GSI Water Solutions, Inc.
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Hydrogeologic Framework and Conceptual Groundwater Flow Model

Review of Groundwater Conditions in the West Plains Area, Spokane County, Washington

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GSI Water Solutions, Inc.

Portland Office
55 SW Yamhill Street
Suite 300
Portland, OR 97204
Phone: 503.239.8799
Fax: 503.239.8940

Corvallis Office
1600 SW Western Boulevard
Suite 240
Corvallis, OR 97333
Phone: 541.753.0745
Fax: 541.754.4211

Bend Office
147 SW Shevlin Hixon Drive
Suite 201
Bend, OR 97702
Phone: 541.678.5117

Kennewick Office
8019 W Quinault Avenue
Suite 201
Kennewick, WA 99336
Phone: 509.735.7135
Fax: 509.735.7067

Santa Barbara Office
418 Chapala Street,
Suite F
Santa Barbara, CA 93101
Phone: 805.895.3956

www.gsiws.com

info@gsiws.com

GSI Water Solutions, Inc.; INTERA, Inc., GeoEngineers, Inc., Carlstad Consulting

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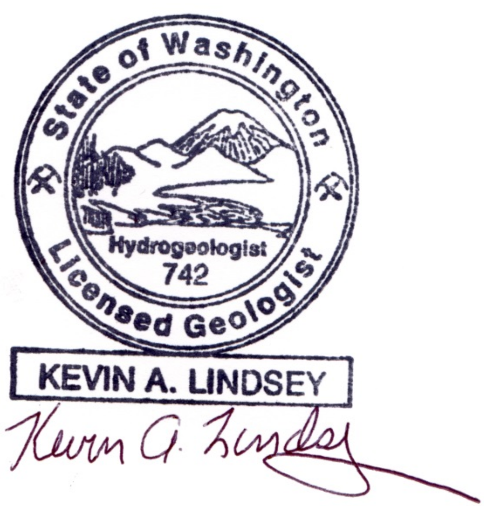

Contents

Tables

Figures

Appendices

A. Quality Assurance/Quality Control Summary Letter Report from GeoEngineers, Inc., to GSI Water Solutions, Inc.
B. Drilling Completion Report for the West Plains Hydrogeologic Framework Project
C. Project Area Well Stratigraphic Data Table

Plates

1. Well Location Map
2. Modeled Structure Contour Map of the Top of Basalt
3. Modeled Structure Contour Map of the Top of Basement

Acronyms and Abbreviations

amsl	above mean sea level
bgs	below ground surface
bgy	billion gallons per year
cfs	cubic feet per second
CRBG	Columbia River Basalt Group
DEM	digital elevation model
Ecology	Washington Department of Ecology
FAFB	Fairchild Air Force Base
gpm	gallons per minute
I-90	Interstate 90
QA/QC	quality assurance/quality control
SVRP	Spokane Valley Rathdrum Prairie
US-2	US Highway 2

Executive Summary

The objective of this report is to describe a hydrogeologic framework and conceptual groundwater flow model for the West Plains area (Project Area) in western Spokane County, Washington. Groundwater in the Project Area is found primarily within the Columbia River Basalt Group (CRBG) and to a lesser extent in Quaternary alluvial sediments. CRBG and Quaternary strata are underlain by older crystalline igneous and metamorphic rocks that locally host small quantities of groundwater. In portions of the Project Area, water level declines of tens to more than 200 feet have occurred historically in the CRBG aquifer system. In recent years, there has been some local recovery in CRBG aquifer system water levels at locations where pumping was the greatest, but only as a result of significant changes (including local reductions) in groundwater pumping by major water suppliers.

For use in this report, 44 geologic and/or hydrogeologic reports, 26 datasets (which include water level, streamflow, geochemistry, climate, geologic, and/or well construction data), 7 geologic maps and/or map sets, and 4 compilation reports were quality assurance/quality control (QA/QC) reviewed. Of the 81 documents QA/QC reviewed, 44 were found to be suitable for use in this effort, 29 were found to be unsuitable at this time, but possibly usable in the future with more complete documentation, and only 8 were found to be unsuitable for use in this effort.

The West Plains area is generally an elevated plateau west of the City of Spokane, west and south of the Spokane River, west of Hangman Creek, and east of a series of hills north and south of the Town of Reardan, Washington. These hills form a topographic divide separating the Project Area from the Columbia Basin lying to the west. Most of the Project Area plateau is a relatively flat surface at elevations of approximately 2,200 to 2,400 feet above mean sea level (amsl) in and around the City of Airway Heights, City of Medical Lake, Fairchild Air Force Base, and Spokane International Airport. This plateau is slightly higher to the west, south, and north. Canyons occupied by Coulee Creek, Deep Creek, the Spokane River, and Marshall Creek are incised into the plateau to elevations of approximately 1,600 to 1,700 feet amsl. In addition, there are several hills projecting above it, generally in the western half of the Project Area.

From the surface downward, the major geologic units found within the Project Area include: (1) Quaternary supra-basalt (or alluvial) sediments and associated soils, (2) CRBG Miocene continental flood basalt and sedimentary interbeds within the CRBG known as the Latah Formation, and (3) older metamorphic and crystalline igneous rocks underlying the CRBG and Quaternary strata and commonly referred to as basement rocks. Quaternary sedimentary strata, also referred to as alluvial sediments or alluvium, consist predominantly of Pleistocene to Holocene-aged alluvium, Pleistocene Missoula flood deposits, and Pleistocene loess. The CRBG has been divided into a host of regionally mappable units based on variations in physical, chemical, and paleomagnetic properties, and stratigraphic position between flows and packets of flows. In the Project Area, only a few CRBG units are present: the Priest Rapids Member of the Wanapum Basalt, consisting of one to four flows where present; the Sentinel Bluffs Member of the Grande Ronde Basalt, consisting of one to three flows where present; and the Wapshilla Ridge Member of the Grande Ronde Basalt, consisting of at least one flow where present.

The alluvial aquifer system is defined by the presence of unconfined groundwater in alluvial sediments overlying basalt and/or basement rock. The lateral extent of the suprabasalt aquifer in the Project Area is controlled by basalt and basement outcrops. As such, it usually occurs in saturated alluvial sediment found in modern canyons and paleochannels. These physical controls on saturated alluvial sediment distribution result in an alluvial aquifer that is very discontinuous, with hydraulic continuity between different areas of saturated alluvial sediment being extremely limited to absent. The depth to water and aquifer thickness in the alluvial aquifer are variable. On floodplains near streams, depth to water ranges from a few inches to several feet. More distally from streams, depth to water may range from several feet, to tens of feet, or even more, assuming an alluvial aquifer is even present. Depth to water in paleochannels can be several tens of feet, or more. Alluvial aquifer thickness is entirely controlled by water table elevation and the elevation of the top of basalt, probably ranging from a few feet to several ten of feet.

Groundwater in the CRBG regionally, and beneath the Project Area, generally is confined. The CRBG aquifer system in the Project Area is separated from the regionally extensive CRBG aquifer system in the Columbia Basin by the basement ridges generally bounding the western side of the Project Area. As a result, the CRBG aquifer system in the Project Area is localized in nature, not being part of a regional system covering thousands of square miles. CRBG groundwater primarily occurs in water-bearing intervals hosted by interflow zones and interbedded Latah Formation sediments where these occur. Groundwater occurring within interflow zones is found in joints, vesicles, fractures, intergranular pores in vesicular and brecciated basalt flow tops and bottoms, and in sediment interbeds. Groundwater occurring in dense basalt is restricted to fully penetrating joints and fractures.

Combining the geologic, water level, and groundwater geochemical features, four basic types of physical geologic features are interpreted to be influencing the hydrogeologic framework of the Project Area. These features are: (1) basement highs, both exposed and buried, (2) location and incision depth of modern topographic canyons, (3) location and incision depth of alluvium filled paleochannels, and (4) stratigraphic features within the CRBG and interbedded Latah Formation. Additional smaller-scale features also may influence local groundwater conditions in the Project Area, but the available data and information are interpreted generally to be insufficient, unless otherwise noted, to specifically identify and delineate these local features.

Basement highs buried beneath the basalt are interpreted to be continuations of the basement cored hills seen in and around the Project Area. These buried highs, in association with their corresponding topographic highs, are interpreted to essentially form the northern, western, and southern boundaries of the Project Area, separating it from the much larger Columbia Basin regional aquifer system. In addition, several generally parallel northeast-southwest oriented basement ridge systems (buried and exposed) are identified within the Project Area, subdividing the Project Area into basement-defined subbasins or subsystems. These basement-bounded subsystems generally are found within the topographic lows in the Project Area and are occupied by most of the modern drainages, the paleodrainages, and the thicker basalt-hosted groundwater systems.

Topographic canyons are interpreted to influence the groundwater system down to elevations equivalent to the bottom of the each canyon. Water-bearing basalts below the canyon bottoms likely form generally continuous flow systems beneath the canyons. These systems would be influenced locally only where they are incised into by a given canyon. Gaining reaches on Coulee Creek and Deep Creek may reflect incision into and discharge into the canyon from deeper Wanapum and upper Grande Ronde water-bearing strata.

Paleochannels generally are interpreted to have limited to no significant influence on the basalt groundwater system beneath the incision depths of the paleochannels. Conversely, the paleochannels have a significant hydrologic connection with the basalt groundwater systems truncated, or intercepted, by them. This relationship likely will vary between paleochannel reaches. Some reaches will act as recharge a source for adjacent shallow basalt aquifer zones. Other reaches act as drains into which shallow basalt groundwater systems discharge.

To conclude, the West Plains groundwater flow system is a local system separated from the regional CRBG aquifer system by basement highs bounding the northern, western, and southern boundaries of the Project Area. Groundwater beneath the West Plains is interpreted to be locally sourced, flow pathways are relatively short (although they can be slow), and groundwater storage capacity is limited by discontinuities that separate the groundwater flow system into several subsystems. At minimum, modern canyons, paleochannels, and basement highs disrupt lateral continuity within the groundwater system. This is interpreted to result in the West Plains groundwater system being broken up into localized groundwater flow systems with relatively limited storage potential and rate of recharge. Consequently, slight variations in precipitation, infiltration, and pumping may have a significant effect on the groundwater flow system. Taken together, limited recharge potential and limited lateral continuity, the West Plains groundwater system is characterized by compartmentalized conditions that are easily affected by pumping and recharge stresses.

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1. Introduction

The objective of this report is to describe a hydrogeologic framework and a conceptual groundwater flow model for the West Plains area (the Project Area) in western Spokane County, Washington (Figure 1). Groundwater in the Project Area is primarily found within Miocene-aged (16.5 to 14.5 million year old) Columbia River Basalt Group (CRBG) and, to a far lesser extent, in Quaternary alluvial sediments (less than 1.5 million years old). CRBG and Quaternary strata are underlain by older (more than 45 million years) crystalline igneous and metamorphic rocks (basement) that locally host small quantities of groundwater. In portions of the Project Area, water level declines of tens to more than 200 feet have occurred historically (especially in the 1990s) in the CRBG aquifer system. In recent years, there has been some local recovery in CRBG aquifer system water levels in locations where pumping was the greatest, but only as a result of significant changes (including local reductions) in groundwater pumping by major water suppliers. These declines and other evidence of stresses on the Project Area groundwater system prompted preparation of this report.

The hydrogeologic framework and conceptual groundwater model proposed in this report describe potential basic controls on the Project Area groundwater flow system, including recharge and discharge, flow direction, and compartmentalization. This report does not describe every localized perturbation suggested by the variety of datasets, large and small, collected across the Project Area during the past few decades. This report attempts to describe the basic themes that are interpreted herein to be central to understanding the West Plains groundwater system. Findings and observations described in this report also may be used in support of future water management decision making and water rights decisions, and to provide a basis for future potential numerical modeling.

This report is based primarily on previously compiled information, data, and reports, including reports that describe hydrogeologic conditions in all, portions of, and/or locally in the Project Area (cited as appropriate in the body of the report). Hydrogeologic information described in these reports include such things as groundwater geochemistry in a small number of wells; water level data (ranging from single measurements to long-term datasets) in dozens of wells; seepage runs on selected creeks; consultant reports, many of which focus on Fairchild Air Force Base (FAFB) groundwater conditions; interpretations of depth and extent of alluvium-filled paleochannels, isopach maps of selected geologic units, and well geologic log databases. Generally, the majority of this information is not reinterpreted, instead it is evaluated for clues that potentially point to basic physical controls on the Project Area groundwater system. Field investigations done for this effort focused on brief field reconnaissance and a limited investigation of locations where basement rock outcrops previously were mapped.

Work products associated with this report include multiple maps that illustrate interpretations of several fundamental hydrostratigraphic surfaces that are described as influencing groundwater occurrence. Report contents include:

1. A summary of the data sets and sources, data analysis, and data quality assurance/quality control (QA/QC) used in interpreting the hydrogeologic framework and conceptual groundwater flow model
2. A review of West Plains geographic setting, land use, climatic conditions, and water uses
3. A review of basic West Plains geologic and hydrogeologic framework

4. An evaluation of water level data and associated groundwater geochemical data, and what they suggest about the West Plains groundwater system
5. A description of West Plains hydrostratigraphy, hydrogeologic framework, and a conceptual groundwater flow model

This work was done under Spokane County Contract P8454. The work was funded by the Washington Department of Ecology (Ecology) through a grant to Spokane County. The consulting team that did the work reported on herein includes Dr. Kevin Lindsey, LHg (lead), Patty Newman, Jon Travis, and Jesse Manley with GSI Water Solutions, Inc.; Patrick Royer with INTERA, Inc.; Cynthia Carlstad with Carlstad Consulting; and Jonathan Rudders, LHg, with GeoEngineers, Inc. Mike Hermanson was the project manager for Spokane County Water Resources.

2. Data, Methods, and QA/QC

2.1 QA/QC and Methods

As noted in the introduction, this report relies primarily on existing data and reports. Consequently, a QA/QC review was conducted to ascertain whether these existing materials were potentially suitable for use in this effort. The results of this QA/QC review are presented in Appendix A and summarized here.

For use in this report, 44 geologic and/or hydrogeologic reports, 26 datasets (containing water level, streamflow, geochemistry, climate, geologic, and/or well construction data), 7 geologic maps and/or map sets, and 4 compilation reports were QA/QC reviewed. Several of the reports, while informative, covered areas outside of the Project Area. Reports also were found that, while they provided informative interpretations useful in unraveling Project Area hydrogeology, had limitations commonly associated with a lack of supporting documentation. Some data sets, in particular geologic unit picks in RockWorks© stratigraphic log data files, were found to have some limitations because several editions of these were encountered and they did not always appear to be reconciled with each other. In addition, some reconciliation issues were encountered in the contour maps built from these well log data files: surfaces were not always compatible, sometimes contradicting each other in different attempts to rebuild 3-dimensional subsurface geologic models of the Project Area. Despite these limitations, these geologic data files and interpretations provided valuable insight into the basic subsurface distribution of geologic units underlying the Project Area. Of the 81 documents QA/QC reviewed, 44 were found to be suitable for use in this effort, 29 were found to be unsuitable at this time, but possibly usable in the future with better documentation, and only 8 were found to be completely un-usable.

Building on the QA/QC review, analysis methods used in in support of the preparation of this Report generally focused on the use of professional judgment in interpreting and evaluating the content of the reports, data sources, databases, and other information as possible hydrogeologic framework and conceptual groundwater flow model concepts and ideas were considered. During the course of this project, ideas and interpretations periodically were reviewed or critiqued within the project team, vetted with Spokane County and Ecology professional staff members for feedback, and discussed in several Technical Advisory Group meetings hosted by Spokane County.

A limited field investigation was done as a part of this project. The goal of the limited field investigation was to ascertain whether several locations mapped as basement outcrop on previously prepared 7.5 minute quadrangle maps were indeed in-place outcrops. The limited field investigation focused on two field activities. The first activity was a walkover of the sites in question, during which professional judgment was used to assess the likely physical nature of the materials in question. The second activity focused on drilling into materials at one of the sites judged to most likely be a basement outcrop. The drilling was done to determine if the basement material found at the surface continued at depth or was underlain by basalt. The results of the limited field investigation were reported in a technical memorandum (see Appendix B), and they are incorporated into the geologic setting discussion.

The remainder of Section 2 introduces the: (1) data and materials that were the primary materials used in the preparation of the hydrogeologic framework and conceptual groundwater flow model described later in this report and (2) flex viewer tool.

2.2 Data and Information Sources

Building on the QA/QC review (Appendix A), the primary types of data and information used in this effort consist of: (1) surface and subsurface geology interpreted from geologic maps, driller's well logs, well geologic logs, and outcrop measured sections; (2) water level data, well hydrologic interpretations, and previously prepared hydrographs; (3) groundwater geochemical data and analyses; and (4) discussions, descriptions, and analysis of area-wide water use and potential groundwater recharge. With respect to these data and information:

1. Geologic information was derived from: (a) a limited field investigation (see Appendix B); (b) geologic maps of the Project Area (Joseph, 1990; Derkey et al., 2003, 2004; Hamilton et al., 2004a, 2004b, 2004c; Derkey and Hamilton, 2007; unpublished maps by McCollum and McCollum; Washington Department of Natural Resources interactive geologic map available online at https://fortress.wa.gov/dnr/geology/?Theme=wigm); (c) Rockworks© databases provided by Spokane County Staff and built from the interpretation of various wells logs by County personnel, Eastern Washington University staff and students; and (d) previously prepared reports (Golder, 2009; McCollum and Hamilton, 2012; McCollum and Pritchard, 2012; NLW, 2012; Pritchard, 2013).
2. Water level data was provided by Spokane County and Ecology staff and reported in Spokane County (2013c).
3. Groundwater geochemical data, predominantly related to potential groundwater age, was taken from NLW (2014).
4. Area-wide water use estimates (Spokane County, 2011), seepage runs (Spokane County, 2013a), and potential groundwater recharge calculations (Spokane County, 2013b) were taken from several reports on these topics.
5. Other reports and data sources cited as appropriate throughout this report.

2.3 Web Applications: Flex Viewer and Water Level Tool

Two Web-based applications were prepared for use in this project. One is a flex viewer for geographic, geologic, and well data and information. The other is a water level tool for evaluating water level data. These applications were developed for the project team to use as a data analysis and visualization tool and as a final deliverable for Spokane County to use as an information and data portal and outreach tool.

The flex viewer contains several information sources and visualizations, including:

- Well locations and basic well information
- Top of basalt and top of basement shaded relief maps
- Surface geologic maps
- Soil, precipitation, and estimated soil infiltration coverages
- Land use summary information
- Water level data for different portions of the aquifer system

The water level tool is a graphical interface used to access water level data, compare different hydrographs, and produce hydrographs for wells that are specified by the user.

3. Geographic Setting

The objective of Section 3 is to provide a brief description of the Project Area surface physical environment, including physical geography, land use, water supply sources, surface water hydrology, and precipitation. Because this discussion is drawn from previously prepared reports, it does not provide detailed information about any of these topics. Instead, it introduces them to give the reader a basic geographic context for the Project Area. Additional citations are provided as appropriate and readers are encouraged to consult these reports for additional information.

3.1 Physical Geography

The West Plains area is generally an elevated plateau west of the City of Spokane, west and south of the Spokane River, west of Hangman Creek, and east of a series of hills located north and south of the Town of Reardan, Washington. These hills form a topographic divide separating the Project Area from the Columbia Basin lying to the west (Figure 1, Plate 1). Most of the Project Area plateau is a relatively flat surface lying at elevations of approximately 2,200 to 2,400 feet amsl in and around the City of Airway Heights, City of Medical Lake, FAFB, and Spokane International Airport. This plateau is slightly higher to the west, south, and north. For this report, all vertical elevations are in the North American Datum of 1983.

Two other significant topographic features punctuate this plateau. One of these features is the deep topographic canyons occupied by Coulee Creek, Deep Creek, the Spokane River, and Marshall Creek (Figure 1, Plate 1). These canyons can be several hundred feet deep, and, in the case of the Spokane River, the canyon is incised into the plateau to elevations of approximately 1,600 to 1,700 feet amsl. The other feature interrupting the Project Area landscape are several hills projecting above it, generally in the western half of the Project Area (Figure 1, Plate 1). These hills commonly extend 100 to 300 feet above the plateau surface, and, as noted above, mark a topographic divide between the Project Area and the Columbia Basin.

The Project Area landscape is covered by a mix of semi-arid shrub steppe grasslands, sparse mixed conifer forest and shrub steppe, barren rock surfaces, actively farmed ground, and urban and semi-urban uses near the Medical Lake, Airway Heights, FAFB, and Spokane International Airport and more actively developed rural residential landscapes. Forest cover is almost always more thick on north-facing canyon walls and hillsides. In the built-up area surrounding the City of Medical Lake, City of Airway Heights, FAFB, and Spokane International Airport, impermeable surfaces and stormwater collection infrastructure are common.

3.2 Groundwater Uses and Sources

Water is used in the Project Area for three primary purposes: public water supply systems, rural residential self-supply, and irrigated agriculture (Spokane County, 2011). Public water system suppliers include FAFB, City of Airway Heights, City of Medical Lake (including Consolidated Support Services for the Washington State Hospital facility), and several Class A systems in unincorporated areas (including Deep Creek Ranchettes, Indian Village Estates, West Prairie Village, and Fairchild Mobile Home Park). Several much smaller Class B systems also are active in the Project Area. The primary water supply sources for these systems, exclusive of the FAFB, are the basalt aquifers underlying the Project Area. FAFB supplies are derived primarily from the Spokane Valley Rathdrum Prairie (SVRP) aquifer. The City of Spokane, which is a major user of the SVRP aquifer, also delivers water to portions of the eastern Project Area, including the Spokane International Airport area. Other, lesser water sources in use in the Project Area include:

- Groundwater from the basement aquifer system (such as in Four Lakes' wells)
- Groundwater from the alluvial aquifer system found in paleochannels (such as at a new City of Airway Heights well)
- Surface water use from Deep and Coulee Creeks (local landowners)
- Reclaimed water (Medical Lake and Airway Heights)

Total water use in the Project Area, primarily from groundwater, is approximately 5 billion gallons per year (bgy) or 15,100 acre-feet per year. Of that use, approximately 3.5 bgy are for irrigated agriculture. As noted above, the basalt aquifer system supplies the large majority of this water, and it supplies essentially all of the agricultural demand. Water use in the Project Area is explained in detail in Spokane County (2011, 2013b).

4. Precipitation/Climate and Surface Water

This section provides a brief introduction to Project Area precipitation, climate, and surface water conditions.

4.1 Precipitation/Climate

Historically, precipitation in the Project Area has ranged from less than 10 inches per year to more than 22 inches per year, averaging approximately 16.9 inches per year in recent years (Spokane County, 2013b). The highest annual precipitation totals, generally exceeding 17 inches per year in wet years, are found in the northernmost, southernmost, and westernmost portions of the Project Area (Figure 2). The lowest amounts of precipitation in the Project Area tend to be in the area bounded by the City of Airway Heights, FAFB, Spokane International Airport, Medical Lake, and Interstate 90 (I-90) (Figure 2). The wettest months generally are November, December, January, March, and May. Consequently, much of this precipitation occurs as snow and ice, and commonly it falls on frozen ground. Given that, a significant portion of annual precipitation in the Project Area, by some estimates approximately 85 percent (Spokane County, 2013b), is lost to evaporation, evapotranspiration, and runoff out of the Project Area. Consequently, most precipitation is not available for groundwater recharge.

Precipitation is interpreted to be the only significant source of natural water introduced into the Project Area. The amount of precipitation that potentially percolates past the root zone and into the subsurface is estimated in Spokane County (2013b). This infiltration and potential groundwater recharge are estimated to range from essentially zero to as much as 12.4 inches per year, with highest rates generally occurring in and near modern canyons and valleys, and the lowest rates generally occurring in areas of basement and to a lesser degree basalt outcrops. Figure 3 illustrates the spatial distribution of potential annual infiltration rates predicted for the Project Area in Spokane County (2013b).

