	6/7/2006	T04N/R13E-32A1	1461956	168902
428310	6	60	11/9/2005	T04N/R13E-32A2	1461956	168902
392557	6	85	11/8/2004	T04N/R13E-32F1	1459310	167761
499087	6	100	9/13/2007	T04N/R13E-32B1	1460635	168986
590555	6	46	4/14/1966	T04N/R13E-32-1	1459950	167071
590557	6	36	7/17/1964	T04N/R13E-32-2	1459950	167071
590558	6	39	4/12/1969	T04N/R13E-32-3	1459950	167071
590709	6	66	7/27/1964	T04N/R13E-32-4	1459950	167071
590762	6	-	6/12/1966	T04N/R13E-32NW1	1458649	168454
590690	6	52	12/27/1967	T04N/R13E-32-1	1459950	167071
145993	6	860	4/25/1994	T04N/R14E-7D1	1484741	189926
145603	6	576	9/13/1977	T04N/R14E-7L1	1486043	187236
144031	6	580	6/8/1981	T04N/R14E-7F1	1486055	188566
142338	6	720	10/24/1996	T04N/R14E-7D1	1484741	189926
499089	6	1356	6/28/2007	T04N/R14E-7D2	1484741	189926
405750	6	445	3/14/2005	T04N/R14E-7R1	1488649	185821
191844	6	700	7/20/1999	T04N/R14E-18H1	1488627	183159
452380	6	250	6/2/2006	T04N/R14E-18R1	1488613	180503
362171	6	310	5/19/2003	T04N/R14E-18H1	1488627	183159
590812	6	30	4/7/1966	T04N/R14E-18SE1	1487963	181201
421996	6	25.8	9/28/2005	T04N/R14E-19B1	1487289	179252
421998	4	37	10/6/2005	T04N/R14E-19B2	1487289	179252
380079	6	185	8/20/1995	T05N/R13E-20J1	1462508	208882
465668	6	400	7/20/2006	T05N/R13E-26N1	1474309	201938

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Well Log ID	Well Dia. (in)	Well Depth (ft)	Date	TRS Identifier	Easting (SPS NAD 83)	Northing (SPS NAD 83)
303791	6	53	1/16/2001	T05N/R13E-30E1	1452934	205145
131671	6	610	9/27/1982	T05N/R13E-35F1	1475420	199286
130784	6	180	5/31/1984	T05N/R13E-35F2	1475420	199286
128108	6	935	9/21/1998	T05N/R13E-35F3	1475420	199286
368394	6	560	8/15/2003	T05N/R13E-35J1	1478027	197918
382348	6	300	6/4/2004	T05N/R13E-35C1	1475473	200568
352352	6	490	9/6/2002	T05N/R13E-35F1	1475420	199286
130715	6	-	11/24/1971	T05N/R13E-36-1	1481383	198495
126359	6	205	11/3/1972	T05N/R13E-36-2	1481383	198495

APPENDIX B

Basin-Scale Water Balance for the Appleton Study Area

Basin-Scale Water Balance for Appleton Study Area

The conventional study area-scale water balance approach partitions 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. Water use by human activities requires the addition of estimated volumes for consumptive water use and return flow to the water balance to complete a full assessment. The water balance analysis for this study area is similar to that applied in the Water Availability Report for Swale Creek and Little Klickitat subbasins [Aspect Consulting, LLC (Aspect), 2007]. The following subsections present the water use estimates, and then the full water balance, for the Appleton study area.

Water Use Estimates

This section estimates actual water use for the Appleton study area, applying the same methodology as used in previous water availability reports for WRIA 30. The water use information is an important element of the study area-scale water balance, supporting the assessment of water availability.

Water use is estimated for the major categories of use including irrigation, residential, and non-residential (e.g., commercial/ industrial). The water use estimates represent average current conditions based on available information and numerous assumptions. Actual use varies for any given time period due to factors such as temperature, precipitation, or cropping practices. A summary of the methods and results of estimating each of these water uses are presented below.

Irrigation Use

As of May 2010, Farm Services Agency (FSA) staff reported no irrigated areas in the Appleton study area. Aerial photography indicates areas of cultivated land, but no areas that appeared irrigated, which is consistent with observations during water level measurement events. Based on the collective information, the study area is assumed to have no significant irrigation water use.

Residential and Non-Residential Use

Using data from the state Department of Health (DOH) public water system (PWS) database, an estimated 56 acre-feet of residential water use is supplied by PWS within the study area, based on multiplying each PWS' number of residents served by an assumed 111 gallons per capita day[1] (gpcd), and converting to an annual volume in acre-feet/year (Table B-1). Based on the DOH database, 508 residents are served by PWS within the study area, equating to 63 acre-feet/year of residential use.