Actual recharge amounts in any given year will depend on the timing of the precipitation and when in the growing season it occurs. For precipitation occurring as snow or rain on frozen ground, infiltration will be small. Conversely, if precipitation occurs as rain when the ground is not frozen, more water may infiltrate into the ground and potentially be available for groundwater recharge. In addition, if precipitation occurs in the late spring and summer, higher evapotranspiration also will reduce total infiltration (and potential groundwater recharge) as a result of plant uptake.

A more detailed analysis of precipitation patterns and timing than was done in the infiltration report cited above (Spokane County, 2013b) was not done for this project. Nevertheless, based on general observations as noted above, it is assumed that historically most groundwater recharge occurred in spring and early summer months. With this assumption, the primary groundwater recharge months associated with precipitation infiltration generally are inferred to be in the March through June time frame. Taking this one step further, and as will be discussed in several places later in this report, hydrographs showing seasonally high water levels in this basic time frame are generally inferred to be responding to spring/early summer groundwater recharge.

4.2 Surface Water

Surface water within the Project Area occurs in several basic settings, as streams generally flowing to the east and northeast across the Project Area toward the Spokane River, and as lakes and wetlands.

The largest lakes in the Project Area include a series of water bodies bounding the southwest edge of the Project Area. These include West Medical Lake, Medical Lake, Silver Lake, Granite Lake, and Willow Lake (Figure 1, Plate 1). These lakes and associated wetlands occupy low areas separating basement rock cored hills in this area. Anecdotal comments by area stakeholders suggest that water levels in these lakes apparently do not fluctuate greatly during the year. Small ponds and wetlands occur throughout the Project Area, especially in undeveloped rural areas.

Three major stream systems drain the Project Area. Two of these are found in the northern half of the Project Area, Deep Creek and its primary tributary Coulee Creek (Figure 1, Plate 1). These streams flow from west to east, from headwaters near Reardan, Washington, toward the Spokane River. Historical flow data for these streams generally is lacking. May and June data from 2010 (Spokane County, 2013a, Table 1) show flow in these creeks ranging from zero to 8.9 cubic feet per second (cfs) in different reaches. Late summer flows, in 2012 were measured at zero to 2.15 cfs (Spokane County, 2013a, Table 1). These data and anecdotal information suggest summer flows in these creeks is low to absent in some reaches, and surface flow rarely reaches the Spokane River during summer months. Winter flows can be significantly higher, with the highest flows commonly associated with rapid snow melt events and rain on snow and frozen ground events. Both creeks have gaining and losing reaches, potentially related to underlying geologic conditions (Spokane County, 2013a).

Marshall Creek, in the southern part of the Project Area, is the third major stream in the Project Area (Figure 1, Plate 1). It flows from the area around Cheney, Washington, toward the northeast and its eventual confluence with Hangman Creek a tributary of the Spokane River. Marshall Creek enters the Project Area just south of Queen Ann Lake (Figure 1, Plate 1).

5. Geologic Framework

This section summarizes Project Area surface and subsurface geology, focusing on unit identification, physical characteristics, and unit distribution. From the surface downward, the major geologic units found within the Project Area include: (1) Quaternary supra-basalt (or alluvial) sediments and associated soils, (2) Miocene continental flood basalt of the CRBG and sedimentary interbeds within the CRBG known as the Latah Formation, and (3) older metamorphic and crystalline igneous rocks underlying the CRBG and commonly referred to as basement rocks. Figure 4 presents a highly idealized geologic cross section of the Project Area. Detailed information about the geology of the Project Area can be found in Deobald and Buchanan (1995), Golder (2009), McCollum and Hamilton (2012), McCollum and Pritchard (2012), NLW (2012), Pritchard (2013), and Spokane County (2013c); the reader is referred to these reports if more detail than is provided below is needed.

5.1 Soils and Quaternary Sedimentary Strata

5.1.1 Soils

Soil types within the Project Area range from thick silt loams to sandy and gravelly soils to thin rocky soils directly on bedrock. The silt loam soils, which dominate the rolling hills between the major drainages and scablands, are mostly well drained and dominate areas underlain by loess. Much of the active modern farming is done on these soils, and these soils typically have been farmed in the past. Unaltered intact silt loam soils are rare because the area has been subjected to urbanization and/or been used for agriculture and livestock grazing for many decades. The infiltration capacity of these soils would be relatively low to moderate.

Sandy and gravelly soils are most common in and around coulees and modern drainages and in currently buried paleochannels. These soils typically are developed on Pleistocene Missoula flood deposits, including sand and gravel bars deposited in and adjacent to the drainages. One would expect these soils to have a relatively high infiltration capacity.

Thin rocky soils commonly are present where basalt or basement bedrock is present at, or just below, the ground surface. Generally, these soils form a thin veneer of rocky silt and sand that has developed directly on rocky substrate. Soils developed over bedrock typically have extremely low to essentially no infiltration capacity. However, there may be cases where an underlying basalt substrate is dominated by a rubbly and/or brecciated interflow zone. In such cases, the infiltration capacity of these soils may be relatively high.

5.1.2 Quaternary Sedimentary Strata

Quaternary sedimentary strata, also referred to as alluvial sediments or alluvium, within the Project Area consist predominantly of Pleistocene to Holocene-aged alluvium, Pleistocene Missoula flood deposits, and Pleistocene loess. For the purpose of this report, these sediments are subdivided into two basic units: coarse Quaternary deposits (consisting predominantly of Missoula flood deposits and subordinate Holocene alluvial deposits) and fine Quaternary deposits (consisting predominantly of loess, although with minor fine-grained Missoula flood deposits).

Coarse Quaternary deposits consist of mixed silt, sand, and gravel deposited predominantly by Pleistocene Missoula flood waters and, to a lesser extent, by post-flood stream reworking of flood deposits and colluvial processes on hill slopes. These strata are most commonly found in and adjacent to coulees, stream and river canyons, and steep cliffs cut into basalt and basement bedrock. In addition, these deposits infill older paleochannels cut into underlying rock. Several more or less completely filled paleochannels have been mapped in the Project Area (Deobald and Buchanan, 1993; Pritchard, 2013). In some areas, Quaternary sediments may form benches in canyons and coulees.

Fine-grained Quaternary deposits consist predominantly of silt, silty sand, and fine sandy loess. These materials mantle many of the hills and valleys in the northern and western portions of the Project Area, especially between Medical Lake and Reardan, Washington, and northeast of Reardan. This unit is largely absent from coulees and drainages.

5.2 Miocene CRBG

Regionally, the CRBG is a thick sequence of more than 300 continental tholeiitic flood basalt flows that cover an area of more than 59,000 square miles (164,000 square kilometers) in Washington, Oregon, and western Idaho (Tolan et al., 1989) with a maximum thickness of more than 10,000 feet. The CRBG has been divided into a host of regionally mappable units (Figure 5) based on variations in physical, chemical, and paleomagnetic properties, and stratigraphic position between flows and packets of flows (Swanson et al., 1979a; Beeson et al., 1985; Bailey, 1989; Tolan et al., 2009; Reidel and Tolan, 2013). The CRBG in the Columbia Basin region is subdivided into four formations. These formations are, from youngest to oldest, the Saddle Mountains Basalt, Wanapum Basalt, Grande Ronde Basalt, and Imnaha Basalt (Swanson et al., 1979a, 1979b). These formations have been further subdivided into members defined, as are the formations, on the basis of a combination of unique physical, geochemical, and paleomagnetic characteristics. These members can be, and often are, further subdivided into flow units.

5.2.1 Physical Geology

Vertical exposures through CRBG flows reveal that they generally exhibit a planar-tabular fabric and a basic three-part internal arrangement of intraflow structures. These features, which originated either during the emplacement of the flow or during the cooling and solidification of the lava after it ceased flowing, are referred to as the flow top, flow interior, and flow bottom (Figure 6).

The flow top is the crust that formed on the top of a molten lava flow. Flow tops commonly consist of glassy to fine-grained basalt that is riddled with countless spherical and elongate vesicles. Some flow tops also can be rubbly or brecciated. Flow interiors are dense, non-vesicular, glassy to crystalline basalt that contains numerous contraction joints (termed cooling joints) that formed when the lava solidified. Columnar basalts are a common manifestation of these flow interior cooling joints. The character of the flow bottom largely is dependent on the environmental conditions the molten lava encountered as it was emplaced. They can be thin, vesicular, and glassy if the flow encountered dry ground. Alternatively, if lava encountered water during emplacement, pillow complexes formed. Outcrop measured sections in McCollum and Hamilton (2012) show that pillow complexes are common CRBG features in the Project Area.

Interflow zones are the intervals between successive planar-tabular basalt flows that can contain various combinations of flow top (from the underlying flow) and flow bottom (from the overlying flow) features. If a sediment interbed is present between the two flows, it also would be part of the interflow zone.

5.2.2 CRBG in the Project Area

In the Project Area, only a few CRBG units are present. CRBG units found in the Project Area, from McCollum and Hamilton (2012), include:

- The Priest Rapids Member of the Wanapum Basalt, consisting of one to four flows where present
- The Sentinel Bluffs Member of the Grande Ronde Basalt, consisting of one to three flows where present
- The Wapshilla Ridge Member of the Grande Ronde Basalt, consisting of at least one flow where present

Interpolating from the area-wide surface geologic map (Joseph, 1990), RockWorks© structure contour maps of the top of the unit generated by Spokane County personnel, and comments in Spokane County (2013c), the top of the Wanapum Basalt generally slopes off basement highs toward the fringe of the Project Area, in particular eastward toward the Spokane River valley. Wanapum Basalt units, although modified by erosion in many areas, generally dip to the east-northeast across the Project Area. Some reaches of Coulee Creek, Deep Creek, Marshall Creek, and the Spokane River completely incise through the Wanapum Basalt. Some paleochannel reaches also appear to locally fully incise through the Wanapum Basalt.

Grande Ronde Basalt units also are interpreted to generally dip to the east-northeast across the Project Area. Interpolating from the area-wide surface geologic map (Joseph, 1990), RockWorks© structure contour maps of the top of the unit generated by Spokane County personnel, comments in Spokane County (2013c), and maps in Pritchard (2013), the top of the Grande Ronde Basalt generally slopes off basement highs toward the fringe of the Project Area, in particular eastward toward the Spokane River valley. The Grande Ronde Basalt is locally incised into in portions of the Coulee Creek, Deep Creek, Marshall Creek, and Spokane River valleys. In addition, it also may be partially incised into in portions of some paleochannels. Figure 7 shows the currently mapped extent of Grande Ronde Basalt outcrops in the Project Area.

5.2.3 Top of Basalt

Except where basement rocks (discussed in Section 5.4) are present at the ground surface or directly underlying Quaternary sediments, the CRBG underlies the entire Project Area. For this project, a top of basalt structure contour map was produced. Well data from which this map was prepared are presented in Appendix C, and the map is included in this report as a shaded relief version in Figure 8 and as a larger format contour map in Plate 2.

The top of basalt map was built in several steps, as follows. First an initial grid model was built using an inverse distance gridding algorithm of the well data in Appendix C. This grid then was merged with the digital elevation model (DEM) where basalt outcrops are mapped on existing geologic maps. This resulting grid then was truncated where the grid model of the top of basement (discussed in Section 5.4) showed basement projecting upward through the top of basalt. The top of basalt grid model portrayed in Figure 8 and Plate 2 is a modeled representation of the top of basalt surface, and as such it provides a reasonable representation of basic surface features, including modern canyons and paleochannels incised into the surface and the pinch out of basalt against basement highs. Field review and grid refinements would be needed to increase the precision/accuracy of the modeled surface.

5.3 Latah Formation

Sedimentary strata interbedded within the CRBG in the Project Area are collectively referred to as the Latah Formation. Throughout the CRBG province, the nature and composition of these sedimentary strata vary greatly, ranging from epiclastic (or continental) to volcanoclastic in origin. Sedimentary interbeds within the CRBG in the Project Area are primarily epiclastic, having been deposited primarily in river (both channel and over bank deposits) and lake systems. Events controlling interbed deposition (Fecht et al., 1987; Smith et al., 1989) include emplacement of CRBG flows and their impact on paleodrainage systems (damming or diverting stream courses) and local and regional tectonism (uplift/subsidence).

Generally, Latah Formation strata in the Project Area are predominantly described as clayey. Sandy to gravelly intervals also may be present. Subsurface geologic interpretations, including cross sections, reviewed for this project (McCollum and Hamilton, 2012) suggest the Latah Formation, and lithologies within the Latah Formation, are laterally variable, thickening, thinning, and even pinching out.

In the Project Area, informal numerical designations, or subdivisions, of the Latah Formation have been adapted. These informal Latah Formation subdivisions (sedimentary interbeds) like the correlative Ellensburg Formation are solely defined and recognized on the basis of which CRBG units lie above and below them (Laval, 1956; Mackin, 1961; Schmincke, 1964, 1967; Bentley, 1977; Grolier and Bingham, 1978; Swanson et al., 1979a; Fecht et al., 1987; Smith et al., 1989). In the Project Area, the Latah subdivisions are referred to as:

- Latah I for sediments between the Wanapum Basalt and the Grande Ronde Basalt
- Latah II for sediments between the Sentinel Bluffs Member and the Wapshilla Ridge Member of the Grande Ronde Basalt
- Latah III for sediments between the Grande Ronde Basalt and the Basement

Un-numbered interbeds also may occur within individual CRBG units. A number of problems arise because these stratigraphic definitions are based solely on the identity of the confining CRBG units and not independent lithostratigraphic criteria. A fundamental problem with this scheme is that the defining CRBG units are not always present. Where this occurs, previously separate named units can merge into one member or even become part of another formation. This situation can, and often does, create confusion when dealing with sedimentary interbed nomenclature and lateral continuity.

5.4 Basement Rocks

Field reconnaissance and existing geologic maps, including Joseph (1990) and Washington Department of Natural Resources online maps (https://fortress.wa.gov/dnr/geology/?Theme=wigm), show that the Project Area is completely underlain by a variety of pre-CRBG crystalline intrusive and metamorphic rocks. These pre-CRBG rocks are reported to consist predominantly of granite and related felsic crystalline rocks and low to medium grade metamorphic rocks, especially quartzite and phyllite. These rocks are exposed on many of the buttes and hills within and surrounding the Project Area (locally termed steptoes), and in some of the deeper canyons.

In addition, basement rocks have been mapped at several locations at the surface between Spokane International Airport, FAFB, and the City of Airway Heights. These locations were investigated via limited field reconnaissance and shallow drilling. Based on recent work (Golder, 2009), the drilling (described in

Appendix B), and the field reconnaissance, these features are interpreted to not be outcrops, rather they are interpreted to consist of Pleistocene Missoula flood deposited debris.

Borehole geologic and driller's well log descriptions in the vicinity of FAFB also were revisited during this project. These logs, found in Budinger (2005) and the Ecology well log database, suggest the presence of a buried basement high extending north-northeast from near the City of Medical Lake, beneath FAFB, and under the west side of the City of Airway Heights. Building on the well data found in Appendix C, the field reconnaissance and drilling results in Appendix B, and interpolations drawn from these logs, a top of basement map was generated for this project.

The top of basement map was built in several steps, as follows. First an initial grid model was built using an inverse distance gridding algorithm of the well data in Appendix C. This grid then was merged with the DEM where basement outcrops are mapped on existing geologic maps. This merged grid then was edited to reflect (1) the presence of the buried high that this is inferred to underlie a portion of FAFB and (2) the absence of basement outcrops suggested on some maps, but eliminated by fieldwork done for this project. The resulting top of basement grid model portrayed in Figure 9 and Plate 3 is a modeled representation of the top of basement surface that the project team judges to be a reasonable representation of basic physical features influencing this surface, such as buried highs. The resolution of the top of basement surface is limited by the small number of wells that extend into basement and the distribution of those wells that leaves significant areas with limited or no data points.

The top of basement map produced for this report shows several features buried beneath the CRBG that will be discussed later in this report. These features, such as the one noted in the previous paragraph underlying FAFB, are named in Figure 9.

5.5 Structural Geology

Surface geologic maps of the Project Area show limited to essentially no structural deformation, with the exception of a few faults usually associated with basement outcrops (Joseph, 1990; Hamilton et al., 2004a, 2004b, 2004c; Derkey and Hamilton, 2007; Derkey et al., 2003, 2004). More recent work by McCollum and Pritchard (2012) show four primary structural features present in the Project Area (Figure 10). Based on Figures 6 and 7 in McCollum and Pritchard (2012) these faults include:

1. The Latah Fault. This fault essentially follows the valley of Hangman Creek and the Spokane River on the eastern boundary northward to the mouth of Deep Creek.
2. The St. Joe Fault. This fault is mapped in the southern portion of the Project Area as a northwest-southeast oriented feature crossing Marshall Creek in the area of Grove Road. The fault is mapped to extend into the Project Area as far northeast as the lower slope of the eastern end of Needham Hill. This feature is not mapped extending northward into the Project Area, potentially being obscured by the CRBG.
3. The Minnie Creek Lineament. This feature, also a northwest-southeast oriented structure, follows the Four Lakes valley northeast into the Project Area. It is inferred to bound the east side of Wright's Hill and Riddle Hill. This feature is not mapped extending northward into the Project Area, potentially being obscured by the CRBG.
4. The Jump Off Joe Fault. This feature is interpreted by McCollum and Pritchard (2012) to trend through the West Medical Lake area and across the upper Deep Creek and Coulee Creek drainage, forming a continuous system across the western portion of the Project Area. The

parallel Clear Lake Fault is mapped just west of the Jump Off Joe Fault near West Medical Lake. Displacement on the Jump Off Joe Fault is reported to be up on the west side, while displacement on the Clear Lake Fault is reported to be up on the east side.

In addition to the faults noted above, work at FAFB (AECOM, 2012) indicates the presence of a fault more or less bounding the eastern side of the base. This fault is shown on geologic cross sections in AECOM (2012). Existing geologic maps of that portion of the Project Area cited above do not show this fault. This fault also is not shown in Figure 10.

6. The Aquifer System

Section 6 address two primary topics. First, in Section 6.1, the general hydrology of the vadose zone, alluvial aquifers, CRBG aquifers, and basement aquifers, and the potential effects of faults are summarized. This discussion is intended to provide a general review of basic hydrogeology in the region. More detailed discussion can be found in the references cited. Second, Section 6.2 uses hydrographs and related hydrologic information to evaluate apparent hydrologic conditions in different portions of the Project Area.

6.1 General Hydrogeology

6.1.1 Alluvial Aquifer and Vadose Zone

Vadose zone conditions, and consequently infiltration capacity, in the suprabasalt sediments are controlled by physical heterogeneities within these coarse (sandy and gravelly) to fine (silty) strata. These heterogeneities result in complex flow paths that include downward percolation, upward diffusion, and lateral movement of vadose zone moisture. For example, local perched groundwater could exist where discrete areas or lenses of fine-grained materials exist and act to inhibit downward percolation. Discontinuous perched groundwater zones also occur locally within sediments overlying bedrock. Vertical downward movement of moisture through coarse vadose zone strata likely can be measured at several feet per day. Vertical movement of moisture through fine vadose zone strata will be several orders of magnitude slower.

The alluvial aquifer system is defined by the presence of unconfined groundwater in alluvial sediments overlying basalt and/or basement rock. The lateral extent of the suprabasalt aquifer in the Project Area is controlled by basalt and basement outcrops. As such, it usually occurs in saturated alluvial sediment found in modern canyons and paleochannels. These physical controls on saturated alluvial sediment distribution result in an alluvial aquifer that is discontinuous, with hydraulic continuity between different areas of saturated alluvial sediment being extremely limited to absent.

Depth to water and aquifer thickness in the alluvial aquifer are variable. On floodplains near streams, depth to water ranges from a few inches to several feet. More distally from streams, depth to water may range from several feet, to tens of feet, or even more, assuming an alluvial aquifer is even present. Depth to water in paleochannels can be several tens of feet, or more. Alluvial aquifer thickness is entirely controlled by water table elevation and the elevation of the top of basalt, probably ranging from a few feet to several tens of feet.

Where saturated alluvial sediments are present, coarse-grained strata generally will have higher hydraulic conductivity and transmissivity than fine sediments. Regional data (USDOE, 1988; GWMA, 2009a, 2009b; Ely et al., 2014) suggest hydraulic conductivity in coarse flood deposits can range from hundreds to thousands of feet/day, with transmissivity of 10,000 to more than 100,000 $feet^2$/day. Values for fine alluvial sediments will be 3 to 5 orders of magnitude lower than these.

As noted earlier in this report (see Section 4), precipitation is the primary source of natural water for the Project Area. Also as noted earlier, the amount of infiltration and groundwater recharge potentially resulting from precipitation is closely related to the timing of that precipitation, whether it occurs as rain or snow, on frozen or unfrozen ground. Given these variables, natural recharge of the alluvial aquifer system from precipitation will vary from year-to-year. Where irrigation occurs on these sediments, recharge is likely because the amount of water available on the surface and in shallow soils periodically can exceed evapotranspiration. Surface discharge from the suprabasalt sediment aquifer system in the Project Area is most likely into streams, lakes, and ponds located in coulees. Subsurface discharge to the underlying basalt aquifer system also may occur, at least locally, as discussed in the next section.

6.1.2 CRBG Aquifer System

Groundwater in the CRBG, and beneath the Project Area, generally is confined. The CRBG aquifer system in the Project Area is separated from the regionally extensive CRBG aquifer system in the Columbia Basin by the basement ridges generally bounding the western side of the Project Area. As a result, the CRBG aquifer system in the Project Area is localized in nature, not being part of a regional system covering thousands of square miles (USDOE, 1988; GWMA, 2009a, 2009b; Kahle et al., 2009, 2011; Ely et al., 2014).

CRBG groundwater primarily occurs in water-bearing intervals hosted by interflow zones and interbedded Latah Formation sediments where these occur (Gephart et al., 1979; Hansen et al., 1994; Packard et al., 1996; Sabol and Downey, 1997; USDOE, 1988; GWMA, 2009c; Ely et al., 2014; Kahle et al., 2009, 2011). Groundwater occurring within interflow zones is found in joints, vesicles, fractures, intergranular pores in vesicular and brecciated basalt flow tops and bottoms and in sediment interbeds. Groundwater occurring in dense basalt is restricted to fully penetrating joints and fractures. Based on water level data and potentiometric maps of the CRBG aquifer system in Spokane County (2013c), the aquifer system may consist of three basic parts generally corresponding to the Wanapum Basalt and upper and lower Grande Ronde Basalt (e.g., Sentinel Bluffs Member and Wapshilla Ridge Member). Basic groundwater flow direction on all portions of the CRBG aquifer system is generally from west to east, toward the Spokane River.

6.1.2.1 Hydraulic Properties

Table 1 summarizes basic hydrologic properties of CRBG interflow structures and sedimentary interbeds. Horizontal hydraulic conductivity of CRBG flow tops and bottoms ranges from 1 x 10^{-6} to 1,000 feet/day and averages 0.1 foot/day. The most hydraulically productive interflow zones are at the high end of this range of hydraulic conductivities. Assuming a physical pathway for water movement is present through crystalline-glassy dense basalt flow interiors via fully penetrating joints and fractures, vertical and horizontal hydraulic conductivity of dense interiors is 6 to 9 orders of magnitude less than those seen in flow tops and bottoms (USDOE, 1988). Given this large difference in hydraulic conductivity, CRBG flow tops and bottoms serve as the primary conduit for lateral groundwater flow in the CRBG. This, coupled with the planar-tabular nature of CRBG units, suggest that the occurrence and distribution of water-bearing interflow zones within it also display a planar-tabular character (USDOE, 1988; PNNL, 2002; GWMA, 2009b; Tolan et al., 2009). With this planar-tabular host rock fabric, it can be surmised that the predominant groundwater flow direction within the Project Area CRBG aquifer system is parallel to, and down-dip, in these strata. With respect to groundwater movement transverse to planar-tabular CRBG fabric, movement is inferred to be occurring via: (1) fully penetrating fractures and joints where they occur, (2) around the edges of basalt flows where otherwise separated interflow zones merge, and (3) through open tectonic features, such as faults, if they are present.

6.1.2.2 Groundwater Levels and Flow Directions

Within the planar-tabular CRBG rock and aquifer system, water levels may differ, or be similar, in closely spaced wells. Wells generally displaying similar water levels and temporal trends generally are open to similar portions of the aquifer system and/or portions of the aquifer system that are subjected to similar potentiometric influences, such as pumping, recharge, and any other boundary effects. Conversely, wells displaying different water levels and trends may be open to different portions of the aquifer system and/or responding to different potentiometric drivers. Given these basic considerations, potentiometric maps for the CRBG aquifer system generally should be limited to using well data from similar units within the CRBG. Following work done by Spokane County (Spokane County, 2013c), the primary hydrostratigraphic units in the Project Area are interpreted to be the Wanapum Basalt, Sentinel Bluffs Member of the Grande Ronde Basalt, Wapshilla Ridge Member of the Grande Ronde Basalt, and associated Latah Formation interbeds.

Depending on which water-bearing zones(s) an individual well is open to and the location of a well, depth to water in the Project Area varies from several tens of feet to several hundred feet below ground surface (bgs). Generally, shallower water depths are associated with lower yielding (<100 gallons per minute [gpm]) water-bearing zones in the shallower Wanapum Basalt, where lateral continuity is disrupted by incised modern canyons and paleochannels. Deeper water levels are associated with deeper, more laterally extensive water-bearing zones more commonly associated with the Grande Ronde Basalt. Higher-yielding wells (>500 gpm) are more common in these deeper zones. The general decrease in water level with well depth can be used, at least in some areas, to differentiate between a shallower water level Wanapum groundwater system and a deeper water level Grande Ronde groundwater system.

Based on potentiometric maps in Spokane County (2013c) for the Wanapum Basalt (Figure 9 in that report) and the Grande Ronde Basalt (Figure 10 in that report), groundwater levels in these units generally are as follows. In the Wanapum Basalt upgradient potentiometric elevations (in the western part of the Project Area) generally range between approximately 2,350 and 2,450 feet amsl and downgradient elevations (in the eastern part of the Project Area) generally are approximately 2,300 feet amsl. Potentiometric elevations in the Wanapum Basalt are influenced by modern stream channel canyons. Spokane County (2013c, Figure 9) shows the generally west to east groundwater flow in the Wanapum Basalt being locally deflected toward canyons. Based on Spokane County (2013c), modern stream canyons are important discharge areas for the Wanapum Basalt portion of the Project Area groundwater system.

In the Grande Ronde Basalt upgradient potentiometric elevations generally are on the order of 2,200 to 2,300 feet amsl, while downgradient elevations are less than 1,800 feet amsl (Spokane County, 2013c, Figure 10). Potentiometric elevations in the Grande Ronde Basalt generally are not influenced by topographic features such as modern stream canyons, except locally and in the most downgradient areas. As shown in Spokane County (2013c), groundwater flow in the Grande Ronde portion of the

Project Area groundwater system is largely toward the east-northeast, with little disruption by stream canyons.

6.1.2.3 CRBG Aquifer Recharge/Discharge

Recharge to shallow portions of the CRBG aquifer system probably results from infiltration of precipitation, runoff, and irrigation water (Newcomb 1969; USDOE, 1988; Hansen et al., 1994; GWMA, 2009a, 2009b, 2009c; Ely et al., 2014). Infiltration and recharge of shallow basalts, where it occurs, likely is through planar-tabular dense basalt flow interiors via fully penetrating open faults, fractures, and joints, around basalt flow pinch-outs, and where CRBG flows are breached by erosional windows. Recharge of deeper portions of the CRBG aquifer system is inferred to be less common and slower, based on groundwater geochemical evaluation and age dating (GWMA, 2009c; NLW, 2014). Given that, where deeper basalt aquifer recharge is occurring, it is inferred to happen where discontinuities in dense basalt flow interiors, such as those noted above, allow movement of groundwater deeper into the aquifer system.

Throughout the CRBG system the impact of uncased and unsealed wells on recharge in the aquifer system cannot be discounted. Uncased and unsealed wells can provide hydraulic connections between different water-bearing CRBG units. Depending on vertical gradient, such wells can allow passive dewatering of the upper zones by cascading down-hole flow into deeper zones. Conversely, such wells also can allow upward movement if deeper zones are under higher pressure than shallower zones. This later case appears to be rare in the Project Area.

Regardless of recharge source(s) and pathway(s) in the CRBG aquifer system, groundwater age dating in the Project Area (NLW, 2014) and in the adjacent Columbia Basin Ground Water Management Area (GWMA)(GWMA, 2009c) suggests that the rate of recharge to deeper portions of the CRBG aquifer system is slow because groundwater more than a few hundred feet deep in this aquifer system commonly displays geochemical characteristics indicative of residence time in the subsurface of thousands to several tens of thousands of years.

Beneath the Project Area, groundwater flow direction in the CRBG is generally toward the east-northeast (Spokane County, 2013c). Given that, groundwater movement in the shallower Wanapum portion of the aquifer system is commonly interrupted by modern canyons and paleochannels, with Wanapum groundwater tending to flow toward these incisions. Paleochannels also may supply groundwater to adjacent portions of the CRBG aquifer system. In such a case, saturated alluvial sediment in the paleochannel would move downgradient, out of the paleochannel, and into the CRBG aquifer system.

Deeper groundwater levels from wells within portions of the CRBG aquifer system, below the bottoms of modern canyons and paleochannels, are less affected by these canyons and paleochannels. As a result, groundwater flow in the deeper system, predominantly in the Grande Ronde Basalt, shows less localized deflection toward canyons and paleochannels and more consistent flow to the east-northeast (Spokane County, 2013c). Based on the observations in Spokane County (2013c), discharge from the shallower CRBG system is generally toward canyons. Conversely, discharge from the deeper portions of the aquifer system will largely be out of the Project Area and only locally into canyons and paleochannels that are incised deep enough to intersect deeper basalt units.

6.1.3 Basement Hydrogeology

The inherent physical properties of the crystalline and metamorphic rocks that constitute the basement rocks underlying the Project Area renders them largely impermeable. The porosity and permeability found in these rocks is likely restricted to interconnected, open joints and fractures. These joints and fractures, in turn, must be in hydraulic connection with water sources to allow them to host groundwater. In addition, they must be interconnected to transmit water through a basement aquifer system any distance. Given these variables, the basement aquifer system generally is extremely restricted, produces small amounts of water, and is easily depleted. Nevertheless, under certain localized conditions, especially where a nearby source of surface water may occur, the basement aquifer may produce water at steady, sustainable, if somewhat small rates.

6.1.4 Effects of Faults

The presence of faults in the CRBG potentially can impact groundwater movement (e.g., Newcomb 1959, 1961, 1969; Lite and Grondin, 1988; USDOE, 1988; Johnson et al., 1993). Faulting in the CRBG tends to produce a roughly planar zone composed of coarsely shattered basalt that grades into fine rock flour. The width of the fault zone (shatter breccia and gouge) can be highly variable (<1 meter to >150 meters thick) and its thickness typically depends on the: (1) magnitude of fault displacement, (2) type of fault (low-angle fault vs. high-angle fault), and (3) type(s) of CRBG intraflow structures cut by the fault (Price, 1982; Reidel, 1984; Hagood, 1986; Anderson, 1987; USDOE, 1988). CRBG flow tops and bottoms (interflow zones) have lesser mechanical strength than the flow interior. This greater structural weakness typically is manifested by the widening of the fault zone, and associated effects, as it passes through these mechanically weaker portions of the flow (Price, 1982; USDOE, 1988). It has also been suggested that the presence of water within flow tops may decrease the relative strength of the interflow zone and be another factor contributing to deformational behavior in flow tops and flow bottoms (USDOE, 1988).

Fault zone shatter breccias often display significant degrees of alteration (clays) and/or secondary mineralization (silica, zeolite, calcite, and pyrite). These materials can cement shatter breccias and create a rock that is so massive and tough that CRBG fault breccias are commonly more resistant to erosion than unbrecciated CRBG (Myers and Price, 1981; Price, 1982; Anderson, 1987). The types of secondary minerals present within CRBG fault zones appear to be dependent on both environmental conditions (oxidizing vs. reducing) and in situ conditions (e.g., water chemistry, thermal regime, hydrologic regime) (Myers and Price, 1981; Price, 1982; USDOE, 1988).

The ability of faults to affect CRBG groundwater systems in a variety of ways reflects the potential for both lateral and vertical heterogeneities in the physical characteristics of fault zones. For example, the degree of secondary alteration and mineralization along a fault zone may vary. Complete alteration and/or mineralization of fault shatter breccias and gouge zones would “heal” these features and produce rock of low permeability. Variations in the completeness of this process would produce hydrologic heterogeneities along the trace of the fault. Even if a fault zone is completely healed by secondary alteration and mineralization, renewed movement (displacement) on the fault could produce new permeability within the healed shatter breccia (USDOE, 1988; Johnson et al., 1993).

6.2 Water Level Data and Groundwater Geochemical Age Indicators

With the general observations of Section 6.1 in mind, the goal of Section 6.2 is to describe Project Area water levels and related data in several local areas. Comparing these data, in particular from wells with more than five water level measurements, provides clues into the nature of the physical and temporal constraints on the Project Area groundwater system. Identifying similarities and differences in water level data, and placing those data in the physical context of the Project Area, provides a basis for evaluating features that may influence groundwater occurrence, hydrologic continuity, and potential aquifer compartmentalization.

The following data evaluation attempts to identify hydrograph characteristics that might be reasonably interpreted to indicate the presence of: (1) spatial subdivisions, lateral or stratigraphic, in the groundwater system and (2) temporal trends that might reflect changing stresses, such as pumping and recharge, on the groundwater system. For this evaluation, Project Area water level data are subdivided into geographic groups, or local area groups, separated by easily identified natural features, such as topographic canyons, previously mapped alluvium filled paleochannels, and basement highs, and artificial features, such as US-2 and I-90. In each local group, long-term water level data sets from deep wells, shallow wells, alluvial wells, and/or basalt wells, whatever type of well is present in each group, are compared. Observations from each local group then are compared to those from other local groups to identify potential similarities and differences that might provide clues useful in deciphering the nature of the West Plains hydrogeologic framework. Other data, as available, are incorporated into the assessments.

The local groupings used in this evaluation are shown in Figure 11 and include the following areas:

- North of Coulee Creek, also referred to as Four Mound Prairie
- Between Coulee Creek and Deep Creek, also referred to as Indian Prairie
- Between US-2 and Deep Creek and west of Craig Road
- West of FAFB
- Westernmost area, which lies essentially between Medical Lake and Reardan, Washington
- Marshall Creek and vicinity
- Central West Plains, which generally is bounded by FAFB (on west), US-2 (on north), Spokane International Airport (on east), and the highlands around Four Lakes and Medical Lake (south and southwest)

Each of these areas is described further in the following sections. These descriptions address the boundaries of each area, including potential physical features that may form hydrologic boundaries, and the long-term water level data in each area, including both spatial and temporal observations. Analysis and interpretation of these observations are presented in Sections 7 and 8.

6.2.1 Four Mound Prairie

The Four Mound Prairie area generally includes the region north of the Coulee Creek canyon and south of the Project Area boundary (Figures 11 and 12). The northern and western boundaries of this area generally correspond to a topographic high that in part corresponds to basement highs projecting through the CRBG. Water level records for six wells within this area (designated 160959, Four Mound or

172968, Fire District #5-Coulee Hite or 439863, Garfield-Lincoln, 441147, and 172184) are evaluated. Basic well construction information for these wells is summarized in Table 2 and hydrographs are plotted in Figure 13.

Wells 160959, 172968, and 439863 are located on the Four Mound Prairie plateau and are approximately 100, 120, and 205 feet deep, respectively. This places their open, or water-producing, intervals in Wanapum Basalt strata that is incised into and/or through by Coulee Creek canyon on the south and the Spokane River on the east. Hydrographs for these three wells (Figure 13) show:

- Static water levels of approximately 2390 feet above sea level (amsl) or higher.
- Seasonal static water level fluctuations in 2012 and 2013 of several feet, with early spring highs and late autumn lows.
- Water level decline in one well (439863) that has records into late 2014. The spring 2014 seasonal high in this well is several feet lower than the previous two seasonal highs.

The other three wells are located on the valley floor downstream of where Coulee Creek exits its canyon (Figure 12) and flows into the subsurface (during most the year) into the gravel bar near its confluence with Deep Creek and the nearby Spokane River. One of these wells is a basalt well (441147), one is an alluvial well (172184), and Garfield-Lincoln well construction is unknown, but it is inferred to be an alluvial well. Garfield-Lincoln water level after September 13, 2013, flattens, reflecting depth to water below the transducer. Hydrographs for these wells (Figure 13) show:

- Water levels of 1,630 to 1,765 feet amsl, significantly lower than the other three wells in this group (all three wells)
- Suggestion of seasonally changing water levels with lows in the late winter and early spring, followed by highs in the late spring (in 441147 and Garfield-Lincoln)
- Suggestions of season to season water level declines of 5 to 10 feet in the winter/spring peak water level period (in 441147 and Garfield-Lincoln).

Although the data record available for these six wells is only a few years, it is interpreted to suggest water level declines may be occurring in shallower Wanapum strata, in deeper Grande Ronde strata, and in the alluvial strata in the Four Mound Prairie area.

6.2.2 Indian Prairie

The Indian Prairie area, as used in this report, is defined as the plateau west of the confluence of Coulee Creek with Deep Creek. It is bounded on the north by Coulee Creek and on the south by Deep Creek (Figures 11 and 14). The western boundary lies on basement highs between N. Coulee Hite Road and S. Wood Road. Three wells with relatively larger data sets (171100, 167996, and 167998), all on the plateau, lie within this area (Figure 14). Basic well construction information for these wells is shown in Table 3. Hydrographs for these wells (Figure 15) show the following:

- Water level in the westernmost well (171100) is approximately 2175 to 2180 feet amsl. This well is interpreted to be in the Grande Ronde Basalt (Table 3) and the open interval is more-or-less equivalent to the bottoms of nearby canyons.

- Water levels in wells 167996 and 167998, which are in the Wanapum Basalt (Table 3), are between approximately 2,285 and 2,315 feet amsl. These elevations are well above the depths of nearby canyons.
- Wells 167996 and 167998 are downgradient of Well 171100 and, as noted in the preceding bullets, in a different portion of the CRBG aquifer system (Spokane County, 2013c).

The data record for well 171100 is too short to illuminate any possible trends. The other two wells show evidence of seasonality with highs in the late spring of 2012 and 2013 and lows in the winter/spring of 2011/2012 and 2012/2013.

6.2.3 Area between US-2 and Deep Creek

This area is defined in part by natural features and in part by arbitrary geographic boundaries designated for convenience in data review. The northern boundary is Deep Creek, the eastern boundary is the Spokane River, the southern boundary is US-2, and the western boundary is N. Craig Road (Figures 11 and 16). This area is traversed by two previously mapped north-south paleochannels (referred to as the Airport paleochannel and the Airway Heights paleochannel) filled with alluvial/cataclysmic flood deposits (Deobald and Buchanan, 1995; Pritchard, 2013). Based on Pritchard's work, the Airport paleochannel is interpreted to incise into the Grande Ronde Basalt along much of its length, while the Airway Heights paleochannel may be incised locally only into the uppermost Grande Ronde.

Eight wells having longer-term water level data sets are evaluated in this area. These wells are designated 472535; Raceway Park wells MW 4, 5, 6, and 7; SCDMW-8; 174648; and PCA 411175 (Table 4). Hydrographs for these wells are shown in Figure 17. Observations about these wells are as follows:

- Well 472535 is an alluvial well in the Airport paleochannel. Water level in this well is higher than nearby wells with long-term data records (SCDMW-8; MW-4, -5, -6, and -7; and 174648), all of which are likely completed in the Grande Ronde Basalt.
- Water level in well 472535 ranges between approximately 2,110 and 2,130 feet amsl, and it is interpreted to display evidence of seasonal effects, being highest in the spring of 2012 and 2013. The total record, while short (September 2011 through January 2014), is interpreted to suggest water level decline is occurring.
- SCDMW-8 has a relatively constant water level, slightly higher than 2,060 feet amsl. Geochemical analyses of water collected from it are interpreted to indicate a mix of older and younger groundwater characteristics (NLW, 2014).
- The Raceway Park wells have water levels just below 2,060 feet amsl and show potential seasonal variation, although not of the magnitude displayed by well 472535. In addition, the high water level in this set of wells occurs in the autumn, not a trend seen in other wells with potential seasonal effects, such as those described earlier in the Four Mound Prairie area that are at their lowest in the late autumn and early winter.
- Well 174648 is a Grande Ronde well located east of the Airport paleochannel. It displays a relatively stable water level and decline trends have not been observed.
- Well PCA 411175 also is a Grande Ronde well. However, it is located below the West Plains plateau, in the Spokane River valley near the river, approximately 300 feet lower than other wells. This well displays high and low levels that have been interpreted as indicating hydraulic continuity with the Spokane River (Spokane County 2013c).

- Spokane County (2013c) describes several Wanapum Basalt wells in the area north of US-2 and south of Deep Creek from which synoptic water level measurements have been collected. Water levels in these wells are reported to be higher than the water level in well 472535, approximately 2,300 feet amsl versus 2,100 feet amsl in 472535.

Excluding well PCA 411175, the other wells referred to in the preceding bullets are completed in groundwater systems high on the plateau above the Spokane River. Well 472535 displays seasonal water level fluctuations and a trend suggestive of water level decline. Wells SCDMW-8 and 174648 appear to have relatively stable water levels. The Raceway Park wells have water levels similar to SCDMW-8, but with some suggestion of fluctuation that does not follow the typical pattern other wells in the Project Area show (e.g., high in the spring and low in the late autumn to early-mid winter).

6.2.4 West of FAFB

This area is defined as lying between FAFB on the east, Deep Creek on the west, and it is situated just south of US-2 (Figures 11 and 18). In this area, four wells (560732, 560766, 560746, and 560763) have water level records spanning a number of years (1992 through 2012) while one well (168759) has a data series of approximately 1.5 years (October 2011 through March 2013) (Table 5 and Figure 19). Observations about these wells are as follows:

- Wells 560732, 560766, 560746, and 560763 are all Wanapum Basalt wells with similar construction and well level data. They are approximately 100 feet deep with top of basalt approximately 10 to 35 feet deep. These wells have water levels ranging between approximately 2,425 and 2,440 feet amsl, display seasonal highs and lows, and might display a slightly rising long-term trend, although it is not well developed.
- Well 168759 also is a Wanapum well, but with a water level of approximately 2,370 feet amsl (lower than the four aforementioned wells). Top of basalt in this well is approximately 110 feet deep, and it is located west of the four wells noted in the preceding bullet.
- The potentiometric surface defined by water levels in these wells suggests groundwater movement toward Deep Creek.

Three other wells in the immediate vicinity of the five aforementioned wells are noteworthy. These wells, designated 168885, 455291, and 375775 in Spokane County (2013c), are interpreted to be Grande Ronde Wells. Synoptic water level measurements from these wells are approximately 2,150 to 2,170 feet amsl (Spokane County 2013c), more than 200 feet lower than the five Wanapum wells noted above, and approximately 100 feet below the bottom of the Deep Creek canyon at US-2.

6.2.5 Western West Plains

This area is defined generally as lying between the City of Medical Lake and the western border of the Project Area near Reardan, Washington (Figures 11 and 20). Basement highs define at least some of the boundaries of this area, including the ridges south of Reardan and the hills adjacent to Medical Lake. Wells within this area with longer-term water level records include 292881, 153821, VA_CMTRY, Reardan Test, and Reardan Muni (Table 6, Figures 21 and 22). Conditions observed in these wells include the following:

- Wells 292881, 153821, and VA_CMTRY in the southeastern portion of this area suggest a cumulative record of a long-term decline from water levels of approximately 2,220 feet amsl in the late 1950s to levels of approximately 2,150 feet amsl by approximately 2010.
- Water level in well VA_CMTRY appears to display seasonal fluctuations. The water level has not declined significantly in the past 4 to 5 years, although the level is significantly lower now (approximately 2,155 feet amsl) compared to its earliest level in 1955 (approximately 2,270 feet amsl).
- The two Reardan wells record higher water levels, above 2,320 feet amsl, seasonal high water levels in the spring, and low water levels in the autumn.
- All of the Western area wells are interpreted to be open primarily to the Grande Ronde.
- Two groundwater geochemical samples (NLW, 2014), one from a Reardan well and one from 292881, suggest relatively old groundwater with average ages greater than 10,000 years being pumped from them.

The Jump Off Joe/Clear Lake fault system is shown to be transecting the Western area by McCollum and Pritchard (2012), although its effect on the CRBG is not known. A general map in McCollum and Pritchard (2012) suggests the well VA_CMTRY is east of the fault, while the other wells are west of the fault.

6.2.6 Marshall Creek

The Marshall Creek area essentially comprises the southeastern portion of the Project Area, encompassing Marshall Creek canyon and adjacent areas (Figures 11 and 23). Basement highs associated with Needham Hill bound much of the western side of the area. The eastern boundary follows the eastern boundary of the Project Area, the Hangman Creek valley. Five wells with longer-term water level records are evaluated in this area: Green, 560333, Spokane Marshall, SCDMW-11, and SCDMW-7 (Table 7 and Figure 24). Observations pertaining to these wells are as follows:

- 560333 is interpreted to be a relatively shallow Wanapum Basalt well. The Green well may be open to both the Wanapum and the Grande Ronde. Both wells are located on the plateau dissected by Marshall Creek. Water levels recorded in these two wells are high above the bottom of the canyon.
- 560333 has a 10-plus-year water level record that shows seasonality. Maximum, or high, water level in the well rose slightly through the 1990s. Beginning in approximately 2004, high water levels have shown a slight decreasing trend.
- The Green well also shows seasonality coupled with a drop in seasonal high levels between 2012 and 2013.
- The Spokane Marshall well is an alluvial well located in the canyon. Water level in this well displays seasonal variation and water levels in the range of 2,120 to 2,145 feet amsl. The limited duration record for this well is interpreted to show season-to-season drops in peak water level between 2012 and 2013.
- SCDMW-7 is reported to be completed in the Grande Ronde and SCDMW-11 is reported to be completed in Quaternary alluvial sediments overlying the top of the Grande Ronde Basalt. Pritchard (2013) indicates these sediments are interpreted to be deposited in a paleochannel branching off the current Marshal Creek canyon. Both wells display seasonal variation, although

the magnitude of that variation differs significantly. Average groundwater ages in each well also differ, being approximately 3,460 years in SCDMW-11 and 10,670 years in SCDMW-7.

All wells in the Marshall Creek area show evidence of seasonal high and low water levels. The well with the longest data record (well 560333) shows evidence of slightly increasing water level in the 1990s. In recent years, maximum, or high, water levels in several of these wells may display a slight decreasing trend, although this is not well developed and may not actually be present.

6.2.7 Central West Plains

The Central West Plains area (Figures 11 and 25) essentially comprises the geographic area lying between all of the previously described geographic areas. It is notable in that it hosts, or has hosted, production wells for the three primary municipalities in the Project Area: Airway Heights, Medical Lake, and Four Lakes. In addition, it hosts several monitoring wells, including wells built to monitor groundwater levels and water quality in deeper and shallower basalt zones. Generally, the Central West Plains area is bounded on the west by FAFB; the southwest and south by basement highlands around Medical Lake and Four Lakes; the southeast and east by I-90, basement associated with Needham Hill, and Spokane International Airport; and the north by US-2.