The Klickitat Water System is the only PWS-supplied non-residential (e.g. commercial, industrial) water use in the study area, using approximately 14 acre-feet/yr based on previous water use estimates as part of a previous WRIA 30 assessment (Aspect, 2004). There are four additional non-residential connections, with demand estimated in the Level 1 Assessment to be 34 gallons per day or

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[1] Estimated per capita water demand is from Klickitat Public Water System data as reported in Aspect (2004).

0.04 acre feet per year per PWS connection, indicating a negligible PWS-supplied non-residential water use outside of the Klickitat PWS (Table B-1).

Table B-1 - Estimated Annual Public Water System (PWS) Use

							Estimated Annual Water Use in Acre-Feet/Year		
PWS ID	**PWS Name**	**Group**	**Residents Served**	**No. Total Connects**	**No. Resid. Connects**	**No. Non-Resid. Connects**	**Residential**	**Non-Residential**	**Total**
42800	KLICKITAT WATER SYSTEM	A	450	180	179	1	56	14	70
7842	WISHBONE WELL	A	1	2	1	1	0.1	0.04	0.2
AC069	MOUNTAIN PINE WATER SYSTEM	B	18	6	6	0	2	0	2
AA549	BORCEA LANE WATER SYSTEM	B	15	4	4	0	2	0	2
6192	SILVA RIDGE WATER SYSTEM A	B	6	2	2	0	1	0	1
7150	SILVA RIDGE WATER SYSTEM B	B	6	3	2	1	1	0.04	1
26161	WOODRUFF WATER SYSTEM	B	5	2	2	0	1	0	1
5878	MILLER, GEORGE WATER SYSTEM	B	4	2	2	0	0	0	0
22397	KLICKITAT CO. F.P.D. #13	B	3	2	1	1	0.4	0.04	0.4
AA090	APPLETON FIRE HALL	B	0	1	0	1	0.0	0.04	0.04
	Appleton Totals		**508**	**204**	**199**	**5**	**63**	**14**	**77**

Assumed residential per capita water use of 111 gallons per day (refer to text).

Self-Supplied (Non-PWS) Water Use

Water uses not supplied by PWS are considered “self-supplied”. The self-supplied residential population (domestic wells) was estimated by first determining the total population (963 people) for the study area using 2010 US Census data for census blocks within the study area as determined with GIS analysis. The study area population served by PWS (as determined by DOH database; Table B-1) was then subtracted from the total population to arrive at the self-supplied population. According to DOH records, 508 people in the study area are served by a PWS, leaving an estimated 455 people as self-supplied water users using private domestic wells (Table B-2). Annual water use estimates for the self-supplied population were calculated assuming the same average residential consumption of 111 gpcd as assumed for PWS-supplied residents, and converting that volume of water into acre-feet/year, for a total of 57 acre-feet/year (Table B-2).

Table B-2 - Estimated Self-Supplied Annual Residential Water Use

Total Population in 2010[a]	Population Served by Public Water Systems[b]	Self-Supplied Population	Self-Supplied Water Use in Acre-Feet/Year
963	508	455	57

Notes:

[a] Based on 2010 US Census data for census blocks within the study area.

[b] Based on Washington State Department of Health database of public water systems.

There are no known large self-supplied non-residential water users in the Appleton study area.

One additional category of minor non-residential water use not included in this water balance is stock watering from wells, which is exempt from water right permitting and for which no information is available. Stock watering is considered to be a relatively small component of total water use in the study area.

Consumptive and Non-Consumptive Water Use

Water delivered for use is either consumed by evapotranspiration, or is not consumed, remaining in the study area as return flow that augments streamflow or groundwater sources.

Based on Klickitat PUD demand data for the Klickitat PWS (70 acre-feet/year excluding unaccounted for water[2]) and discharge data from the Klickitat wastewater treatment plant (35 acre-feet/year), we estimate a total consumptive use – residential and non-residential uses – of 50%. Since the wastewater treatment plant discharge (nonconsumptive return flow) is not resolved between residential and non-residential uses, this value is assigned to all uses for the Klickitat PWS. The Klickitat wastewater treatment plant discharge is directed to the Klickitat River, which is treated as en export from the study area.

Using domestic water use numbers for Washington State (Solley et al, 1998), it is assumed that 12 percent of the self-supplied residential use in the study area is consumptive. We assume the self-supplied residents in the study area treat their wastewater via septic tanks and drain fields. Therefore, the self-supplied residential return flow is assumed to be 100 percent groundwater recharge in the water balance.