Wells in this area with long-term water level records that are described in this section include 560746, Four Lakes School (164395), 164483 (Town of Four Lakes), 417068 (City of Medical Lake), Parkwest, 167192 (Thorp Road), FAFBMWD-1, 617922 (Geophysical well), 344207 (Airway Heights 7 or AWH-7), 488063, and Craig Road Landfill wells designated MW-70, -74, -80, -82, -84, -95, -101, -117, -118, -127, and -139 (Tables 8 and 9; Figures 26, 27, and 28).

Wells 164483, 417068, 488063, Parkwest, 617922, and 167192 (which from here on in the report will be referred to as the pumping center wells) appear to display similar long-term and short-term water level trends (Figure 26) as follows:

- Wells with data records dating back into the 1990s display declining water level trends into the late 2000s. Beginning in late 2009 and early 2010, water levels in these wells with data records for that period appear to begin to rise. This change in trend corresponds to when Parkwest well pumping by the City of Airway Heights began to be reduced and ultimately ended in July 2013.
- The oldest data, for well 164483, indicates maximum water levels of approximately 2,400 feet amsl in the late 1990s. Maximum water levels declined to approximately 2,220 feet amsl (+/- 20 to 30 feet) by about 2010. Water levels have risen several tens of feet in the last 3 to 4 years in most of these wells (excluding 167192).
- Seasonal pumping high and low levels are apparent throughout the datasets.
- These wells are relatively close to each other and their open, or water-producing intervals, at least partially overlap, being open to the lower portions of the Wanapum and portions of the Grande Ronde (Table 8). Several of these wells penetrate most, if not all, of the basalt sequence in this area.
- Three wells in the Central West Plains area, Parkwest (301 feet deep), 488063 (depth unknown), and 164483 (775 feet deep), have groundwater geochemical data that suggest ages of approximately 1,490, 4,200, and 10,670 years, respectively (NLW, 2014).

The Four Lakes School well, FAFBMWD1, and AWH-7 (also referred to as well 344207) display long-term water level characteristics (Figure 26) different than those seen in the pumping center wells, as follows:

- The Four Lakes School well and FAFBMWD1 do not display the water level elevation changes noted for the pumping center wells. These two wells also have average water level elevations that are different than the pumping center wells, generally being higher than the pumping center wells.
- The data record for AWH-7 has a large time gap in it, missing most of 2011, 2012, 2013, and 2014. The available data show water level elevations on the order of 2,050 to 2,075 feet amsl. This is 200+ feet deeper than the pumping center wells, but similar to the Raceway Park wells and SCDMW-8 north of US-2 (described earlier in this report, Figure 17).
- FAFBMWD1 and AWH-7 are both Grande Ronde wells, while the Four Lakes School well is a basement well.

There are approximately two dozen wells at the Craig Road Landfill. Hydrographs for several of those wells having water level data collected through much of the 1990s and in to the early 2000s are reproduced in Figures 27 and 28. Some basic observations about these wells are:

- Shallower water levels above approximately 2,305 feet amsl (Figure 27) are more frequently associated with shallower, possibly Wanapum, wells. Since the late 1990s, water levels in these wells, while showing seasonal variations, have not developed significant decline trends.
- Deeper water levels generally below 2,300 feet amsl (Figure 28) are more frequently associated with the deepest wells at the landfill, wells potentially open to the uppermost Grande Ronde. These wells appear to display decline trends from the 1990s until 2004/2005. Since then, water levels appear to have risen.
- All of the water levels in Craig Road Landfill wells are above the lowest elevations inferred for the bottom of the Airway Heights paleochannel, which lies just east of the landfill and appears to lie at least 200 feet bgs.

One additional factor that is associated with the Craig Road Landfill water levels is the history of pump-and-treat at the landfill. Based on information supplied by Spokane County personnel, this system operated frequently between October 1994 and October 2006. From then through 2010, the system ran approximately 6 to 8 months each year. Since then, the system operates approximately 3 months of the year. The period of apparent recovery (beginning in late 2005 and into 2006) noted for the deeper wells plotted in Figure 28 may coincide with the change in pump-and-treat operations that began in 2006.

The pumping center wells in the Central Plains area consist of wells showing significant, similar, long-term decline and recovery trends. Around the fringes of the Central Plains area, several wells open to at least portions of the same water-bearing zones that are open to the pumping center wells do not display these trends and they do not display the same basic water level elevations.

7. Hydrostratigraphy and Hydrogeologic Framework

Combining the geologic, water level, and groundwater geochemical features described in the previous sections of this report, four basic types of physical geologic features are interpreted to be influencing the hydrogeologic framework of the Project Area. These are: (1) basement highs, both exposed and buried, (2) location and incision depth of modern topographic canyons, (3) location and incision depth of alluvium filled paleochannels, and (4) stratigraphic features within the CRBG and interbedded Latah Formation. These features are explored and described further below. Additional smaller-scale features also may influence local groundwater conditions in the Project Area, but the available data and information are interpreted to generally be insufficient, unless otherwise noted, to specifically identify and delineate these local features.

7.1 Basement Surface

Basement highs are interpreted to be one of the primary features that compartmentalize the CRBG aquifer system within the Project Area. Buried basement highs underlying the CRBG are interpreted to be continuations of the basement cored hills seen in and around the Project Area. The buried highs, in association with their corresponding topographic highs, are interpreted to essentially form the northern, southern, and western boundaries of the Project Area, separating it from the much larger Columbia Basin regional aquifer system. In addition, several generally parallel northeast-southwest oriented basement ridge systems (buried and exposed) are identified within the Project Area (Figure 9, Plate 3), potentially subdividing the Project Area into basement-defined subbasins or subsystems. These basement bounded subsystems generally are found within the topographic lows in the Project Area and occupied by most of the modern drainages, the paleodrainages, and the thicker basalt-hosted groundwater systems. The importance of the basement ridges interpreted in this report to Project Area groundwater conditions are discussed further below.

7.1.1 Medical Lake – Airway Heights Ridge

A basement ridge is interpreted to extend from near the City of Medical Lake to the north-northeast, where it passes under FAFB and through the vicinity of the intersection of Rambo Road with US-2 (Figure 9, Plate 3). Beneath the southern part of FAFB, geotechnical borings south of the western half of the main runway indicate the presence of weathered basement rock within 20 to 30 feet of the ground surface (Budinger, 2005). Outcrops of basement rocks occur just to the south of these geotech wells in and north of the City of Medical Lake. Just north of the Rambo Road/US-2 intersection, several well logs also suggest the presence of weathered basement within 150 to 250 feet of the ground surface.

Drawing a line from the outcrops in the south (just north of the City of Medical Lake) through the two apparent buried basement features, one can separate the relatively stable water levels in well FAFBMWD1 from those seen in the pumping center wells. Given that observation, a basement high is hypothesized to be present, high enough, and continuous enough to form a hydrologic barrier separating water-bearing basalt several hundred feet deep to the west of it from the water-bearing basalt that hosts the pumping center wells east of it. Figure 29 diagrammatically illustrates this basic point. Given the elevation of the screened/open interval in the Parkwest well, the inferred ridge may be higher than currently mapped, also as shown in Figure 29.

Recent work at FAFB (AECOM, 2012) suggests the presence of a fault in the same general area as the northern projection of the hypothesized Medical Lake-Airway Heights ridge hypothesized above. A fault could influence water levels in the same way as noted above. The AECOM work though does not note the presence of potential basement highs suggested by well logs in the vicinity of FAFB. Given that, the reported evidence on well logs of potential basement highs is hypothesized to be the most likely explanation for the water level discontinuities described above.

Wells to the east of FAFBMWD1, including SCDMW-8, the Raceway Park wells, and AWH-7, also display water level characteristics different than the pumping center wells. All of these wells are in the 300- to 400-foot depth range and appear to be open to many of the same hydrostratigraphic units as the pumping center wells. A branch of the hypothesized Medical Lake-Airway Heights ridge could extend to the east, south of the City of Airway Heights, separating these wells from the pumping center wells. While this ridge is not confirmed by drilling, its presence would help explain the differences in water level measurements collected at the various wells.

A hypothetical branch of the Medical Lake-Airway heights ridge generally in the location of the dotted line in Figure 9 could account for the observed differences in water level. A ridge at this general location was modeled by the gridding algorithm to produce the top of basement map (Plate 3). The modeled top of basement grid suggests this roughly east-west oriented feature would be approximately 1,600 feet amsl, as is shown in Figure 30. If the grid predicted high were to exist, it would need to reach an elevation of approximately 2,100 to 2,200 feet amsl to explain the apparent differences in water level between the wells noted above and the pumping center wells. Figure 30 diagrammatically shows what this hypothetical relationship might look like in cross section. If such a high is not present, then the strikingly different water levels would be caused by other features, such as hydrostratigraphic unit pinchouts and/or faults, for which no direct evidence is currently available.

7.1.2 Needham Hill Ridge

Another basement high extends northeast from Needham Hill, parallel to and south of I-90 (Figure 9, Plate 3). Generally, this feature is probably several hundred feet bgs because most wells in the area east of I-90 are not reported to go deep enough to intersect it. However, isolated outcrops in the Marshall Creek canyon suggest this feature, and/or related basement high features, form an irregular surface with localized basement highs underlying this area. If present, such a ridge would form at least a partial barrier to groundwater flow through the basalt system between the area south of I-90 and the Central Plains area. Such a feature would separate groundwater flow subsystems in a manner similar to that hypothesized for the Medical Lake-Airway Heights ridge.

7.1.3 Western and Northern Ridges

The western and northern boundary of the Project Area is marked by a series of basement cored hills connected by inferred buried basement ridges. One of these ridges, which in this report is referred to as the Grays Butte-Shoemaker Butte ridge, forms the northern boundary of the Project Area, extending from Reardan, Washington, essentially to Nine Mile Falls (Figure 9). The other ridge, referred to as the Hanning Butte ridge, extends south from Reardan, forming the western boundary of the Project Area (Figure 9). These ridges, and associated basement highs, separate the Project Area from the much larger Columbia Basin regional aquifer system just to the west. West and north of these ridges, groundwater flow generally would be directed away from the Project Area. East and south of these ridges, within the Project Area, groundwater flow generally would be toward the Spokane River, as previously described in Spokane County (2013c).

A third basement ridge in the western Project Area occurs east of the Reardan, Washington, and generally parallels the Grays Butte-Shoemaker Butte ridge to the north and the hypothesized Medical Lake-Airway Heights ridge to the south. This ridge, referred to in Figure 9 as the Radar Hill ridge, essentially forms the western end of the Indian Prairie area, projecting above the basalt plateau several hundred feet. The gridding algorithm used to produce the top of basement map predicts that the Radar

Hill ridge would extend beneath the ground surface to the southwest toward US-2 and generally lie west of upper Deep Creek. This hypothetical feature, if proven to be present, might account for the different trends displayed by the Reardan well hydrographs and those for wells (292881, 153821, VA_CMTRY) located closer to Medical Lake.

7.2 Topographic Canyons

Topographic canyons are interpreted to influence the groundwater system down to elevations equivalent to the bottom of the each canyon. For example, in the Four Mound Prairie and Indian Prairie areas, basalt-hosted groundwater above the bottom of Coulee Creek canyon is separated by the canyon (Figures 31 and 32). Deep Creek plays a similar role in separating shallower basalt groundwater on Indian Prairie from groundwater above the base of the canyon to the south (Figures 31 and 32). Given these spatial relationships, these canyons are interpreted to separate shallow groundwater systems, isolating shallow groundwater in the plateaus separated by these canyons, and acting as drains for these portions of the groundwater system.

Below the incision depths of these canyons, their effect on the groundwater system is different. Water-bearing basalts below the canyon bottoms likely form generally continuous flow systems beneath the canyons, as suggested in Spokane County (2013c). These systems would be influenced locally only where they are incised into by a given canyon. Gaining reaches on Coulee Creek and Deep Creek shown by Spokane County may reflect canyon incision and discharge into the canyon from deeper Wanapum and upper Grande Ronde water-bearing strata (Spokane County, 2013a). Losing reaches on the other hand, in turn reflect stream losses to the underlying basalt, typically the Grande Ronde (Spokane County, 2013a).

7.3 Paleochannels

Previous work by Deobald and Buchanan (1996), McCollum and Pritchard (2012), and Spokane County (2013c) has discussed the potential influence of alluvium filled paleochannels on Project Area groundwater systems. Two of these, the Airport paleochannel and the Airway Heights paleochannel (Figure 8), transect the Central West Plains area and are the primary focus of this discussion.

As described earlier, well 472535 located in the Airport paleochannel (Figure 33) displays water levels higher than the long-term water levels observed in Grande Ronde wells in the surrounding area from 0.5 to 2 miles away (Figure 17). It also displays seasonal water level fluctuations for which no contemporaneous response is evident in the nearby Grande Ronde wells. If there were significant hydraulic continuity between these Grande Ronde wells and the paleochannel, the water level fluctuations seen in the paleochannel fill also should be seen in pressure fluctuations in the basalt wells. The lack of contemporaneous seasonal water level fluctuations in Grande Ronde wells suggests limited hydraulic continuity with the paleochannel, even with paleochannel water levels higher than those in nearby basalts. Because these Grande Ronde wells have water levels deeper than is seen in the paleochannel, but lack apparent hydraulic continuity, the Airport paleochannel is inferred to not be a significant source of water to underlying Grande Ronde.

Groundwater in the Airport paleochannel is inferred to drain to the north and east down the paleochannel and eventually toward the Spokane River. Where Wanapum Basalt groundwater levels are higher than the paleochannel water level in well 472535, this Wanapum groundwater likely is draining into the paleochannel. In such cases, the Airport paleochannel is inferred to act as a drain for the

Wanapum Basalt. Conversely, where Wanapum Basalt groundwater level is at or near the bottom of the paleochannel, the paleochannel may be a source for some Wanapum groundwater.

The Airway Heights paleochannel extends from the Deep Creek canyon southward beneath Airway Heights and can be projected to cross the Central West Plains area toward the Medical Lake area (Pritchard, 2013). For this report, in Plate 2, the gridding algorithm used to build the top of basalt map only shows that low as a fairly broad, low-amplitude feature with its deepest locations associated with well 385235 north of the City of Airway Heights, well BCF544 in the City, and a cluster of wells near the City of Medical Lake well east of that city and north of Four Lakes near the intersection of Craig Road and Highway 902. The basalt aquifer units intercepted in the relatively shallow Craig Road Landfill wells (generally less than approximately 200 feet deep) are truncated east of the landfill by this paleochannel, the bottom of which appears to vary between 100 and 300 feet bgs. Consequently, the paleochannel could separate the shallow Craig Road wells – and similar shallow wells farther west – from the pumping center wells. Given that, the depth and inferred location of the paleochannel suggest it is plausible that it could, at least in part, contribute to the apparent hydraulic separation of the pumping center wells from shallow, less than approximately 200 foot deep, wells to the west and northwest.

With respect to deeper wells, the depth of the Airway Heights paleochannel, again ranging from 100 to 300 feet deep, but generally less than 200 feet throughout most of its extent beneath the Central Plains area, is inferred to not be great enough to explain the apparent hydraulic discontinuity (as manifest in water levels) between pumping center wells and other wells (as described in preceding sections). For example, Wells AWH-7 and SCDMW-8, with open intervals at 380 to 440 feet bgs and 355 and 370 feet bgs, respectively, are deeper than the paleochannel, suggesting they should have some degree of hydraulic connection with the pumping center wells via groundwater flow pathways under the paleochannel. As described earlier though, these wells do not appear to have such a connection given the 100-plus-foot difference in static and dynamic water levels between them and the pumping center wells.

Based on the longer-term and/or continuous hydrographs at the core of this evaluation, paleochannels generally are interpreted to have limited to no significant influence on the basalt groundwater system beneath the incision depths of the paleochannels. Conversely, the paleochannels have a significant hydrologic relationship with the basalt groundwater systems truncated, or intercepted, by them. This relationship likely will vary between paleochannel reaches, with some reaches acting as recharge sources for the adjacent shallow basalt aquifer and other reaches, acting as drains into which shallow basalt groundwater systems discharge. Such relationships would be similar to those discussed and illustrated for Deep Creek and Coulee Creek (Figures 31 and 32).

7.4 Stratigraphy and Structure (Faults)

The presence of shallower basalt groundwater systems and deeper basalt groundwater systems can be inferred from the Indian Prairie, Four Mound Prairie, Marshall Creek, and Central Plains/Craig Road Landfill wells as illustrated in Figures 13, 15, 17, 19, 24, 26, 27, and 28. Shallow basalt and deeper basalt wells in each of these areas have potentiometric levels separated by several hundred feet of elevation, and commonly with different trends. Earlier work by Spokane County (Spokane County, 2013c) had suggested this was likely, with essentially Wanapum, shallow Grande Ronde (Sentinel Bluffs), and deep Grande Ronde (Wapshilla Ridge) aquifer systems being present. The apparent hydrologic separation seen in the hydrographs is interpreted to indicate the presence of stratigraphically distinct aquifer systems, which are generally caused by stratigraphic controls, such as extensive, low permeability, dense basalt flow interiors and Latah Formation interbeds.

An additional stratigraphic feature that may be influencing the hydrogeologic framework is heterogeneity within the CRBG and Latah Formation. Features such as basalt flow pinch outs and coarse Latah strata may allow a greater degree of hydraulic connection, at least locally. Conversely, thick dense basalt flow interiors, claystone sequences, and weathered altered basalt could act to limit hydraulic connection, yielding evidence indicative of groundwater flow and level separation. Further, the Project Area is situated near the margin of the Columbia Plateau, where basalt flows can terminate in a complex compound flow morphology. This flow morphology can result a lack of horizontal continuity, further compartmentalizing the aquifer system and limiting potential hydraulic connection between wells installed at similar elevations. Unfortunately, the available data are insufficient to determine which of these, if any, has a dominant influence on groundwater flow in the Project Area groundwater flow system.

Faults are mapped in the Project Area (Figure 10). Hydrogeologic investigations in different areas of the Columbia Basin have shown that faults can influence CRBG groundwater systems by acting as: (1) a barrier to lateral groundwater flow and/or as (2) as a vertical conduit to groundwater flow, cross-connecting shallower and deeper portions of the groundwater flow system. The effects of mapped faults on the Project Area groundwater flow system are unknown.

8. Conclusions: Conceptual Groundwater Flow Model

The West Plains groundwater flow system is a local system separated from the regional CRBG aquifer system by basement highs bounding the northern, western, and southern sides of the Project Area. Groundwater beneath the West Plains is interpreted to be locally sourced, flow pathways are relatively short (although they can be slow), and groundwater storage capacity is limited by discontinuities that separate the groundwater flow system into several subsystems. There is evidence that modern canyons, paleochannels, and basement highs disrupt lateral continuity within the groundwater system. Basalt flow morphology also may influence hydrologic continuity. These basic factors are interpreted to result in the West Plains groundwater system being broken up into localized groundwater flow systems with relatively limited storage potential. Taken together, the limited recharge potential, limited lateral continuity, and limited storage capacity, results in a West Plains groundwater system characterized by compartmentalized conditions and sensitive to local pumping and recharge effects.

While these distinct, compartmentalized aquifer systems display different head relationships and sometimes different recharge areas (particularly those separated by topographic canyons), they all appear to be saturated and capable of being recharged. Shallower portions of the aquifer system appear to have relatively rapid recharge from the surface while deeper portions of the system are interpreted to see significantly slower recharge. Recharge of the shallower portions of the aquifer system seems to occur seasonally and likely occurs via fully penetrating joint/fracture systems and in eroded valleys and canyons. It is not understood how groundwater recharge makes it into the deeper basalt system, given the basement ridges that separated the basalt flows when they flowed into the area 15 million years ago. Based on the few groundwater age dates reported for the Project Area, one would surmise that this recharge pathway is slow and tortuous. It might be occurring via some combination of the few joints/fractures that fully penetrate individual basalt flows, basalt flow unit pinchouts, and slow leakage through sediment interbeds.

These conclusions and the conceptual groundwater flow model associated with them are explored further in this section.

8.1 Compartmentalization

The West Plains groundwater flow system, focusing primarily on the basalt aquifer system, is interpreted to be stratigraphically and spatially compartmentalized with hydraulic continuity between different portions of the system being limited. This compartmentalization limits groundwater storage, hydraulic continuity, recharge potential, and ultimately sustainable pumping capacity.

8.1.1 Basement Highs

Basement highs, consisting of exposed hills and their buried extensions underlying the ground surface, are interpreted to be a primary factor in Project Area aquifer system compartmentalization. These basement highs are interpreted to limit basalt aquifer system continuity and lateral extent by simply projecting upward into, and in some areas through, the planar-tabular layered CRBG and Latah Formation, disrupting these strata and any groundwater movement through them. The basalt aquifer system in the Project Area is interpreted to be compartmentalized by the Radar Hill ridge on the west side of Indian Prairie, Medical Lake-Airway Heights ridge, Needham Hill ridge, Grays Butte-Shoemaker Butte ridge system on northern edge of the Project Area, and Hanning Butte ridge system on the west (Figure 9, Plate 3). These later two ridges systems essentially form the northern and western boundaries of the Project Area groundwater system, separating it from the much more extensive Columbia Basin regional aquifer system. The other ridges are interpreted to form boundaries within the Project Area.

The Radar Hill ridge forms a boundary within the Project Area, bounding the western side of the Indian Prairie area. It may also separate a groundwater subsystem in the area east of Reardan, Washington, (referred to in Figure 34 as the Reardan-upper Coulee Creek subsystem) from a potential groundwater subsystem west of Medical Lake (referred to in Figure 34 as the Deep Creek-Espanola subsystem). As noted earlier, wells in the Medical Lake area seem to display different water level trends than the Reardan wells, showing evidence of long-term water level declines suggestive of pumping exceeding recharge.

The pumping center wells are interpreted to be located within another subsystem (referred to in Figure 34 as the Central Plains subsystem), bounded on at least three sides by basement highs. These bounding highs include the basement hills around Medical Lake in the south, Needham Hill ridge parallel to and east of I-90, and the hypothesized Medical Lake-Airway heights ridge on the west and northwest. Although some reports prepared recently for FAFB do not describe this feature, geotechnical borings and water well logs along this feature describe lithologies that are indicative of a basement high.

The pumping center wells also may be bounded on the north. While the nature of this boundary is not clear, water levels in wells, such as Raceway Park MW 4-7, SCDMW8, and AWH-7, display depths and trends over time suggestive of a lack of hydraulic continuity with the pumping center wells. This flow limiting boundary is inferred to be a basement feature based on the basement grid model. If present, this hypothetical basement high may divide the Central Plains subsystem into northern and southern portions.

A fourth subsystem inferred from the data reviewed here is a small subsystem associated with the Marshall Creek valley (and referred to in Figure 34 as the Marshall Creek subsystem). This area is bounded by basement highs, including the inferred Needham Hill ridge, which also project upward into the bottom of the Marshall Creek canyon.

As currently drawn, the basement-bounded Reardan-upper Coulee Creek, Deep Creek-Espanola, and Central Plains subsystems extend to the northeast and east, toward the lower reaches of Deep Creek before it empties into the Spokane River. In this area, these subsystems may merge, becoming more hydraulically connected than currently inferred to be the case to the west.

Faults, many of which commonly are associated with basement highs, also may contribute to the groundwater flow boundaries inferred to be associated with these highs. However, specific examples of the direct influence of faults on compartmentalization are not identified in this report. Given that, mapped faults in the Project Area are not interpreted at this time to be associated with groundwater flow boundaries. Additional work may demonstrate such a relationship.

8.1.2 Canyons and Paleochannels

In the northern and western portions of the Project Area, the basalt groundwater flow system above the depth of incision of Coulee Creek and Deep Creek is further compartmentalized by the canyons occupied by those streams (Figures 1, 8, 13, and 32). Where water-bearing basalts are incised by these canyons, water discharges from the basalts into the canyons. Conversely, water-bearing basalts near the base of the canyons display a more complex relationship with the streams in the canyons. Based on seepage studies, some reaches of these canyons may act as recharge sources to the basalt aquifer system, while other reaches act as discharge areas for the basalt aquifer system. Below the depth of canyon incision, the canyons are inferred to have minimal influence on water-bearing basalts that extend uninterrupted beneath the canyon. Given these relationships, canyons are interpreted generally to provide local modification of the larger subsystems defined by the basement highs.

The Airway Heights paleochannel and the Airport paleochannel may have a similar influence on the basalt groundwater flow system, although one that cannot be easily observed because of the presence of alluvial fill in the paleochannels. Generally, the paleochannels are interpreted to have limited to no significant influence on the basalt groundwater system beneath the incision depths of the paleochannels. Conversely, they are inferred to have a significant hydrologic relationship with the basalt groundwater systems truncated, or intercepted, by them. This relationship likely will vary from reach to reach in the paleochannels, just as it appears to do in modern stream reaches. Some paleochannel reaches will act as recharge sources for adjacent shallow basalt aquifer while other paleochannel reaches will act as drains into which shallow basalt groundwater systems discharge.

Combining canyons and basement highs, the Project Area groundwater system is inferred to have both limited continuity and storage, making it susceptible to pumping stresses. The long-term groundwater level declines seen in the Central Plains subsystem (Figure 26) and the Deep Creek-Espanola subsystem (Figure 22) are interpreted to directly reflect this. Evidence for this limiting effect also is seen in the shallow portion of the system on Four Mound Prairie, where season-to-season water level declines are present (Figure 13).

8.2 Recharge

Within the compartmentalized groundwater system summarized above, the primary source of natural groundwater recharge is infiltration of precipitation and snow melt into the ground, and eventually into the groundwater system. There are no significant surface water inflows into the Project Area. Marshall

Creek and Hangman Creek are inferred to contribute little or no significant recharge to the Project Area groundwater system, except locally along these stream courses.

Area-wide estimated potential groundwater recharge from infiltration of precipitation and snow melt appears to exceed total groundwater pumping. In most years, potential recharge is estimated to exceed total pumping by a factor of 2 to 4 times. Given this generalization, the groundwater system should show evidence of significant recharge and recovery of water removed via pumping. However, based on many of the hydrographs reviewed throughout this report, this generalization does not appear to be borne out by field data.

Hydrographs for generally shallower wells showing spring and early summer water level rises are interpreted to show seasonal recharge in the shallow basalt and alluvial portions of the groundwater system. This apparent seasonal recharge is interpreted to quickly influence the basalt system down to depths equivalent of the depth of modern canyons and paleochannels. As such, seasonal recharge has some influence on the upper Grande Ronde, at least locally, while having a more broad effect on the Wanapum throughout the Project Area.

With that basic observation in mind, several hydrographs for wells in the Four Mound Prairie area (441147, Garfield-Lincoln, 439863), Airport paleochannel (472535), and Marshall Creek area (Green, Spokane Marshall) appear to show the seasonal water level rises (reflective of recharge), but with decreasing seasonal peak water levels in the relatively short data record currently available. Because these are generally areas of low density rural housing and limited irrigated agriculture, this admittedly short data record could be interpreted to reflect sensitivity to external stresses, such as reduced recharge and/or increased pumping. If additional data collection shows successively lower peak water levels in subsequent years in an area of relatively small groundwater pumping from the shallow basalt groundwater system, the sustainable pumping capacity of this portion of the system may be more limited than the apparent ease of recharge would suggest.

Below the depth of modern canyon and paleochannel incision, the influence of seasonal surface recharge is interpreted to be small. Some movement of groundwater into deeper portions of the aquifer system likely is occurring, as suggested by rising water levels in the pumping center wells occurring in recent years as pumping in some wells has been reduced. However, these water level rises also, at least in part, may indicate the deep aquifer system adjusting to a new equilibrium, reflecting reduced pumping stresses. In addition, relatively old average groundwater ages (>10,000 years) in some deep wells in the pumping center area and in the Western area, suggest relatively long travel times for water to get into the deeper groundwater system.

Paleochannels also may have limited influence on facilitating rapid deeper basalt aquifer recharge. The long-term hydrograph for the alluvial well in the Airport paleochannel shows the presence of seasonally higher and lower water levels. Conversely, wells completed more than 300 feet into the basalt on either side of the paleochannel do not show the seasonal fluctuation so obvious in the paleochannel alluvial well. This suggests the pressure effects of seasonal highs and lows in the paleochannel filling alluvial aquifer system are not propagating into deeper portions of the underlying basalt aquifer system to which these other wells are open. By implication, this suggests that the hydraulic connection between the paleochannels and deeper portions of the basalt aquifer is limited.

Declining water levels several wells may suggest that potential groundwater recharge is less than would otherwise be suggested by area-wide water budgets and infiltration estimates. High spring and early summer water levels in a number of alluvial and shallow basalt wells are suggestive of seasonal recharge influences, although the limited amount of data suggests the peak water levels are dropping. While the relatively short data record is not directly indicative of any primary influence, season-to-season declines in peak (or high) water levels is suggestive of at least a temporary loss of stored groundwater. If such trends continue, the shallow groundwater system (both alluvial and shallow basalt) would appear to have limited storage capacity and be potentially sensitive to changes in recharge and pumping stresses. The extent and rate of deep basalt groundwater recharge are unknown. Limited amounts of groundwater geochemical data suggest that it is slow. Long-term water level declines in areas with significant pumping are interpreted to indicate that recharge is slower than historical pumping rates. The water level data reviewed for this report suggest there is a limit to sustainable groundwater use in the Project Area, and in much of it, groundwater recharge has been, or could be, exceeded by groundwater pumping.

8.3 Groundwater Flow and Discharge

The area-wide groundwater flow directions interpreted for the Wanapum and Grande Ronde portions of the aquifer system in earlier work prepared by Spokane County are interpreted to be essentially correct. Based the potentiometric maps in Spokane County (2013C), groundwater flow beneath the Project Area generally will be from west to east, with modern canyons and the paleochannels locally deflecting shallower levels. Most water infiltrating past the root zone and into the shallow subsurface is inferred to predominantly move laterally where it discharges to springs, seeps, and creeks. Where water infiltrates into the primary paleochannels, a portion is inferred to discharge rapidly out of the paleodrainages to the Spokane River valley and a portion may recharge shallow basalt groundwater systems truncated by the paleochannels.

Based on the compartmentalized conceptual groundwater flow model outlined in this section, the only significant modification to that earlier work would be to reconcile water table grid models with basement high and top of basalt grid models to further refine potential local groundwater flow, recharge, and discharge areas. Such efforts may provide additional insight into the influences of the canyons, paleochannels, and basement highs on localized groundwater flow and groundwater discharge patterns.

8.4 Unanswered Questions and Recommendations

From a numerical groundwater model perspective, major unanswered questions centers on: what are aquifer hydraulic properties and what is the degree of aquifer/water-bearing zone continuity within the groundwater system? This applies to both the CRBG and the Latah Formation. If a groundwater model were to be attempted in the future, these questions should be answered to at least a moderate extent. Several pumping tests in different portions of the aquifer system would at least provide some bounds on aquifer hydraulic properties that might prove useful in preparing a model, if a model were determined to be useful in supporting future groundwater management efforts. Such testing would have the additional benefit of better defining the potential groundwater flow barriers that seem to be so important in the Project Area.

Associated with the general scarcity of hydraulic data is the need to update grid models and maps illustrating the subsurface distribution of major aquifer hosting geologic units. For this report, only the top of basement and top of basalt surfaces were reinterpreted. Grid models for these two surfaces were built because they are interpreted to be fundamental hydrologic boundary surfaces. Other Project Area aquifer host units – including coarse and fine Quaternary units, the Wanapum Basalt, the different Grande Ronde units, and the different Latah units – were not reevaluated for this Report. Instead, existing grid models and maps of these units were used. For any future numerical groundwater modeling effort, all grid model surfaces will need to be reconciled, either by regenerating all of them and/or by using grid math methods. As a part of such an effort, older grid models of these surfaces should be discarded.

Several of the apparent hydraulic discontinuities identified in this report as causing compartmented groundwater subsystems are not directly observed. These features, including the southwest extension of the Radar Hill ridge and the potential subdivision of the Central Plains subsystem, are inferred solely from hydrographs and are not identified from field evidence and/or pumping tests. Further exploration of these features would be warranted if more robust analysis and management of the groundwater system are desired. Additional investigation of the Medical Lake-Airway Heights ridge also may be warranted because, while it is interpreted to be important in this report, other reports do not describe its presence.

The available water level data, as reported on in previous reports, proved generally acceptable in delineating area-wide groundwater flow systems and water level trends in different hydrostratigraphic units. However, in many parts of the Project Area, it proved difficult to reconstruct local potentiometric surfaces and gradients because potential hydrologic boundaries, such as canyons, paleocanyons, basement highs, and stratigraphic features, commonly intervened between wells having long-term records. As a result, it proved difficult in many local areas (except the Central Plains area) to find three wells needed to define the local unit-specific potentiometric surfaces that are not separated by some kind of hydrologic boundary. One of the most important datasets made available to this study has been the long-term water level monitoring efforts of a whole host of entities for a multitude of reasons.

The water level data collected by multiple entities – county, state, cities, U.S. Geological Survey, conservation district, local water purveyors, landfills, FAFB, and others – during the past several decades from specific wells for specific projects were invaluable in the completion of this Report. However, most of the funding for these efforts is not dedicated or guaranteed. It is strongly recommended that these entities be encouraged to continue with these monitoring programs and work to share their datasets to make sure they are available in perpetuity. If additional well monitoring points are added to the long-term water level monitoring effort local ground water flow directions and gradients will be better understood than is currently the case, especially within local areas such as described in Section 6 of this Report.

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Tables

Feature		Hydraulic Conductivity Ranges ft/day	Hydraulic Conductivity Ranges m/day (approx. conversion)	Reference	Comments
Flow Tops	Kh	1 x 10^{-6} to 1,000	3 x 10^{-7} to 3 x 10^{2}	USDOE, 1988	Average = 0.1 ft/day
	Kv	3 x 10^{-9} to 3 x 10^{-3}	9 x 10^{-10} to 9 x 10^{-4}	USDOE,1988	
	Kv	1 x 10^{-5} to 1 x 10^{-1}	3 x 10^{-6} to 3 x 10^{-2}	Sabol and Downey, 1997	Measured near Lind, Washington
Flow Interiors	Kh	1 x 10^{-9} to 1 x 10^{-3}	3 x 10^{-10} to 3 x 10^{-4}	USDOE, 1988	Approximately 5 orders of magnitude less than flow tops
	Kv	3 x 10^{-9} to 3 x 10^{-3}	9 x 10^{-10} to 9 x 10^{-4}	USDOE,1988	
	Kv	1 x 10^{-5} to 1 x 10^{-1}	3 x 10^{-6} to 3 x 10^{-2}	Sabol and Downey, 1997	Measured near Lind, Washington
Flow Tops	Kh	7 x 10^{-3} to 1,892	2 x 10^{-3} to 6 x 10^{2}	Whiteman et al. (1994)	Vertically Averaged for Saddle Mountains Basalt
	Kh	7 x 10^{-3} to 5,244	2 x 10^{-3} to 2 x 10^{3}		Vertically Averaged for Wanapum Basalt
	Kh	5 x 10^{-3} to 2,522	5 x 10^{-3} to 6 x 10^{2}		Vertically Averaged for Grande Ronde Basalt
Ellensburg Formation Interbeds	Kh	1 x 10^{-6} to 1	3 x 10^{-7} to 3 x 10^{-1}	USDOE, 1988	Average for various interbeds = 0.01 to 0.1 feet/day
	Kh	1 x 10^{-6} to 100 feet/day	3 x 10^{-7} to 3 x 10^{1}	Sabol and Downey, 1997	Measured for interbeds in Pasco Basin

Kh = horizontal hydraulic conductivity
Kv = vertical hydraulic conductivity

Table 1 - Summary of hydraulic conductivity values typical for CRBG interflow structures and sedimentary interbeds.

Well ID	Surface Elevation (ft)	Well Depth (ft)	Open Interval (ft)	Hydrogeologic Unit	Estimated Groundwater Age
160959	2479	100	80-100	Wanapum/Grande Ronde	
172968 (Four Mound)	2409	205	50-305	Wanapum/Grande Ronde	
439863 (Coulee Hite)	2429	120	60-120	Wanapum	
Garfield-Lincoln	1901				
441147	1868	235	235	Grande Ronde/Basement	
172184	1877	303	290-303	Alluvial	

Table 2. Characteristics of selected wells in the Four Mound Prairie area.

Well ID	Surface Elevation (ft)	Well Depth (ft)	Open Interval (ft)	Hydrogeologic Unit	Estimated Groundwater Age
171100	2453	475	20-475	Wanapum/Grande Ronde	
167996	2338	75	20-75	Wanapum	
167998	2321	198	20-128	Wanapum	

Table 3. Characteristics of selected wells in the Indian Prairie area.

Well ID	Surface Elevation (ft)	Well Depth (ft)	Open Interval (ft)	Hydrogeologic Unit	Estimated Groundwater Age
472535	2268	185	160-185	Alluvial	
Raceway MW4	2346	363		Grande Ronde	
Raceway MW5	2349	˜350		Grande Ronde	
Raceway MW6	2358	˜350		Grande Ronde	
Raceway MW7	2342	360		Grande Ronde	
SCD MW8	2334	380	355-370	Grande Ronde	4600 years
174648	2218	297	265-297	Grande Ronde	
411175	1866	264	240-264	Grande Ronde	

Table 4. Characteristics of selected wells in the area between Deep Creek and US-2.

Well ID	Surface Elevation (ft)	Well Depth (ft)	Open Interval (ft)	Hydrogeologic Unit	Estimated Groundwater Age
560732	2464	114	85-95	Wanapum	
560736	2476	112	102-112	Wanapum	
560746	2467	111	101-111	Wanapum	
560763	2470	107	96-106	Wanapum	
168759	2457	135	110-135	Wanapum	

Table 5. Characteristics of selected wells in the area west of Fairchild Air Force Base.

Well ID	Surface Elevation (ft)	Well Depth (ft)	Open Interval (ft)	Hydrogeologic Unit	Estimated Groundwater Age
292881	2380	440	75-440	Grande Ronde	11,700 years
153821	2368	335			
VA_CMTRY	2450	570		Grande Ronde	
Reardan Test (164270)	2447	268	230-268	Grande Ronde	
Reardan Muni (164560)	2442	452		Grande Ronde	12,900 years

Table 6. Characteristics of selected wells in the western portion of the Project Area (Western Area).

Well ID	Surface Elevation (ft)	Well Depth (ft)	Open Interval (ft)	Hydrogeologic Unit	Estimated Groundwater Age
Green	2339	440	440	Wanapum/Grande Ronde	
560333	2340	137	100-135	Wanapum	
Marshall	2165	80	60-78	Alluvial	
SCDMW-11	2342	240	230-240	Alluvial	3,470 years
SCDMW-7	2342	360	345-360	Grande Ronde	10,670 years

Table 7. Characteristics of selected wells in the Marshall Creek area.

Well ID	Surface Elevation (ft)	Well Depth (ft)	Open Interval (ft)	Hydrogeologic Unit	Estimated Groundwater Age
560746	2467	111	101-111	Wanapum	
Four Lakes School (164395)	2446	200	113-200	Basement	
164483 (Town of Four Lakes)	2409	775	320-775	Wanapum/Grande Ronde	10,670 years
417068 (City of Medical Lake)	2400	1404	329-1380	Wanapum/Grande Ronde	
Parkwest (City of Airway Heights)	2410	301	152-301	Wanapum/Grande Ronde	1,490 years
167912	2389	185	55-185	Wanapum	
FAFBMWD1 (371438)	2411	442	377-439	Grande Ronde	
617922 (Geophysical Well)	2419	450	240-450	Grande Ronde	
Airway Heights #7 (344207)	2368	440	380-440		
488063	2377				4,200 years

Table 8. Characteristics of selected wells in the Central Plains area.

Well ID	Surface Elevation (ft)	Well Depth (ft)	Open Interval (ft)	Hydrogeologic Unit	Estimated Groundwater Age
MW 70	2397	27		Alluvial	
MW 74	2396	185		Grande Ronde	
MW 80	2414	120		Wanapum	
MW 82	2379	82		Wanapum	
MW 84	2408	128		Wanapum	
MW 95	2397	149		Wanapum	
MW 101	2399	201		Grande Ronde	
MW 117	2368	166		Wanapum	
MW 118	2378	114		Grande Ronde	
MW 127	2369	199		Wanapum	
MW 139	2368	200		Grande Ronde	

Table 9. Characteristics of selected wells at the Craig Road Landfill.

Appendix A

Quality Assurance/Quality Control Summary

Letter Report from GeoEngineers, Inc. to

GSI Water Solutions, Inc.

GeoEngineers
523 East Second Avenue
Spokane, Washington 99202
509.363.3125

June 10, 2015

GSI Water Solutions, Inc.
8019 West Quinault Avenue, No. 201
Kennewick, Washington 99336

Attention: Kevin Lindsey

Subject: Quality Assurance/Quality Control Summary
West Plains Hydrogeological Framework Project
Spokane County, Washington
File No. 0188-162-00

INTRODUCTION

This letter presents the results of our quality assurance/quality control (QA/QC) review of existing background information related to the West Plains Hydrogeological Framework Project in Spokane County, Washington. The purpose of our QA/QC review was to evaluate whether available background information components are suitable for use during development of a hydrogeologic framework and conceptual model for the aquifer system underlying the West Plains portion of Spokane County. The information provided in this letter, and its associated attachments, are intended to support development of one or more project Technical Memorandums by GSI Water Solutions, Inc.

METHODOLOGY

Background information reviewed by GeoEngineers, Inc. (GeoEngineers) consisted of the following components, which were compiled by the Spokane County Water Resource Program:

- Forty-four technical geologic and/or hydrogeologic reports.
- Twenty-six datasets containing hydrologic (including groundwater level, streamflow, water quality and climate) and geologic (including whole rock geochemical, stratigraphic, well characteristic and other) data.
- Seven geologic maps (individual or map sets).
- Four compilations of publications and supporting documents.

These documents were provided to GeoEngineers electronically via a File Transfer Protocol (FTP) site administered by Spokane County.

GeoEngineers' QA/QC review methodology was presented to the project Technical Advisory Group (TAG) on February 24, 2014, and is summarized in the flow chart provided in Attachment A. The intent of the QA/QC review is to provide a systematic approach for evaluating data suitability and a technical basis for the exclusion of documents from project analyses. The flow chart includes established criteria and decision points. By following this approach, reports, datasets and maps were evaluated for the following:

- Relevance: Do the reports and datasets contain information specific to geologic and/or hydrogeologic conditions within the West Plains study area?
- Uniqueness: Do the reports and datasets contain new information not provided in one or more other reports within the project database?
- Suitability of Hydraulic Testing Data: Were hydraulic testing data generated and analyzed using methods consistent with the current standard of practice?
- Credibility of Water Quality Data: In general compliance with the Washington State Credible Data Policy (Ecology, 2006), were water quality data generated in compliance with a Quality Assurance Project Plan (QAPP) and contain usable metadata?
- Suitability of Groundwater Level Data: Is groundwater level data associated with known hydrostratigraphic units, horizontal locations and elevations?
- Correctability: Is a data deficiency, if identified, correctable?

RESULTS

Results of GeoEngineers' QA/QC review are provided in the summary spreadsheets (Summary Spreadsheet – Background Information, Table B-1 and Summary Spreadsheet – Review Results, Table B-2) provided. Table B-1 compiles summary information regarding the contents of reviewed documents. For each document listed in Table B-1, Table B-2 provides the results of our QA/QC review, including our assessment of data suitability.

Our interpretation of data suitability can be summarized by the following categories:

- Suitable: A total of 44 of the documents were interpreted to be suitable for use.
- Unsuitable: A total of 37 documents were interpreted to be unsuitable for use.
  - Correctable: The data deficiencies for 29 of the unsuitable documents were interpreted to be correctable, primarily through research and review of information related to data origin and collection processes.
  - Not Correctable: The data deficiencies of eight of the unsuitable documents were interpreted to be uncorrectable. These determinations generally were related to non-uniqueness of data or a geographic study area that did not include the West Plains.

LIMITATIONS

We prepared this letter report for use by GSI Water Solutions, Inc. to assist in their evaluation of the hydrogeologic framework of the West Plains portion of Spokane County, Washington. Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of hydrogeology in this area at the time this letter report was prepared. No warranty or other conditions, express or implied, should be understood.

REFERENCE

Ecology, 2006. Washington State Department of Ecology, Water Quality Program Policy, Ensuring Credible Data for Water Quality Management. WQP Policy 1-11. Olympia, WA.

Sincerely,
GeoEngineers, Inc.