PWS-supplied non-residential uses can include industrial and commercial uses.

Summary of Water Uses

Applying the methodology and assumptions described above, the resultant estimated annual consumptive and non-consumptive (return flow) volumes for each use category are presented in Table B-3.

The estimated total annual water use (roughly 134 acre-feet/year) is approximately 28% of the appropriated annual water rights for the study area (482 acre-feet/year), based on water right certificates and permits for the study area reported in Ecology's Water Rights Tracking System (WRTS). This summation of annual water rights excludes the following water right categories recorded in WRTS: Klickitat River water rights for irrigation use since no large-scale irrigation use is noted in the study area (smaller Klickitat River rights for domestic use are included in the assessment); industrial rights for the former Klickitat mill since, while the rights may be valid, they are not being exercised under current conditions[3]; and large non-consumptive rights for fish rearing since the water is not imported into the study area for use. Also note that approximately 42% of the estimated total water use is residential use supplied by private wells that are exempt from water right permitting (thus not recorded in Ecology's WRTS).

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[2] Unaccounted water is assumed lost from leaking subsurface pipes, so it is return flow to groundwater (without "use"). Since the water is supplied by groundwater, this return flow has no net effect on the water balance.

[3] Klickitat PUD transferred the Mill's domestic water right to four groundwater wells in 2001, and is exercising the right for municipal supply.

Table B-3 – Estimated Water Use in Appleton Study Area

	Water Use in Acre/Feet/Year by Category				
Study area	**Irrigation**	**PWS-Supplied Residential**	**Self-Supplied Residential**	**PWS-Supplied Non-Residential**	**Total Use in Acre-Feet/Year**
Total Use	0	63	57	14	**134**
Consumptive Use	0	29	7	7	43
Total Return Flow	*0*	*34*	*50*	*7*	*91*
Return Flow to Groundwater	*0*	*6*	*50*	*0*	*56*
Return Flow to Study Area Streams	*0*	*0*	*0*	*0*	*0*
Return Flow to Klickitat River	*0*	*28*	*0*	*7*	*35*

Notes:

PWS: Public water system.

Refer to text regarding assumptions for consumptive vs. nonconsumptive uses.

Water Balance Calculations

Water Balance Methods

For the water balance, precipitation translates into groundwater recharge, runoff becoming streamflow, evapotranspiration, consumptive water use and return flow on an annual basis, which is expressed by:

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

Each component of the water balance is described below. The water balance values are presented in Table B-5, with the annual volume values rounded to the nearest 10 acre-feet/year. Return flow quantities are assigned a negative sign in Table B-5 to reflect that they are returned to the watershed as groundwater recharge or streamflow (not consumed).

Mean annual precipitation in the Appleton study area is estimated at 24 inches per year, which is the value estimated for the Lower Klickitat subbasin[4] of WRIA 30 in the WRIA 30 Level 1 Watershed Assessment (WPN and Aspect, 2004). The precipitation data for the Level 1 assessment were obtained from the Parameter-Elevation Regressions on Independent Slopes Model (PRISM; Daly and others, 1994; http://www.prism.oregonstate.edu/). PRISM is the USDA's official climatological data. In Section 3.5.1 of this report, precipitation data from Glenwood (29.7 inch/year) are used to assess precipitation trends over time. The PRISM model data provide an average value estimate, not precipitation data over time; however, because the model encompasses the entire study area, it is

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[4] Study area is within the Lower Klickitat subbasin (refer to Figure 1.1 in main body of report).

considered the best available estimate of average precipitation for the water balance analysis. Applying the 24 inches per year across the study area's approximately 53,300 acres provides an average annual precipitation volume of approximately 108,380 acre-feet/year (Table B-5).

The WRIA 30 Level 1 Assessment applied USGS recharge estimates from a regional modeling study (Bauer and Vaccaro, 1990) to estimate average recharge for the Lower Klickitat subbasin. The USGS' recharge estimates were developed using a deep percolation model for the entire Columbia Plateau regional aquifer system to represent then-current land use conditions, and the model covered the study area excluding the westernmost portion. Using this information, the natural condition mean annual groundwater recharge in the study area is estimated at approximately 10 inches, which equates to an annual recharge volume of 44,420 acre-feet/year (Table B-5). An estimated additional 90 acre-feet/year of groundwater recharge is generated by return flow (Table B-3).

The annual runoff in the study area was estimated from a continuous-flow stormwater runoff model, WWHM4 (Clear Creek Solutions, 2010). The model uses land cover (vegetated, hard surface, etc.), the land slope gradient, the permeability of the soils, and historical precipitation data to estimate the amount of stormwater runoff.