Jonathan E. Rudders, LHG
Senior Hydrogeologist

James A. Miller. PE, LEG, LHG
Senior Principal

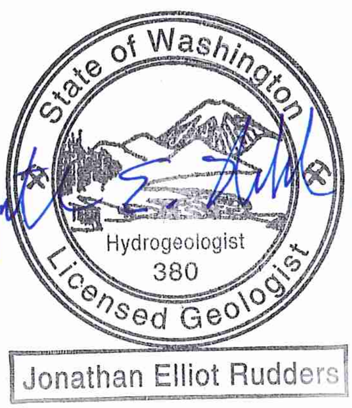
JER:JAM:tjh:mce:tlm

Attachments:

Attachment A. Flow Chart – Data Suitability for Inclusion in the West Plains Hydrogeological Framework Project

Table B-1. Summary Spreadsheet – Background Information, Quality Assurance/Quality Control Review of Project Reports and Datasets

Table B-2. Summary Spreadsheet – Review Results, Quality Assurance/Quality Control Review of Project Reports and Datasets



06/10/15

Attachment A

Flow Chart - Data Suitability for Inclusion in the West Plains Hydrogeological Framework Project

Spokane County, Washington

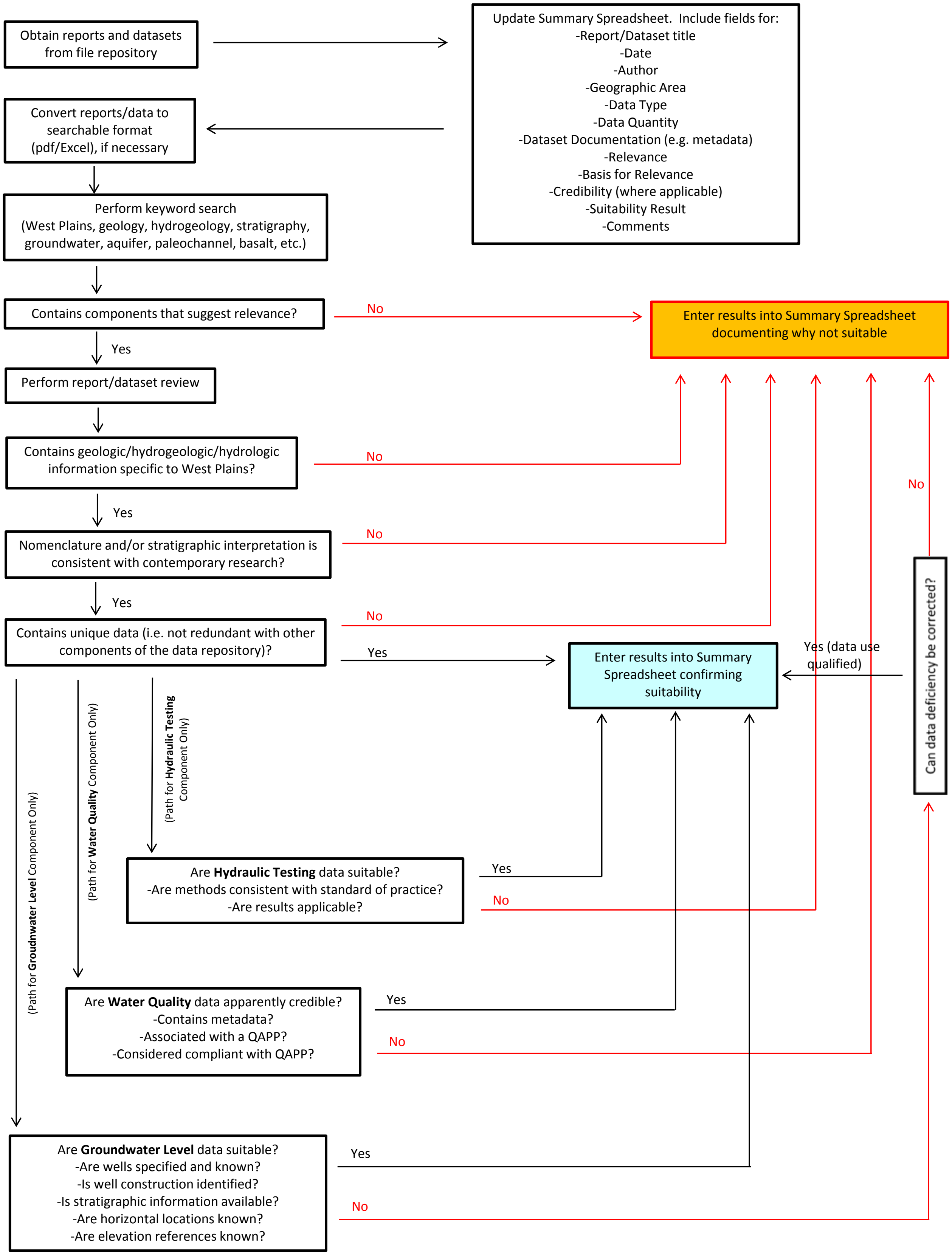


Table B-1

Summary Spreadsheet - Background Information
Quality Assurance/Quality Control Review of Project Reports and Datasets
West Plains Hydrogeological Framework Project
Spokane County, Washington
GeoEngineers Project No. 0188-162-00

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
1	McCollum, L.B. and M.M. Hamilton	West Plains Delineation of Aquifer Zones Within Basalt Formations Project, WRIA 54 –Lower Spokane	Report	Jun-12	3/6/2014	JER	West Plains	Lithostratigraphic identification and correlation	Fence diagrams; lithostratigraphic profiles; geochemical analysis spreadsheet (evaluated under ID No.2)	One fence diagram with 14 panels; 20 pages of lithostratigraphic profiles	Yes; report methods discussion
2	Pritchard, Chad	Pritchard XRF Results for WRIA 54 2012-2013.xlsx	Dataset	Undated	3/6/2014	JER	WRIA 54	Excel spreadsheet containing geochemical data	Whole rock geochemical data by x-ray fluorescence	42 samples with latitude/longitude data	Referred to in ID No. 2, no other documentation encountered
3	McCollum, M.B. and C.J. Pritchard	WRIA 54 Delimiting geologic structures affecting water movement and flow direction of the CRBG West Plains aquifer	Report	Jun-12	3/6/2014	JER	West Plains	Structural geology and tectonic history of West Plains area and surrounding region	Figures depicting local and regional geologic structures	11 figures	Yes, report discussion
4	C.J. Pritchard	Summary for Spokane County WRIA 54 2012-2013, Subsurface Projection of the Stratigraphy of the Columbia River Basalt Group and Paleodrainages in the West Plains Area	Report	28-Jun-13	3/7/2014	JER	West Plains	Lithostratigraphic identification and correlation, geometry of paleodrainages	Cross sections and contour maps showing geometry of paleodrainages (including a newly-identified paleodrainage near Marshall Creek), and elevation contour maps showing top of Sentinel Bluffs and Wapshilla Members	5 cross sections, 3 contour maps	Yes, report discussion
5	Northwest Land & Water, Inc.	West Plains (WRIA 54) & Lower Hangman Creek Watershed (WRIA 56), Hydrogeologic Characterization & Monitoring Well Drilling, Final Report	Report	30-Jun-12	3/27/2014	JER	West Plains/Lower Hangman Watershed	Drilling and monitoring well construction, stratigraphic correlation, groundwater age dating	Hydrostratigraphic cross-sections, water quality (including major ions) data, groundwater isotopic data, well logs, low-flow pumping test data	4 monitoring well logs, pumping tests in three wells, 18 groundwater samples, 3 cross sections	Yes, report discussion, QAPP referenced, lab QA/QC discussed

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
6	Spokane Co. Water Resources, McCollum, L.B. and M. Hamilton	West Plains Hydrogeologic Database; Prepared for: WRIA 54 Watershed Implementation Team	Dataset	30-Jun-11	5/19/2014	BAA	West Plains	GIS, Excel, and Rockworks water well report inventory dataset (1,000 records); location, lithologic and stratigraphic interpretation, water level, well yield, and construction details	3D stratigraphic model, surface topography and unit thickness maps, potentiometric surface maps, spatial distribution of well yield maps, lithostratigraphic/hydrostratigraphic cross sections with well construction data	19 figures, 31 cross sections	Yes; report methods discussion
7	Spokane Co. Water Resources	West Plains Hydrogeology, Groundwater Recharge Estimate	Report	30-Jun-13	6/20/2014	BAA	West Plains	DPM groundwater recharge analysis and recharge estimates	Annual estimated precipitation and recharge, recharge rate and soil characteristics, spatial distribution of annual recharge, monthly water budget components for West Plains recharge estimates from 1996 to 2012	9 figures, 6 tables, 1 Appendix (8 pages) containing monthly water budget components for the years 1996 to 2012	Yes; report methods discussion
8	Spokane Co. Water Resources	West Plains Hydrogeology, West Plains Groundwater Elevation Monitoring and Mapping	Report	30-Jun-13	6/23/2014	BAA	West Plains	Groundwater elevation monitoring and mapping	Synoptic, monthly, and continuous water level measurements from 85 wells (public supply wells, domestic wells, and monitoring wells) between 2011 and 2013	19 strip logs, 12 monthly hydrographs, 10 continuous groundwater elevation/temperature plots, 3 continuous groundwater elevation/precip plots, 4 groundwater elevation maps, 2 change in water level maps, 2 groundwater contour maps, 6 data tables	Yes, report discussion, QAPP referenced
9	Golder Associates	West Plains Geophysical Orientation Survey Feasibility Report	Report	Jul-09	6/23/2014	BAA	West Plains	Feasibility of geophysical methods to map subsurface geologic contacts, cost-benefit analysis of two best methods, monitoring well installation data to field check geophysical results	Well logs located near the 3 geophysical lines, geophysical survey results (electrical resistivity, gravity, TEM, and seismic reflection) for 3 lines including interpreted geologic cross-sections, monitoring well construction log for new well	13 existing well logs, 12 geophysical survey maps/figures (4 per line), 1 monitoring well construction log	Yes; report methods discussion, QAPP referenced

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
10	Water & Natural Resource Group, Inc. and GSI Water Solutions, Inc.	Groundwater Level Gauging Project Lower Lake Roosevelt Watershed (WRIA 53), Northern Lincoln County, Washington	Report	20-Jun-11	6/24/2014	BAA	Lower Lake Roosevelt Watershed (WRIA 53)	Surface water and groundwater level measurements between 2009 and 2011 throughout WRIA 53	Climate data, Lake Roosevelt hydrograph, flow data and hydrographs for 3 surface stations, water elevations and hydrographs from wells completed in the sand and gravel aquifer (6 wells), basalt aquifer (41 wells total), and basement rock aquifer (5 wells)	22 figures (maps and hydrographs), 12 data tables (climate data, flow measurements, and water level elevations), 3 attachments, 3 plates	Yes; reports methods discussion, QAPP referenced
11	Deobald, W.B. and J.P. Buchanan	Hydrogeology of the West Plains Area of Spokane County, Washington	Report	May-95	6/25/2014	BAA	West Plains	Geologic history of the West Plains area, stratigraphic correlation, occurrence of groundwater, groundwater quality	Geologic cross-sections, unit thickness and elevation maps, water level data and potentiometric surface maps, water quality data	7 cross-sections, water levels from 69 wells, 46 water quality samples	Yes: report methods discussion
12	Spokane Co. Water Resources	West Plains Hydrogeology, Deep Creek and Coulee Creek Groundwater/Surface Water Interaction	Report	30-Jun-13	6/25/2014	BAA	West Plains	Seepage run analysis on Deep Creek and Coulee Creek within the West Plains area	Stream flow measurements, seepage run data, geologic cross-sections, potentiometric surface maps	Seepage run results for 25 locations, 2 geologic cross-sections, 2 seepage run/aquifer contour maps	Yes; QAPP referenced
13	Durham, F.E. (MS Thesis)	Geology and Hydrogeology of Eastern Lincoln County, Washington	Report	Fall 1993	7/24/2014	BAA	Eastern Lincoln County	MS Thesis; groundwater recharge and nitrate contamination susceptibility assessment	Geologic, pedologic, hydrogeologic, and topographic summary of the area from other sources. Recharge assessment based on lithology and interflow information from well logs	10 summary tables, 68 figures. Appendices with unique data/figures are missing	Yes; report methods discussion
14	Gilmour, E.H. and M. Bacon	Groundwater Resources and Potential Sewage Pollution in Southern Spokane County	Report	30-Sep-74	7/24/2014	BAA	Southern Spokane County, primarily south of Cheney	Analysis of the recharge, use and movement of goundwater, and examination of possible groundwater pollution from sewage lagoon systems	Summary of geology and groundwater occurrence, results from bacteria sampling	8 figures, 47 bacterial analyses	Yes; report methods discussion

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
15	Siems, Barbara A.	Stratigraphic Identification and Correlation of Basalt Aquifers Using Geophysical and Chemical Techniques	Report	Jul-74	7/25/2014	BAA	Central Washington, between Odessa, Othello, Connell, Washtucna, and Ritzville	Correlation of CRBG stratigraphic units using geophysical and geochemical data	Results from various geophysical methods and geochemical results (K_2O, TiO_2) from drilling chips	19 figures, 6 maps, 13 geophysical lines	Yes; report methods discussion
16	Olson, T.M., E.H. Gilmour, M. Bacon, J.L. Gaddy, G.R. Robinson, O.J. Parker	Geology, Groundwater, and Water Quality of Part of Southern Spokane County, Washington	Report	11-Jul-75	7/25/2014	BAA	Southern Spokane County, between Spokane and Spangle	Summary of geology and groundwater resources, bacterial water quality data and chemical water quality data	Broad aspects of geology and hydrogeology discussed; general relationships of surface water/groundwater; poor and good groundwater potential delineated	13 figures (including 5 hydrographs), 2 plates (not included), 402 wells inventoried	Yes; report methods discussion
17	Science Applications International Corp. (SAIC)	Remedial Investigation Report, Craig Road Landfill (CRL), Fairchild Air Force Base (FAFB)	Report	Apr-92	7/28/2014	BAA	FAFB	Remedial Investigation Report for the Craig Road Landfill located on FAFB	Geologic data from wells/borings, seismic refraction, gravity and magnetics, borehole geophysics; environmental data from soil and gas surveys, borehole sampling; groundwater data from groundwater sampling, packer tests, slug tests, groundwater flow model	Contains a large amount of data, 113 figures (including 16 cross-sections)	Yes; report methods discussion and QA/QC validation procedures
18	Science Applications International Corp. (SAIC)	Feasibility Study Report, Craig Road Landfill (CRL), Fairchild Air Force Base (FAFB)	Report	Aug-92	7/28/2014	BAA	FAFB	Feasibility Study Report for the Craig Road Landfill located on FAFB	Review of various remediation alternatives	Data is included in RI report	NA
19	Ecology and Environment, Inc.	Removal Evaluation Report, Euclid Road TCE Monitoring Site, Reardan, Washington	Report	Dec-10	7/28/2014	BAA	Spokane County near Reardan	Contamination removal evaluation in the vicinity of a former Nike missile launching site	Environmental contamination evaluation (NDMA, perchlorate, and TCE) over a 35 square mile area	478 field samples from 128 separate properties	Yes; QA/QC documentation and discussion
20	Jones, F. O.	Evaluation of Water Supply for the Proposed Indian Village Estates Development, Indian Prairie, Spokane County, Washington	Report	May-77	7/28/2014	BAA	Indian Prairie Plateau, Spokane County	Groundwater supply evaluation for 320 acre development located on Indian Prairie	Summary of geologic history; geology, groundwater level, and production information for 52 existing wells	Data for 52 wells (16 with logs and 36 based on interviews with owners), 1 plate	No (does not include methods discussion)

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
21	URS	Analysis of Potable Water System, Fairchild Air Force Base, Washington; Appendix F and Test Logs	Report	Mar-04	7/28/2014	BAA	FAFB	Appendix F - Test Well Program to evaluate the option of drilling a new water supply well for FAFB	Overview of hydrogeology, drilling methodolgy, well construction, aquifer testing and analysis, water quality analyses	3 well logs, 1 pumping test, 1 groundwater quality sample	Yes; report methods discussion
22	CH2M HILL	Final Second Five-Year Review Report for Priority One and Two Sites, Fairchild Air Force Base, Washington	Report	Jun-08	7/28/2014	BAA	FAFB	Second five-year review of in-place remedies for 28 IRP sites at FAFB	Review of existing reports and documentation for each site	NA	No, report only provides a review of existing reports
23	Engineering and Geologic Resources, Inc.	Geohydrological Assessment for the Graham Road Mining and Disposal Site, Lined Limited Purpose Landfill, Spokane County, Washington	Report	Jul-93	7/28/2014	BAA	Medical Lake area near FAFB	Geohydrologic assessment based on existing information (water well reports, water rights), monitoring well installation, permeability testing, water quality testing	Site geology and groundwater summary, monitoring well installation, rock coring, groundwater levels, packer testing, slug testing, water quality testing, water balance, groundwater flow, water rights review	11 figures (1 cross-section, 1 hydrograph, 2 piezometric maps), 9 water well reports, 3 water right documents, 9 boring logs, 2 coring logs, 5 packer tests, 1 water quality sample	Yes; report methods discussion and Work Plan included
24	Olson, T. M. (MS Thesis)	The Geology and Groundwater Resources of Part of the Hangman and Marshall Creek Drainage Basins, Spokane County, Washington	Report	Winter 1975	7/28/2014	BAA	West Plains area	Summary of geology and groundwater resources, field check geologic map	Broad aspects of geology and hydrogeology discussed; general relationships of surface water/groundwater; poor and good groundwater resource potential delineated	1 plate (geology map and 4 cross-sections) MISSING, 312 water supply systems inventoried	Yes; report methods discussion
25	Sceva, J.E.	Ground Water in the Vicinity of Geiger Field, Spokane County, Washington	Report	1953	7/28/2014	BAA	Geiger Field/Spokane Airport area	Groundwater supply potential for the Capehard Project, Geiger Field	Review of existing wells onsite and offsite to determine the groundwater supply potential within the study area	4 plates (geologic map, hydrogeologic map, and 2 cross-sections), numerous well records but many locations are not accurate	No (does not include methods discussion)

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
26	Century West Engineering	Landfill Siting and Development, Spokane Regional Solid Waste Disposal Project, Environmental Impact Statement, Technical Report 5: Geology/Hydrology	Report	1989	7/28/2014	BAA	West Plains near Marshall, WA	Description of topography, geologic history, hydrogeology, aquifer characteristics, groundwater resource potential	Newly installed well logs, groundwater elevations from newly installed wells and private wells in the area, water quality data	5 well logs, water quality analyses	No; does not include methods discussion and report is missing supporting data
27	Pacific Groundwater Group	Marshall Landfill 2005 Hydrogeologic Summary	Report	23-Dec-05	8/4/2014	BAA	West Plains near Marshall, WA	Report provides a summary of VOC contamination within the basement, basalt, and sand aquifers at the Marshall Landfill site based on years of water quality data	Overview of geology, groundwater, VOC contamination and water quality, potential contamination of surrounding water users, and recommendations. Provides a detailed discussion of interconnectedness of the basement, basalt, and sand aquifers	18 data tables (mostly VOC summary for individual monitoring wells), 28 figures (3 cross-sections, 3 hydrographs)	No; report interprets previous geochemical results; results are located in an Equis database which is not included as part of this report
28	Land and Water Environmental Services, Inc.	Marshall Landfill, Ground Water Monitoring Results for November 2010, Fourth Quarter Event	Report	7-Jan-11	8/5/2014	BAA	West Plains near Marshall, WA	Quarterly groundwater quality sampling results for the Marshall Landfill	Results from sampling 3 domestic wells and 1 monitoring well in November 2010	1 round of water quality data for 3 domestic wells and 1 monitoring well. Water level measurements for 16 wells. Historical water quality and water level data attached.	Yes; report methods discussion and laboratory QA/QC sheets included
29	URS Corporation (URS)	Groundwater Investigation for Trichloroethene, Spokane County Raceway, Airway Heights, Washington	Report	10-Dec-11	8/5/2014	BAA	West Plains near Airway Heights, WA	Environmental investigation for the presence of TCE in groundwater at the Spokane County Raceway	Monitoring well installation (3 deep wells), groundwater monitoring (water levels and water quality) during two events	3 boring logs, geochemical and water level data for 3 monitoring wells, 4 groundwater contour maps	Yes; report methods discussion and laboratory QA/QC sheets included

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
30	Spokane County Water Resources	Spokane County Water Demand Forecast Model	Report	1-Jan-11	8/5/2014	BAA	Spokane County	Development and use of the Spokane County Water Demand Forecast Model	Demand model which forecasts the total water demand for the period 2008 to 2040 for Spokane County by water use sector, geographic location, and in time. Uses spatial, water use, historical weather, and agricultural data.	Numerous	Yes; model calibration and verification section
31	Spokane County Water Resources	Spokane County Water Demand Forecast Model, Model 3.0 and 2013 Forecast Update	Report	1-Jun-13	8/5/2014	BAA	Spokane County	Update to the existing Water Demand Forecast Model 2.0 and 2011 Water Demand Forecast	Model 3.0 and the 2013 Forecast utilize the latest demographic data, add the capability to evaluate consumptive and non-consumptive components, and adds the capability to determine how and where return flows reenter the hydrologic system	Numerous	No model calibration/verification sections but report does describe where data was mined from (existing county data, census)
32	Griggs, A.B. with D.A. Swanson/USGS	USGS Bulletin 1413 - The Columbia River Basalt Group in the Spokane Quadrangle, Washington, Idaho, and Montana	Report	1976	8/12/2014	BAA	NE corner of the Columbia Plateau near Spokane and Coeur D'Alene	Large-scale investigation of the CRBG in the Spokane Quad	Includes nomenclature, distribution, physical characteristics, thickness, source, age, deformation, petrography, chemistry, and landslide data for CRBG and Latah formation	27 petrographic samples, 26 chemical samples	Yes; refers to specific methods from other reports
33	Whiteman, K.J., J.J. Vaccaro, J.B. Gonthier, and H.H. Bauer/USGS	USGS Bulletin 1413-B - The Hydrogeologic Framework and Geochemistry of the Columbia Plateau Aquifer System, Washington, Oregon, and Idaho; Regional Aquifer-System Analysis (RASA) - Columbia Plateau, Washington-Oregon	Report	1994	8/12/2014	BAA	Columbia Plateau; WA, OR, ID	Large-scale RASA program study of the entire Columbia Plateau aquifer system	Describes the hydrogeologic framework, characteristics of the hydrogeologic units, the areas water budget, groundwater-surface water interaction, and water quality characteristics of the Columbia Plateau aquifer system	Summarizes numerous data from other sources and professional papers	Yes; report methods discussion

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
34	Hosterman, J.W./USGS	USGS Bulletin 1270 - Clay Deposits of Spokane County Washington; a geological, mineralogical, and chemical study	Report	1969	8/14/2014	BAA	Spokane County	Overview of clay deposits throughout Spokane County and their suitability for making clay products or as sources of alumina	Laboratory determination of mineralogy, chemical composition, and ceramic properties of clay from pre-Tertiary rock saprolite, CRBG saprolite, Latah Formation, and Palouse Formation samples from auger borings throughout Spokane County	At least 67 x-ray flourescence samples, 5 x-ray diffactometer traces, 3 thermal analysis curves	Yes; report methods discussion
35	Luzier, J.E. and R.J. Burt/USGS	USGS Water-Supply Bulletic No. 33 - Hydrology of Basalt Aquifers and Depletion of Ground Water in East-Central Washington	Report	1974	8/14/2014	BAA	All of East-Central Washington	Large-scale overview of the hydraulic characteristics of the basalt aquifers and the effects of present and projected pumping on the the long-term groundwater supply	Rate of groundwater level decline, summary of hydraulic properties (specific capacity, storage coefficient, transmissivity) based on well logs, pumpage based on electrical/power records (particularly in the Odessa and Pullman areas)	72 borehole geophysical logs (not included); 3 plates	Incomplete; logs used for interpretation are not included in report
36	Drost, B.W., K.J. Whiteman, and J.B. Gonthier/USGS	USGS Water-Resources Investigations Report 87-4238 - Geologic Framework of the Columbia Plateau Aquifer System, Washington, Oregon, and Idaho	Report	1990	8/14/2014	BAA	Columbia Plateau; WA, OR, ID	First step in development of a conceptual model of the Columbia Plateau regional aquifer flow system; continuation of RASA program	Development of 10 sheets including geologic map, structural features, thickness and altitude maps of the hydrogeologic units. Compiled from several existing reports. Large-scale 1:500,000 to 1:250,000 scale	2 general geologic cross-sections; 10 sheets (geology, structure, thickness and altitude maps). NOT included in document reviewed	Yes; references reports used for development of data sheets

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
37	Lane, R.C. and K.J. Whiteman/USGS	USGS Water Resources Inventory (WRI) Report 88-4018 - Ground-water Levels, Spring 1985, and Ground-water Level Changes, Spring 1983 to Spring 1985, in three Basalt Units Underlying the Columbia Plateau, Washington and Oregon	Report	1989	8/14/2014	BAA	Columbia Plateau; WA, OR, ID	Groundwater level contour maps for three basalt units of the Columbia Plateau regional aquifer system; continuation of RASA study	Groundwater levels from spring 1985 and changes in groundwater levels from 1983 to 1985 for three basalt units	Water levels from 1,105 wells measured in spring 1985; 4 sheets (1-text; 2-water levels in the Saddle Mountains unit; 3-water levels in the Wanapum unit; 4-water levels in the Grande Ronde unit)	No; water level data not included
38	Bauer, H.H. and A.J. Hansen, Jr./USGS	USGS Water-Resources Investigations Report 96-4106 - Hydrology of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho	Report	2000	8/14/2014	BAA	Columbia Plateau; WA, OR, ID	Development of a five-layer, three-dimensional numerical finite-difference groundwater model to simulate the Columbia Plateau regional groundwater flow system	Simulated and calibrated to water level data from 1983 to 1985 using a time-averaged steady-state approach. After the time-averaged model was calibrated, the predevelopment (1850's) and hypothetical future flow systems were simulated.	Input data derived from previous studies. Simulated groundwater discharge, recharge, and average streamflows for 21 drainage basins	Yes; detailed model methods and calibration section. Lists all references used.
39	Snyder, D.T. and J.V. Haynes	USGS Scientific Investigations Report 2010-5040 - Groundwater Conditions During 2009 and Changes in Groundwater Levels from 1984 to 2009, Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho	Report	2010	8/15/2014	BAA	Columbia Plateau; WA, OR, ID	Regional overview of groundwater conditions in spring 2009 used to interpolate the generalized groundwater elevations for each of the basalt hydrogeologic units and to provide information on regional flow	Groundwater levels from spring 2009 compared with levels from spring 1984 were used to make groundwater contour and groundwater change maps	Water levels from 1,752 wells measured in spring 2009; 9 plates showing water levels and water level changes	Yes; report methods discussion