Data from GIS databases for the area were used to determine the land cover, slopes, and soil types for the study area. For residential areas, it was assumed a portion of the lot was impervious (roofs and driveways) and pervious (yards and open land). Higher density residential areas were weighted more heavily towards impervious (90 percent impervious), lower density towards pervious (10 percent impervious).

WWHM4 is used because of its ability to account for soil moisture and recharge before converting the flow into runoff. For this analysis, this feature was a way to reduce runoff overestimation. The model was run for each year that annual precipitation data are available. Based on the basin-scale model results, runoff as percent of precipitation ranges from 0.8% to 2.6% annually, with a long-term average of 1.7%. This long-term average value equates to 1,840 acre-feet/year of runoff applied in the water balance. Note that this is a basin-scale estimate, and runoff percentages can be different for specific areas or for specific precipitation events.

There are no reliable study-area-scale natural ET estimates (non-irrigated vegetation/soil cover) that can be used in the water balance equations for the Appleton study area. 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. The resultant ET estimates were 62,160 acre-feet/year, or 14 inches/year. This value represents ET for all non-irrigated vegetation/soil cover, which comprises the entire area. (Table B-5).

Table B-4 – Summary of Land Surface Parameters for WWHM Model of Study Area

Pervious Surfaces in Acres	Soil Type			
	A	B	C	D
Forest, Flat	27	15545	5167	156
Forest, Mod	5	5005	1058	114
Forest, Steep	1	941	74	299
Shrub, Mod	52	4338	992	227
Shrub, Steep	12	1472	1530	485
Shrub, Flat	118	5994	782	178
Pasture, Flat	16	2810	235	116
Pasture, Mod	1	441	54	15
Pasture, Steep	0	58	90	76
Lawn, Flat	66	1502	338	26
Lawn, Mod	14	581	133	21
Lawn, Steep	3	82	59	15
Impervious Surfaces in Acres				
Roads and Roofs, Flat	252			
Roads and Roofs, Mod	107			
Roads and Roofs, Steep	28			
Wetlands	234			
Rock (impervious natural), Flat	14			
Rock (impervious natural), Mod	1			
Rock (impervious natural), Steep	1			
Open Water	3			

Notes:

Total acres used in model are based on those acres with GIS data. Runoff was determined as a percentage of precipitation based on the ratio of runoff to precipitation found via the model results.

Water Balance Results

Table B-5 provides the estimated average annual water quantities (acre-feet/year) associated with each water balance term for the Appleton study area.

Table B-5 – Annual Water Balance Summary for Appleton

				Outputs						
	Inputs			Natural Conditions				Water Use		
Area	Precipitation		Import from Klickitat River	ET (non-irrigation)		Recharge	Runoff	Consumptive Use	Return Flow	Export to Klickitat River
in acres	in inches [1]	in ac-ft [2]	in ac-ft [3]	in inches [5]	in ac-ft [4]	in ac-ft [6]	in ac-ft [7]	in ac-ft	in ac-ft	in ac-ft
53,300	24	108,380	0	14	62,170	44,420	1,840	40	-90	0

Notes:

1) Source: Study area average from PRISM data.

2) Source: Calculated from value in inches.

3) Source: Klickitat River water imported based on proportion of Klickitat River rights (excluding rights for irrigation use and fish rearing) vs. groundwater and other surface water rights (Ecology's Water Rights Tracking System), and total estimated use. Estimated value is 2 acre-ft/year, which rounds down to zero in this basin-scale water balance.

4) Source: Calculated in water balance from other parameter estimates.

5) Source: Calculated from ET value in ac-ft.

6) Source: USGS deep percolation model (Bauer and Vaccaro 1990), as reported in WRIA 30 Level 1 Assessment using 10 inches per year.

7) Source: Based on percentage of precipitation that is converted to runoff (1.7%), estimated using stormwater modeling software WWHM4.

8) All acre-foot quantities rounded to nearest 10.

On the scale of the study area, we estimate that 32% of the total water use, 43 of 134 acre-feet/year, is consumptive use. Water availability can be assessed on the basin scale by comparing total consumptive surface water use relative to total streamflow, and total consumptive groundwater use relative to groundwater recharge.