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
40	Burns, E.R., D.S. Morgan, R.S. Peavler, and S.C. Kahle	USGS Scientific Investigations Report 2010-5246 - Three-Dimensional Model of the Geologic Framework for the Columbia Plateau Regional Aquifer System, Idaho, Oregon, and Washington	Report	2011	8/15/2014	BAA	Columbia Plateau; WA, OR, ID	Development of a three-dimensional geologic model of the Columbia Plateau to define the general aquifer system geometry for use in a regional numerical model	Data compiled from numerous databases and detailed studies	Stratigraphic interpretation of more than 13,000 wells	Yes; modeling methodology and workflow report discussion
41	Kahle, S.C., D.S. Morgan, W.B. Welch, D.M. Ely, S.R. Hinkle, J.J. Vaccaro, and L.L. Orzol	USGS Scientific Investigations Report 2011-5124 - Hydrogeologic Framework and Hydrologic Budget Components of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho	Report	2011	8/15/2014	BAA	Columbia Plateau; WA, OR, ID	Summary of existing hydraulic data and water budget components to be used in numerical model. Groundwater use estimated. Detailed description of Columbia Plateau.	Summarizes numerous existing data (hydraulic characteristics of the aquifer and stable isotope data), estimates water budget components (recharge, ET, groundwater use)	Summarizes numerous data from existing sources; difficult to quantify.	Yes; all sources are well documented
42	Burns, E.R., D.T. Snyder, J.V. Haynes, and M.S. Waibel	USGS Scientific Investigations Report 2012-5261 - Groundwater Status and Trends for the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho	Report	2012	8/15/2014	BAA	Columbia Plateau; WA, OR, ID	Compilation of well information and groundwater levels to develop a simple linear groundwater level trend map for 1968-2009. Data was used to identify barriers to groundwater flow and to determine groundwater level declines to be used in numerical model.	Water level data from 1968 to 2009	Full dataset included 60,000 wells and 450,000 water level measurements. Used a subset of 761 wells.	Yes; all sources are well documented
43	Kahle, S.C., T.D. Olden, and D.S. Morgan	USGS Scientific Investigations Map 3088 - Geologic Setting and Hydrogeologic Units of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho	Report	2009	8/15/2014	BAA	Columbia Plateau; WA, OR, ID	Updates the hydrogeologic framework for the CPRAS using available geologic mapping and well information to develop a digital, three-dimensional hydrogeologic model that could be used as the basis of a groundwater-flow model	Surficial geologic map, regional hydrogeologic sections and unit extent maps	Dataset of 2,523 wells	Yes; all sources are well documented

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
44	Spokane County Water Resources	Airport West	Compilation of Project Documents	Undated	9/16/2014	JER	West Plains	Document summarizing the work performed by Brown and Caldwell and GeoEngineers from 2006 to 2010.	Various, including draft reports, letters, memorandums, bibliography, and photographs.	Various	No
45	Budinger & Associates, Inc.	Results of Seismic Refraction Survey, Paleo-Channel Investigation, Airway Heights, Washington	Report	27-Apr-01	9/16/2014	JER	West Plains	Seismic refraction survey intended to delineate the Airport Paleochannel.	Seismic refraction data	9 seismic refraction lines	Yes, documentation of survey method and velocity interpretation
46	Michael, M.M, R.E. Derkey, and D.F. Stradling.	Preliminary Geologic Map of the Four Lakes and Spokane SW Quadrangles	Report	Jun-01	9/16/2014	JER	Western Spokane County, including the West Plains	Map, cross sections, and associated report describing distribution of geologic units within the study area.	Surficial geologic map, cross sections.	1 map, 2 cross sections	Yes, mapping method and geologic unit descriptions are included
47	Tetra Tech/KCM	Water Resource Inventory Area 54 (Lower Spokane) Watershed Plan, Phase 2, Level 1 Data Compilation and Technical Assessment	Report	Jan-07	9/16/2014	JER	WRIA 54, the Lower Spokane River Watershed	Data compilation and technical assessment of watershed characteristics	Data compilation, water balance and future demand analyses	Numerous data compilation figures and tables. Analytical results for water balance and future demand analyses.	Yes, results and methods descriptions provided
48	URS and Brown and Caldwell	Final Report, Stormwater Management Plan for the West Plains Planning Area	Report	Feb-03	9/16/2014	JER	West Plains	Stormwater Management Plan	Description of stormwater management alternatives and associated improvements	NA	Yes, methods description

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
49	Schuster, J.E.	Selected Papers on the Geology of Washington, Washington Division of Geology and Earth Resources Bulletin 77	Compilation of Geologic Publications	1987	9/17/2014	JER	State of Washington	A wide range of geologic publications and associated data	Various	Various	Yes, methods description for specific publications
50	Various	Numerous files within a database folder entitled Stormwater Utility West Plains Geology Documents that contain incomplete documentation, are draft/preliminary, or are intepretive/ subjective in nature. These include electronic files entitled the following: Ltr_Paleo Channel Update_Hamilton ~Sims_20070511_; Ltr_SIA~Sims_Airport SW Impacts Sleepy Hollow_20020418; Ltr_URS~Sims_20070707 _Prgrss Rprt; Ltr_URS~Sims_Drainage Impacts Sleepy Hollow_20000925; Ltr_WP Sims~Economic Development Alliance_20021115_ unsigned copy; Map_Basin_Figure X-X_URS; Map_Citizen Complaints Areas of Flooding Observed by County Staff_Figure 3-1_URS; Map_Contours_Woodward Clyde_20010419; Map_Existing Drng Probs Airport W~S StudyArea _BrownCaldwell _2008; Map_Major Roads~Topo_Sleepy Hollow_URS_ Fig 1; Map_Overburden Data Availability for West Plains Area_Figure X-X_URS; Map_Potential Opportunity Areas_Figure 4-1_URS; Map_Prelim Paleo Channel Map_Memo URS~Sims_20010413; Map_Preliminary Geologic of Airway Hts Spok NW Quadrangles, Spokane County_Derkey ~Hamilton~ Stradling; Map_Preliminary Geologic of Spok SW Four Lakes Quadrangles, SpokCo_ Derkey~Hamilton~Stradling; Map_Proposed SWSA Boundary Expansion_WP_Geiger Spur_20070320; Map_Spring 1999 Flooding in the WP Area_Figure 3-3_URS; Map_Structural Recommenda Airport West Srvc Area_Figure 4-1_URS; Map_Surface Contours~Drng Channels_Sleepy Hollow_URS Fig 3; Map_Surface Waters~Major Drng Patterns_SleepyHollow_ URS Fig 2; Map_SW Mgmt Opps in Airport W~S StudyArea_ BrownCaldwell_2008; Map_Water Well~Paleo Channel Locations 6-1-01; Map_Water Well~Paleo Channel Locations; Map_West Plains SW Mgmt Plan_Prelimin Alternatives for Drainage Improvements West Portion Planning Area_URS; Map_WP Planning Area_Figure 1-1_URS; Map_WP SW Mgmt Area_URS; Map_WP_W~SE Culv Locas_URS Fig 3-1; Memo_Little~BoCC_AirportWestUpdate_20070322; Memo_West Plains SW Mgmt Alternatives Analysis_20020708; Memo_WP SW Mgmt Plan_Evap Pond Sizing_20030430; Memo~Misc_Mtg Coord_Little_20080228; Nwsltr_2006; Nwsltr_Plainspoken_WP CoC_2002 Nov; Questionnaire Results_WP SW Mgmt Public Mtg_ 20010806; References_Airport West_GeoEng_undated; Report Draft_Existing Conditions Problems Opportunities WP SW Mgmt Planning Area_July 2000_URS; Report_draft_for BoCC from AdHoc~Sims_20020419; Report_Paleo Channel_Hamilton_20070511;	Compilation of letters and maps.	Various	9/16/2014	JER	West Plains	Misc. files	NA	NA	NA
51	Unknown	SRHD Specific Capacity.xlsx	Dataset	Unknown	8/15/2014	BAA	West Plains	Excel spreadsheet containing parcel ID, geographic coordinates, drawdown, pumping rate, and specific capacity data	Specific capacity and location data	157 specific capacity results	No

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
52	Unknown	Craig Rd Landfill Data (Directory)	Dataset	Unknown	8/29/2014	BAA	FAFB	Misc. files	2 GIS shapefiles containing well locations (no metadata): 'CRL wells' shapefile contains aquifer and name only, 'AH wells' shapefile contains InService Y or N; 1 cross-section image/figure; 1 site plan figure; 1 water level data Excel spreadsheet; 1 misc. PDF file with files from multiple projects	2 shapefiles, 1 cross-section image, 1 site plan, 1 water level data spreadsheet, 1 misc. PDF	No
53	McCollum (?)	24k_mccollum_quads.gdb (Directory)	Dataset	Unknown	8/29/2014	BAA	West Plains	GIS file geodatabase	3 shapefiles covering 9 geologic quads; gline, gunitl, gunitp	3 shapefiles	Yes but possibly erroneous, metadata refers to Snoqualmie Quad
54	Unknown	Deep Coulee Seepage Run (Directory)	Dataset	Unknown	8/29/2014	BAA	West Plains	GIS point and polyline shapefiles	Previous Data Collection Sites' shapefile includes study, site name, sample date, and flow; 'Seepage Run Points' shapefile includes location ID, elevation and flow; 'Deep Creek Seepage Run' and 'Coulee Creek Seepage Run' shapefiles include gain/loss and length data	4 shapefiles	No
55	Deobold (?)	Deobold West Plains GIS Files (Directory)	Dataset	Unknown	8/29/2014	BAA	West Plains	GIS data	GIS polyline files digitizing the following figures from Deobold 1995; Surface Geology - Fig 6; Thickness of Overburden - Fig 10; Elev. Of the top of the Grande Ronde - Fig 13; Elev. Of the top of the Wanapum - Fig 14; Potentiometric Surface Map of the Grand Ronde - Fig 20; and Potentiometric Surface Map of the Wanapum Aquifer - Fig 22	6 polyline files, 1 polygon files	Yes; contains wp_metadata.doc file

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
56	Unknown	Deep Percolation Model (Directory)	Dataset	Unknown	9/2/2014	MSA/BAA	West Plains	GIS point and polygon shapefiles, also includes excel spreadsheets "landuse key" and "soil properties worksheet"	DPM Model points - points w/aspect, points w/elevation, points w/land use, points w/precip, points w/slope, points w/soil, weather stations polygons - avg annual recharge, DPM Model Cells	8 point / 2 polygon shapefiles	No
57	Pritchard, McCollum (?)	Faults, Pritchard McCollum 2012 (Directory)	Dataset	Unknown	9/2/2014	MSA/BAA	West Plains	GIS polyline shapefiles of faults	5 shapefiles polylines - fig1_joint_system, fig1_spokane faults, Jumpoff_Joe_Fault, Needham_fault, St_Joe_fault	5 polyline shapefiles	No
58	Unknown	Geochemistry (Directory)	Dataset	Unknown	9/2/2014	MSA/BAA	West Plains	GIS point shapefile basltgeochempts_83_S_harn.shp and excel spreadsheets	GIS - point file with BSAMP_LOC, X & Y fields excel - 23 samples_2010, all-bchem2010_RESULTS_6-30, Pritchard XRF results for WRIA 54 2012-2013, W54-56 2012 age dating chem data from SCD	1 point shapefile, 4 excel spreadsheets	No
59	Unknown	Grande Ronde-Wanapum GW contours (Directory)	Dataset	Unknown	9/2/2014	MSA/BAA	West Plains	GIS polyline shapefiles of gw contours	Grande Ronde Contours, Wanapum Contours (includes WLE_spro field)	2 polyline shapefiles	No
60	Unknown	Grande Ronde Flow Member Contours (Directory)	Dataset	Unknown	9/2/2014	MSA/BAA	West Plains	GIS polyline shapefiles of gw contours	Points (with elevation, sample loc, thickness, and misc. fields - Sentinel_Bluff_Pts and Wapshilla_Ridge_Pts)	2 poly line shapefiles (contours) and 2 point shapefiles	No
61	City of Airway Heights / Blue Star Enterprises NW	Misc pumping test info (Directory)	Dataset	10/18/2012	9/2/2014	MSA/BAA	City of Airway Heights/West Plains	pdf of a single water well report	pdf of water well report containing well construction and pumping test data	1 page pdf water well report	Yes; details included on well log

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
62	Pritchard	Paleodrainage Contours, Pritchard 2013 (Directory)	Dataset	2013	9/2/2014	MSA/BAA	West Plains	GIS polyline shapefiles	Contours_18June2013, GeneralPaleodrainageBoundary_18June2013	2 polyline shapefiles	No
63	Various	Water Level Data (Directory)	Dataset	Various	9/2/2014	MSA/BAA	West Plains	Excel spreadsheets and pdfs	Excel spreadsheets: 24n40e_03, 24N24E_25G01D1, Consolidated West Plains WL Data, Craig Rd Landfill WL Data from CH2M Hill, Eastern State Hospital Well Levels 2009 and 2010, Four Lkaes WL data, Medical Lk Craig Rd well, SCD wells, Sceva Report hydrograph data, well 472535 Additional WL data, West Plains continuous Monitioring Data, West Plains GW Elevation data in report, West Plains Obs Well from ECY to 7-13. PDFs: Spokane County Raceway Park GW Elevation Data - Jan 2013, Spokane County Raceway Park Well Map	13 excel spreadsheets, 2 pdfs	No
64	Unknown	West Plains Geologic Database Project - Rockworks (Directory)	Dataset	Unknown	9/2/2014	MSA/BAA	West Plains	Rockworks database (mdb), maps/images (pdf/jpeg, etc.), .grd files, KML (google earth)	GE database contains points used in Rockworks project; points include total depth, lithology, water level information, etc.	Multiple miscellaneous Rockworks and image/pdf files, West Plains Geologic Rockworks database, many .grd files within "USGS GeoModel"	No

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
65	Unknown	West Plains Hydrogeologic Database Raster Data Set (Directory)	Dataset	Unknown	9/2/2014	MSA/BAA	West Plains	GIS polyline and rasters	Basement contours and rasters of unit thickness, water levels and unit top elevations	1 polyline shapefile, 15 raster files (bsmt_tp, gnrnd_top, grnrnd_thk, grdrnd_yld, grrd_wl_elev, lw_latah_thk, lw_latah_top, uncs_thk, uncs_top, up_latah_thk, up_latah_top, wanapum_yld, wanapum_wl_elev, wnpm_thk, wnpm_top)	No
66	Unknown	West Plains Water Level Monitoring (Directory)	Dataset	Unknown	9/5/2014	MSA/BAA	West Plains	GIS point shapefiles	Depth to water, water level, and synoptic data	3 point shapefiles - Deobald_DTW_Data, Deobald_West_Plains_WL_Measurements, West_Plains_Synoptic_Data	No
67	Unknown	WP Climate data (Directory)	Dataset	Unknown	9/5/2014	MSA/BAA	West Plains	csv, txt files, and exel spreadsheets	Contains climate data in txt files or excel spreadsheets for: (Climate Reference Network Station - Spokane, Davenport-Ag, Green Bluff-Ag, MesoWest-Cheney, MesoWest-FAFB, MesoWest-Medical Lake, MesoWest-Reardan, MesoWest-Spokane Airport, NWS Station-Rambo Rd, 2010-2011 Data, NWS Rambo Rd 1996-2012, NWS Spokane Airport 1996-2012	Numerous	No

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
68	Unknown	gw_elevation_study_area (multiple GIS files)	Dataset	Unknown	9/5/2014	MSA/BAA	West Plains	GIS Dataset	Single GIS polygon shapefile	1 shapefile containing unknown "study area"	No
69	McCollum (?)	McCollum basement outcrop, McCollum basement outcrop_poly (multiple GIS files)	Dataset	Unknown	9/5/2014	MSA/BAA	West Plains	GIS Dataset	McCollum Basement Outcrop (polyline and polygon)	1 polyline and 1 polygon shapefile	No
70	Unknown	modified_Deobald_Paleochannel (multiple GIS files)	Dataset	Unknown	9/5/2014	MSA/BAA	West Plains	GIS Dataset	modified_Deobald_Paleochannel polyline shapefile	1 polyline shapefile	No
71	Unknown	Seepage Run Data Analysis.xlsx	Dataset	Unknown	9/7/2014	MSA/BAA	West Plains	Excel Spreadsheet	Seepage run data; contains several sheets of location, elevation, and flow data gain/loss, length, beg/end elevation, river reach, etc.	Data for 16 reaches along Deep Creek and 6 reaches along Coulee Creek	No
72	Unknown	West Plains Hydrogeologic Database 10-24-13.xlsx	Dataset	Unknown	9/7/2014	MSA/BAA	West Plains	Excel Spreadsheet	Borehole data; contains several sheets of location, aquifer, well construction, stratigraphy, and lithology data for numerous wells	Numerous	No
73	Unknown	West Plains Study Area Water demand.xlsx	Dataset	Unknown	9/7/2014	MSA/BAA	West Plains	Excel Spreadsheet	Water demand data; contains sheets of non-consumptive and consumptive water use data and water demand forecasts	Numerous	No
74	Unknown	WP Rockworks 9-16-13 (multiple GIS files)	Dataset	Unknown	9/7/2014	MSA/BAA	West Plains	GIS Dataset	Single GIS point shapefile containing location and comments (gpm, etc.)	1380 points	No
75	Derkey, R.F, M.M. Hamilton and D.F. Stradling	Geologic Map of the Airway Heights 7.5-minute Quadrangle, Spokane County, Washington	Map	2004	9/24/2014	JER	Central Portion of West Plains	Geologic Map	Surficial geologic map;geologic cross sections	One surficial geologic map and two geologic cross-sections	Attached to map

Bibliography Identification	Author	Report/Dataset Title	Report, Dataset, or Map	Date	Date Screened	Reviewer	Geographic Area	Type of Report/Dataset	Data Type	Data Quantity	Dataset Documentation
76	Hamilton, M.M., R.F. Derkey, and D.F. Stradling	Geologic Map of the Four Lakes 7.5-minute Quadrangle, Spokane County, Washington	Map	2004	9/24/2014	JER	South Portion of West Plains	Geologic Map	Surficial geologic map;geologic cross sections	One surficial geologic map and two geologic cross-sections	Attached to map
77	Derkey, R.F and M.M. Hamilton	Geologic Map of the Four Mound Prairie 7.5-minute Quadrangle, Spokane and Stevens Counties, Washington	Map	2007	9/24/2014	JER	North Portion of West Plains	Geologic Map	Surficial geologic map;geologic cross sections	One surficial geologic map and four geologic cross-sections	Attached to map
78	Derkey, R.F, M.M. Hamilton and D.F. Stradling	Geologic Map of the Nine Mile Falls 7.5-minute Quadrangle, Spokane and Stevens Counties, Washington	Map	2003	9/24/2014	JER	Northeast Portion of West Plains/Northwest Spokane County	Geologic Map	Surficial geologic map;geologic cross sections	One surficial geologic map and two geologic cross-sections	Attached to map
79	Derkey, R.F, M.M. Hamilton and D.F. Stradling	Geologic Map of the Spokane Northwest 7.5-minute Quadrangle, Spokane County, Washington	Map	2004	9/24/2014	JER	East Portion of West Plains	Geologic Map	Surficial geologic map;geologic cross sections	One surficial geologic map and two geologic cross-sections	Attached to map
80	Hamilton, M.M., R.F. Derkey, and D.F. Stradling	Geologic Map of the Spokane Southwest 7.5-minute Quadrangle, Spokane County, Washington	Map	2004	9/24/2014	JER	Southeast Portion of West Plains	Geologic Map	Surficial geologic map;geologic cross sections	One surficial geologic map and two geologic cross-sections	Attached to map
81	Unknown	Various Geologic Maps attributed to EWU, including maps entitled; Deep Creek Quadrangle; Edwall and Waukon Quadrangles; Little Falls and Long Lake Quadrangles; Medical Lake and Four Lakes Quadrangles; and Reardan East and Reardan West Quadrangles. An accompanying file entitled "Unit descriptions used on the quadrangle maps submitted by EWU" appears to provide a Legend for these maps.	Map Compilation	Undated	9/24/2014	JER	Various portions of the West Plains	Geologic Maps	Surficial geologic maps	Five surficial geologic maps	None

Acronyms:
CRBG = Columbia River Basalt Group
CRPAS = Columbia River Plateau Aquifer System
DPM = Deep Percolation Model
FAFB = Fairchild Air Force Base
GIS = Geographic Information System
NA = Not Applicable
NDMA = N-Nitrosodimethylamine
NOAA = National Oceanic and Atmospheric Administration
NWS = National Weather Service
QA/QC = Quality Assurance/Quality Control
QAPP = Quality Assurance Project Plan
RASA = Regional Aquifer System Analysis
TCE = Trichloroethylene
TEM = Transmission Electron Microscopy
USDA = U.S. Department of Agriculture
USGS = U.S. Geological Survey
VOC = Volatile Organic Compound
WRIA = Water Resource Inventory Area

Table B-2

Summary Spreadsheet - Review Results

Quality Assurance/Quality Control Review of Project Reports and Datasets

West Plains Hydrogeological Framework Project
Spokane County, Washington
GeoEngineers Project No. 0188-162-00

Bibliography Identification	Author	Report/Dataset Title	Relevance	Basis for Relevance	Apparent Credibility	Basis for Credibility	Suitability Result	Basis for Suitability	Report-Identified Gaps	Comments
1	McCollum, L.B. and M.M. Hamilton	West Plains Delineation of Aquifer Zones Within Basalt Formations Project, WRIA 54 –Lower Spokane	Yes	Contains geologic information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, stratigraphic interpretation is unique.	NA	
2	Pritchard, Chad	Pritchard XRF Results for WRIA 54 2012-2013.xlsx	Yes	Contains geochemical data and stratigraphic interpretation specific to West Plains	Uncertain	Could not locate associated QAPP or metadata	No	Relevant; uncertain credibility	NA	Data deficiency could be corrected through research regarding data origin and procedures.
3	McCollum, M.B. and C.J. Pritchard	WRIA 54 Delimiting geologic structures affecting water movement and flow direction of the CRBG West Plains aquifer	Yes	Contains structural geologic information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, structural interpretation is unique.	NA	
4	C.J. Pritchard	Summary for Spokane County WRIA 54 2012-2013, Subsurface Projection of the Stratigraphy of the Columbia River Basalt Group and Paleodrainages in the West Plains Area	Yes	Contains geologic information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, stratigraphic interpretation is unique.	NA	
5	Northwest Land & Water, Inc.	West Plains (WRIA 54) & Lower Hangman Creek Watershed (WRIA 56), Hydrogeologic Characterization & Monitoring Well Drilling, Final Report	Yes	Contains geochemical data and stratigraphic interpretation specific to West Plains	Yes	Water quality data associated with QAPP and QA/QC evaluated by author	Yes	Nomenclature is contemporary, stratigraphic interpretation is unique, data appear credible.	Yes - 11 recommendations related to additional data collection, analyses, and planning	
6	Spokane Co. Water Resources, McCollum, L.B. and M. Hamilton	West Plains Hydrogeologic Database; Prepared for: WRIA 54 Watershed Implementation Team	Yes	Contains geologic and hydrogeologic information specific to West Plains	Yes	Data review included multiple levels of QA/QC prior to inclusion into dataset	Yes	Nomenclature is contemporary, stratigraphic interpretation is unique, data appear credible.	Recommended next steps include collection of current groundwater data including groundwater and geochemical data	Dataset includes well data from two USGS data sets: Columbia Plateau Regional Aquifer System Analysis and USGS National Water Information Systems
7	Spokane Co. Water Resources	West Plains Hydrogeology, Groundwater Recharge Estimate	Yes	Contains groundwater recharge information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, hydrogeologic data (recharge estimates) are unique, input values acquired from reliable sources (USGS, NOAA, USDA, NWS, etc.). DPM developed by USGS.	No	
8	Spokane Co. Water Resources	West Plains Hydrogeology, West Plains Groundwater Elevation Monitoring and Mapping	Yes	Contains groundwater level information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, groundwater level data is unique (some data from other sources), interpretation is unique, data appear credible. Water level monitoring QAPP approved by Ecology; could not locate associated QAPP, likely to be in Spokane Co. files.	No	Ask Spokane County for QAPP
9	Golder Associates	West Plains Geophysical Orientation Survey Feasibility Report	Yes	Contains geophysical and geologic information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, stratigraphic interpretation is unique. Geophysical orientation QAPP found online at Spokance County	No	
10	Water & Natural Resource Group, Inc. and GSI Water Solutions, Inc.	Groundwater Level Gauging Project Lower Lake Roosevelt Watershed (WRIA 53), Northern Lincoln County, Washington	No	Not specific to West Plains; contains geologic and hydrogeologic information for WRIA 53 located adjacent to the West Plains area	Yes	Field data collected under a project QAPP.	No	Does not include information specific to the West Plains	Monitoring period too brief to observe long-term water level trends, need to continue monitoring for several years.	File directory includes monitoring memo and report, 4 plates and 3 attachments. Report contains hydrogeologic data but is not specific to the West Plains area