Ecology's WRTS includes several Klickitat River water rights for irrigation use but, based on review of aerial photographs and reconnaissance of the area, this larger-scale irrigation water use no longer occurs. We assume Klickitat River water rights for domestic uses are in use. In addition, there are four recorded water right permits and certificates, diverting from smaller creeks (two from Silvas Creek, two from unnamed creeks), totaling 17 acre-feet/year of annual water use, for commercial, domestic, stock watering, and irrigation uses; use of these water rights is uncertain. A water right on Snyder Creek for the former Klickitat Mill is assumed not in use at this time, Based on the proportion of these water right quantities, we assume that approximately 95% of the study area's total water use, or 153 acre-feet/year, is supplied by groundwater, with approximately 4% (7 acre-feet/year) and 1% (2 acre-feet/year) supplied by small streams and the Klickitat River, respectively.

The water use assessment concludes that approximately 90% of the annual water use in the study area is for residential supply, and 10% is for non-residential use. Return flow from the Klickitat PWS (residential and non-residential uses) is returned to the Klickitat River via the Klickitat wastewater treatment plant. Based on the water balance analysis, an estimated 35 acre-feet/year of water is discharged to the Klickitat River via return flow from the Town of Klickitat (supplied by groundwater wells) (Table B-3). Assuming that 88% of the self-supplied residential water use within the study area is not consumed during use, and that return flow discharges entirely to septic, an estimated 50 acre-feet/year of additional groundwater recharge is generated from that return flow.

There is little surface water use in this study area, due to the lack of reliable year-round flows in the small streams, and lack of water storage to capture and make use of the higher winter flows. In addition, we are aware of no streamflow gaging data for streams that drain only the study area. Assuming that small streams supply approximately 4% of the total water use, the consumptive surface water use is estimated at about 2 acre-feet/year. This is roughly 0.1% of natural runoff within the study area.

The estimated annual quantity of groundwater-supplied use that is consumed is approximately 40 acre-feet/year (95% of the total 43 acre-feet/year of consumptive use). This quantity is only 0.09% of the annual natural groundwater recharge. This calculation “nets out” nonconsumptive groundwater use (return flow) that recharges the groundwater system. Because the water right information in Ecology’s WRTS may not accurately represent the water sources supplying the study area, we can generate a more conservative estimate of groundwater consumption as a percent of recharge by assuming the entire estimated 134 acre-feet/year of water use is supplied by groundwater. In this case, an estimated 43 acre-feet/year is consumed, which is approximately 0.1% of the annual natural groundwater recharge. While there is uncertainty in the water balance analysis (detailed in next section), it indicates that total groundwater use is a very small percentage of groundwater recharge for the study area as a whole.

In summary, using the available information, total groundwater use is less than 1 percent of the total annual recharge in the Appleton study area. However, this assumes that recharge and groundwater pumping are distributed equally across the entire study area; it does not account for localized concentrated pumping or differentiate pumping from vertically distinct aquifer zones. As described in Section 3, the study area’s basalt aquifer system appears to be “compartmentalized” by geologic structures and deeply incised valleys. Furthermore, return flow preferentially recharges the shallowest aquifer zones, while pumping in a given area may be predominantly from deeper aquifer zones. Therefore, empirical groundwater monitoring, as has now been initiated under the watershed planning and implementation process, provides the best measure for assessing sustainability of groundwater production in specific localities within the study area.

Uncertainties in Basin-Scale Water Balance

The basin-scale water balance estimate does not accurately reflect hydrologic conditions at all locations within a study area, or during all years, or all seasons. They are meant to represent the generalized long-term average hydrologic conditions of the study area. 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 the study area can be discussed in terms of the uncertainties associated with each water balance term.

As the primary input to the 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 study area-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 water availability within the Appleton study area.

Groundwater recharge as modeled by the USGS also introduces uncertainty into the study area-scale water balance. It was a regional model that included most of the Appleton study area but did not specifically model the local conditions of the study area. 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).

The use of a continuous simulation stormwater model to estimate runoff can introduce some uncertainty into the water balance since the model uses precipitation and ET data that may not be applicable to every portion of the study area. The model uses an HSPF (Hydrological Simulation Program – Fortran) for modeling the stormwater runoff, which is considered to be one of the more robust modeling methods for estimating this term. An HSPF model takes into account soil moisture and storage, whereas most other stormwater runoff models do not. Since there are no gages in streams to measure actual streamflow draining only the study area, this model provides a reasonable estimate of runoff volumes for the purposes of this study.

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 associated with the other terms are propagated into the resultant ET value for the Appleton study area.

Finally, the assumed water supply sources for the study area are based on water rights information, which may not accurately reflect current conditions. Groundwater use is of critical importance for the study area; therefore, using available information, the water balance analysis brackets a range of groundwater use estimates, both of which come to the same general conclusion regarding groundwater use as a very small percentage of groundwater recharge annually.

References for Appendix B

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