Bibliography Identification	Author	Report/Dataset Title	Relevance	Basis for Relevance	Apparent Credibility	Basis for Credibility	Suitability Result	Basis for Suitability	Report-Identified Gaps	Comments
11	Deobald, W.B. and J.P. Buchanan	Hydrogeology of the West Plains Area of Spokane County, Washington	Yes	Contains geologic and hydrogeologic information specific to West Plains	NA	NA	Yes	Relevant; unique data	No	Data deficiency could be corrected through research regarding data origin and procedures.
12	Spokane Co. Water Resources	West Plains Hydrogeology, Deep Creek and Coulee Creek Groundwater/Surface Water Interaction	Yes	Contains groundwater/surface water interaction data specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, seepage run data are unique, interpretation is unique, field work conducted according to QAPP approved by Ecology.	No	
13	Durham, F.E. (MS Thesis)	Geology and Hydrogeology of Eastern Lincoln County, Washington	No	Not specific to West Plains; contains geologic and hydrogeologic information for Eastern Lincoln County located west of the West Plains area	Uncertain	No discussion of QA/QC	No	Does not include information specific to the West Plains	Author suggests refinement of mapping of groundwater levels	Thesis uses and summarizes existing data. Unique data (recharge zone maps for Wanapum Basalt aquifers and maps of upper surface of Wanapum Basalt) are not included in the documents reviewed.
14	Gilmour, E.H. and M. Bacon	Groundwater Resources and Potential Sewage Pollution in Southern Spokane County	No	Not specific to West Plains	Yes	Detailed discussion of sampling and analytical techniques	No	Not specific to West Plains, geologic/CRBG nomenclature is not contemporary.	Other parts of study will be presented in separate papers	Study area is not West Plains but nearby
15	Siems, Barbara A.	Stratigraphic Identification and Correlation of Basalt Aquifers Using Geophysical and Chemical Techniques	No	Not specific to West Plains, geologic/CRBG nomenclature is not contemporary	NA	NA	No	Not specific to West Plains, geologic/CRBG nomenclature is not contemporary, describes results as preliminary	No	
16	Olson, T.M., E.H. Gilmour, M. Bacon, J.L. Gaddy, G.R. Robinson, O.J. Parker	Geology, Groundwater, and Water Quality of Part of Southern Spokane County, Washington	Yes	Contains geologic and hydrogeologic information specific to West Plains	Yes	Detailed discussion of sampling and analytical techniques	Yes	Contains information specific to West Plains; bacteria and chemical data are unique	No	General discussion of basement rock, Latah Formation and CRBG, Palouse Formation, and other unconsolidated material
17	Science Applications International Corp. (SAIC)	Remedial Investigation Report, Craig Road Landfill (CRL), Fairchild Air Force Base (FAFB)	Yes	Contains geologic and hydrogeologic information specific to West Plains	Yes	Detailed discussion and documentation of QA/QC and validation procedures	Yes	Contains information specific to West Plains; nomenclature is contemporary, stratigraphic interpretation is unique, data appear credible	No	Report located in 'Craig Rd Landfill' Directory. Contains information regarding alluvial channels
18	Science Applications International Corp. (SAIC)	Feasibility Study Report, Craig Road Landfill (CRL), Fairchild Air Force Base (FAFB)	Yes	Contains geologic and hydrogeologic information specific to West Plains; FS portion of RI/FS for the landfill. Unique data is included in RI but FS is still relevant	Yes	Based on information from RI report	Yes	Contains information specific to West Plains; this report is the FS portion of the RI/FS for the landfill. Unique data is included in RI but the FS is still relevant	No	Report located in 'Craig Rd Landfill' Directory
19	Ecology and Environment, Inc.	Removal Evaluation Report, Euclid Road TCE Monitoring Site, Reardan, Washington	Yes	Contains environmental data specific to the West Plains area	Yes	Detailed discussion and documentation of QA/QC and validation procedures	Yes	Contains groundwater level/flow direction data specific to West Plains; data appear credible	No	No geologic information but does contain groundwater flow direction data
20	Jones, F. O.	Evaluation of Water Supply for the Proposed Indian Village Estates Development, Indian Prairie, Spokane County, Washington	Yes	Contains geologic and groundwater supply data specific to West Plains	NA	NA	Yes	Contains general geologic and groundwater information specific to West Plains; field checked well locations and interviews with homeowners	No	Interpretation of 36 wells based on interviews with owners. Interesting historical groundwater occurrence information

Bibliography Identification	Author	Report/Dataset Title	Relevance	Basis for Relevance	Apparent Credibility	Basis for Credibility	Suitability Result	Basis for Suitability	Report-Identified Gaps	Comments
21	URS	Analysis of Potable Water System, Fairchild Air Force Base, Washington; Appendix F and Test Logs	Yes	Contains geologic, hydrogeologic, and water chemistry information specific to West Plains	Yes	Laboratory QA/QC sheets	Yes	Contains information specific to West Plains; discussion of hydraulic testing methods appears consistent with standard of practice.	Author recommends conducting longer term pumping test to define aquifer leakage and short-term safe yield of aquifer	Documents located in 'FAFB Analysis of Potable Water System, URS 2004' Directory. Documents include Appendix F only; the rest of the report is not included in database
22	CH2M HILL	Final Second Five-Year Review Report for Priority One and Two Sites, Fairchild Air Force Base, Washington	Yes	Contains environmental data specific to the West Plains area	Yes	EPA review	No	Contains information specific to West Plains; environmental data appear credible but does not contain unique data, report provides a summary of previous reports and data	Issues and recommendations described for each site	Does not contain unique data, report provides a summary of previous reports and work
23	Engineering and Geologic Resources, Inc.	Geohydrological Assessment for the Graham Road Mining and Disposal Site, Lined Limited Purpose Landfill, Spokane County, Washington	Yes	Contains geologic and hydrogeologic information specific to West Plains	Yes	Assessment performed in accordance with Work Plan, approved by Ecology.	Yes	Contains information specific to West Plains; hydraulic testing, water quality, and groundwater level data appear suitable and compliant with Work Plan	No	Page 18 describes 2 aquifers present which merge into one across the site.
24	Olson, T. M. (MS Thesis)	The Geology and Groundwater Resources of Part of the Hangman and Marshall Creek Drainage Basins, Spokane County, Washington	Yes	Contains geologic and hydrogeologic information specific to West Plains	NA	NA	Yes	Same information as ID No. 16 without water quality data. Contains information specific to West Plains. No unique data but interpretation of well logs is unique. Includes discussion of well location procedure.	No	Essentially the same document as ID No. 16 without the bacterial analyses. Missing Plate 1.
25	Sceva, J.E.	Ground Water in the Vicinity of Geiger Field, Spokane County, Washington	Yes	Contains geologic and hydrogeologic information specific to West Plains; review of existing well logs	NA	NA	Yes	Contains geologic and groundwater information specific to West Plains; stratigraphic interpretation is unique	No	Report completed by State Geological Survey based on existing well logs. Indicates none of the basalt layers are under artesian pressure; also states that there is a continuous loss of water from the upper basalt layers to the lower layers
26	Century West Engineering	Landfill Siting and Development, Spokane Regional Solid Waste Disposal Project, Environmental Impact Statement, Technical Report 5: Geology/Hydrology	Yes	Contains geologic and hydrogeologic information specific to West Plains	No	Not credible as is; missing supporting data and associated methods discussion	No	Report is missing data, figures, and other elements of the report.	No	Key portions of report are missing, begins at Section 3 and does not include Appendix D with aquifer test data. Refers to occurrence of alluvial channels. Data deficiency could be corrected through research regarding data origin and procedures.
27	Pacific Groundwater Group	Marshall Landfill 2005 Hydrogeologic Summary	Yes	Summarizes geochemical data and provides a hydrogeologic interpretation of the site, which is specific to West Plains	Uncertain	Report reviews and summarizes data collected in previous studies	Yes	Nomenclature is contemporary; stratigraphic interpretation is uniqe (modified earlier work); groundwater contamination interpretation is unique	Yes; Authors recommend replacing/installing additional monitoring wells, conducting hydraulic conductivity testing, conducting a geophysical survey	Does not contain unique data but does provide a unique interpretation of existing data
28	Land and Water Environmental Services, Inc.	Marshall Landfill, Ground Water Monitoring Results for November 2010, Fourth Quarter Event	Yes	Contains geochemical and water level data specific to West Plains	Uncertain	No QAPP referenced but water quality monitoring is being conducted with approval from Ecology and Spokane County	Yes	Water quality data appear credible, laboratory data sheets are included, sampling conducted with approval from Ecology and Spokane County	No	

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29	URS Corporation (URS)	Groundwater Investigation for Trichloroethene, Spokane County Raceway, Airway Heights, Washington	Yes	Contains geochemical and water level data specific to West Plains	Uncertain	No QAPP referenced but water quality monitoring is being conducted with approval from Ecology and Spokane County	Yes	Water quality data appear credible, laboratory data sheets are included, sampling conducted with approval from Ecology and Spokane County	No	File directory includes report, a table, and water level contour map from January 2013
30	Spokane County Water Resources	Spokane County Water Demand Forecast Model	Yes	Contains water demand and forecast data (water use, weather, land use, etc) specific to West Plains	NA	NA	Yes	Unique analyses. Model calibration and verification procedures documented, County oversight and review.	No	
31	Spokane County Water Resources	Spokane County Water Demand Forecast Model, Model 3.0 and 2013 Forecast Update	Yes	Contains water demand and forecast data (water use, weather, land use, etc) specific to West Plains	NA	Model update; model calibration and verification procedures documented in previous report	Yes	Unique analysis. Model update; model calibration and verification procedures documented in previous report.	No	
32	Griggs, A.B. with D.A. Swanson/USGS	USGS Bulletin 1413 - The Columbia River Basalt Group in the Spokane Quadrangle, Washington, Idaho, and Montana	Yes	Contains CRBG petrographic and chemical data for the entire Spokane Quadrangle; is not specific to West Plains and nomenclature is not contemporary	Yes	Completed by USGS, references data from other professional papers	No	Petrographic and chemical data appear credible, however the report is large-scale and not specific to West Plains, nomenclature is not contemporary	No	Data are not specific to West Plains but may be useful in providing regional scale information
33	Whiteman, K.J., J.J. Vaccaro, J.B. Gonthier, and H.H. Bauer/USGS	USGS Bulletin 1413-B - The Hydrogeologic Framework and Geochemistry of the Columbia Plateau Aquifer System, Washington, Oregon, and Idaho; Regional Aquifer-System Analysis (RASA) - Columbia Plateau, Washington-Oregon	Yes	Contains hydrogeologic data for the entire Columbia Plateau aquifer system; is not specific to West Plains	Yes	Completed by USGS, references data from other professional papers	No	Data appear credible, interpretation is unique, however the report is very large-scale and not specific to West Plains	No	Data are not specific to West Plains but may be useful in providing regional scale information
34	Hosterman, J.W./USGS	USGS Bulletin 1270 - Clay Deposits of Spokane County Washington; a geological, mineralogical, and chemical study	Yes	Contains chemical and mineralogical data for clays within Spokane County, including West Plains	Yes	Sampling and laboratory methods described in detail, completed by USGS, references data from other professional papers	Yes	Data appear credible, interpretation is unique	No	Data are tangentially relevant to the hydrogeologic framework of West Plains
35	Luzier, J.E. and R.J. Burt/USGS	USGS Water-Supply Bulletic No. 33 - Hydrology of Basalt Aquifers and Depletion of Ground Water in East-Central Washington	Yes	Contains hydrogeologic/water level data for the entire Columbia Plateau aquifer system but is not specific to West Plains	NA	NA	No	Does not use contemporary stratigraphic nomenclature. Potentiometric levels represent composite levels. Interpretation is unique, however, supporting data are missing.	No	
36	Drost, B.W., K.J. Whiteman, and J.B. Gonthier/USGS	USGS Water-Resources Investigations Report 87-4238 - Geologic Framework of the Columbia Plateau Aquifer System, Washington, Oregon, and Idaho	No	Contains hydrogeologic data for the entire Columbia Plateau aquifer system but is not specific to West Plains	NA	NA	No	Interpretation is unique, however, the study is very large-scale and not specific to West Plains. Data sheets are not included in document reviewed	At the large compilation scales and relatively low well density, geologic structures tend to be very generalized, and smaller structures can be missed entirely.	Very little information specific to West Plains but may be useful in providing regional scale information. Deficiency could be corrected by obtaining relevant data sheets.

Bibliography Identification	Author	Report/Dataset Title	Relevance	Basis for Relevance	Apparent Credibility	Basis for Credibility	Suitability Result	Basis for Suitability	Report-Identified Gaps	Comments
37	Lane, R.C. and K.J. Whiteman/USGS	USGS Water Resources Inventory (WRI) Report 88-4018 - Ground-water Levels, Spring 1985, and Ground-water Level Changes, Spring 1983 to Spring 1985, in three Basalt Units Underlying the Columbia Plateau, Washington and Oregon	No	Contains water level data for the entire Columbia Plateau aquifer system but is not specific to West Plains	NA	NA	No	Interpretation is unique, however, the study is very large-scale and not specific to West Plains. Completed by USGS, though data are not included, methods are not referenced.	No	File directory includes 4 plates. Data are not specific to West Plains but may be useful in providing regional scale information. Deficiency could be corrected by obtaining relevant data.
38	Bauer, H.H. and A.J. Hansen, Jr./USGS	USGS Water-Resources Investigations Report 96-4106 - Hydrology of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho	No	Contains hydrogeologic/water level data for the entire Columbia Plateau aquifer system but is not specific to West Plains	NA	NA	Yes	Groundwater model and simulation data are unique, however, the study is very large-scale and not specific to West Plains. Model verification and calibration documented; describes model reliability and sensitivity.	Yes; Verification data was not available for several aquifer units and variables. The model resulted in lateral and vertical K values that were not evident in the specific capacity data	Data are not specific to West Plains but may be useful in providing regional scale information
39	Snyder, D.T. and J.V. Haynes	USGS Scientific Investigations Report 2010-5040 - Groundwater Conditions During 2009 and Changes in Groundwater Levels from 1984 to 2009, Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho	No	Contains hydrogeologic/water level data for the entire Columbia Plateau aquifer system but is not specific to West Plains	NA		Yes	Interpretation is unique, however, the study is very large-scale and not specific to West Plains. Includes database of wells used in study.	Yes; Additional monitoring would better define the response of the groundwater system to stresses such as pumping, irrigation, and climate	File directory includes report, plates, and well database. Data are not specific to West Plains but may be useful in providing regional scale information
40	Burns, E.R., D.S. Morgan, R.S. Peavler, and S.C. Kahle	USGS Scientific Investigations Report 2010-5246 - Three-Dimensional Model of the Geologic Framework for the Columbia Plateau Regional Aquifer System, Idaho, Oregon, and Washington	Yes	Contains hydrogeologic/water level data for the entire Columbia Plateau aquifer system but is not specific to West Plains	NA	NA	Yes	Groundwater model and simulation data are unique, however, the study is very large-scale and not specific to West Plains. Detailed description of methodology and model development; results were analyzed numerically and visually for fit.	No gaps identified but the limitations of the model were discussed	File directory includes report and 7 figure documents. Data are not specific to West Plains but may be useful in providing regional scale information
41	Kahle, S.C., D.S. Morgan, W.B. Welch, D.M. Ely, S.R. Hinkle, J.J. Vaccaro, and L.L. Orzol	USGS Scientific Investigations Report 2011-5124 - Hydrogeologic Framework and Hydrologic Budget Components of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho	Yes	Contains hydrogeologic/water level data for the entire Columbia Plateau aquifer system but is not specific to West Plains	NA	NA	Yes	Interpretation is unique, however, the study is very large-scale and not specific to West Plains. Detailed discussion of data used and process used to calculate water budget components, etc.	No	File directory includes report and 16 figure documents. Data are not specific to West Plains but may be useful in providing regional scale information
42	Burns, E.R., D.T. Snyder, J.V. Haynes, and M.S. Waibel	USGS Scientific Investigations Report 2012-5261 - Groundwater Status and Trends for the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho	Yes	Contains hydrogeologic/water level data for the entire Columbia Plateau aquifer system but is not specific to West Plains	NA	NA	Yes	Interpretation is unique, however, the study is very large-scale and not specific to West Plains. Methods discussion and data sources are well documented.	No	Method of identifying aquifers with similar water levels and trends may be useful in understanding the geometry of local and regional aquifers
43	Kahle, S.C., T.D. Olden, and D.S. Morgan	USGS Scientific Investigations Map 3088 - Geologic Setting and Hydrogeologic Units of the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho	Yes	Contains hydrogeologic/water level data for the entire Columbia Plateau aquifer system but is not specific to West Plains	NA	NA	Yes	Interpretation is unique, however, the study is very large-scale and not specific to West Plains. Data sources are well documented.	No	Data are not specific to West Plains but may be useful in providing regional scale information

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44	Spokane County Water Resources	Airport West	Yes	Contains original figures and cross sections depicting geologic/hydrogeologic features within the West Plains	NA	NA	Yes	Figures and cross-sections are unique and could be instructive. However, there is abundant extraneous information.	No	
45	Budinger & Associates, Inc.	Results of Seismic Refraction Survey, Paleo-Channel Investigation, Airway Heights, Washington	Yes	Contains unique geophysical data specific to the West Plains	NA	NA	Yes	Contains unique data and interpretation specific to the West Plains. Identification of paleochannel boundaries is an objective of the current study.	Yes, subsurface exploration and down-gradient investigation	
46	Michael, M.M, R.E. Derkey, and D.F. Stradling.	Preliminary Geologic Map of the Four Lakes and Spokane SW Quadrangles	Yes	Contains original geologic mapping, study area contains the West Plains	NA	NA	Yes	Nomenclature is contemporary; interpretation is unique	No	
47	Tetra Tech/KCM	Water Resource Inventory Area 54 (Lower Spokane) Watershed Plan, Phase 2, Level 1 Data Compilation and Technical Assessment	Yes	Comprehensive data compilation and analyses specific to the West Plains	NA	NA	Yes	Nomenclature is contemporary; interpretation is unique	Various data gaps identified, primarily related to components of the watershed water balance.	
48	URS and Brown and Caldwell	Final Report, Stormwater Management Plan for the West Plains Planning Area	No	No specific hydrogeologic data specific to West Plains hydrogeologic framework	NA	NA	No	No specific hydrogeologic data specific to West Plains hydrogeologic framework	No	
49	Schuster, J.E.	Selected Papers on the Geology of Washington, Washington Division of Geology and Earth Resources Bulletin 77	Yes	Portions of the provided geologic information provides context for the West Plains Hydrogeologic Framework.	NA	NA	Yes	Geologic information therein generally uses comtemporary nomenclature and is well documented. Utility of this compilation of papers likely is limited to providing geologic context for the Hydrogeologic Framework of the West Plains.	NA	

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50	Various	Numerous files within a database folder entitled Stormwater Utility West Plains Geology Documents that contain incomplete documentation, are draft/preliminary, or are intepretive/subjective in nature. These include electronic files entitled the following: Ltr_Paleo Channel Update_Hamilton~Sims_20070511_; Ltr_SIA~Sims_Airport SW Impacts Sleepy Hollow_20020418; Ltr_URS~Sims_ 20070707_Prgrss Rprt; Ltr_URS~Sims_Drainage Impacts Sleepy Hollow_20000925; Ltr_WP Sims~Economic Development Alliance_20021115_unsigned copy; Map_Basin_Figure X-X_URS; Map_Citizen Complaints Areas of Flooding Observed by County Staff_Figure 3-1_URS; Map_Contours_Woodward Clyde_20010419; Map_Existing Drng Probs Airport W~S Study Area_BrownCaldwell_2008; Map_Major Roads~Topo_Sleepy Hollow_URS_ Fig 1; Map_Overburden Data Availability for West Plains Area_Figure X-X_URS; Map_Potential Opportunity Areas_Figure 4-1_URS; Map_Prelim Paleo Channel Map_Memo URS~Sims_20010413; Map_Preliminary Geologic of Airway Hts Spok NW Quadrangles, SpokaneCounty_ Derkey ~Hamilton~Stradling; Map_Preliminary Geologic of Spok SW Four Lakes Quadrangles, SpokCo_Derkey ~Hamilton~Stradling; Map_Proposed SWSA Boundary Expansion_WP_Geiger Spur_20070320; Map_Spring 1999 Flooding in the WP Area_Figure 3-3_URS; Map_Structural Recommenda Airport West Srvc Area_Figure 4-1_URS; Map_Surface Contours~Drng Channels_Sleepy Hollow_URS Fig 3; Map_Surface Waters~Major Drng Patterns_Sleepy Hollow_URS Fig 2; Map_SW Mgmt Opps in Airport W~S Study Area_BrownCaldwell_2008; Map_Water Well~Paleo Channel Locations 6-1-01; Map_Water Well~Paleo Channel Locations; Map_West Plains SW Mgmt Plan_Prelimin Alternatives for Drainage Improvements West Portion Planning Area_URS; Map_WP Planning Area_Figure 1-1_URS; Map_WP SW Mgmt Area_URS; Map_WP_W~SE Culv Locas_URS Fig 3-1; Memo_Little~BoCC_AirportWestUpdate_20070322; Memo_West Plains SW Mgmt Alternatives Analysis_20020708; Memo_WP SW Mgmt Plan_Evap Pond Sizing_20030430; Memo~Misc_Mtg Coord_Little_20080228; Nwsltr_2006; Nwsltr_Plainspoken_WP CoC_2002 Nov; Questionnaire Results_WP SW Mgmt Public Mtg_ 20010806; References_Airport West_GeoEng_undated; Report Draft_Existing Conditions Problems Opportunities WP SW Mgmt Planning Area_July 2000_URS; Report_draft_for BoCC from AdHoc~Sims_20020419; Report_Paleo Channel_Hamilton_20070511;	Variable	Variable content and specificity to West Plains hydrogeology.	NA	NA	No	Generally these documents do not contain unique hydrogeologic information with sufficient documentation to support suitability.	NA	
51	Unknown	SRHD Specific Capacity.xlsx	Yes	Contains specific capacity data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Data deficiency could be corrected through research regarding data origin and procedures.
52	Unknown	Craig Rd Landfill Data (Directory)	Yes	Contains information specific to West Plains	NA	NA	No	Relevant; uncertain source; no metadata available; appears to contain miscellaneous data from various reports	NA	Data deficiency could be corrected through research regarding data origin and procedures.
53	McCollum (?)	24k_mccollum_quads.gdb (Directory)	Yes	Contains geologic data specific to West Plains	NA	NA	No	Relevant; metadata questionable, refers to Snoqualmie Quad	NA	Data deficiency could be corrected through research regarding data origin and procedures.
54	Unknown	Deep Coulee Seepage Run (Directory)	Yes	Contains information specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Appears to be associated with ID. No. 12. Data deficiency could be corrected through research regarding data origin and procedures.
55	Deobold (?)	Deobold West Plains GIS Files (Directory)	Yes	Contains geologic GIS data specific to West Plains	NA	NA	No	Relevant; older GIS format, some data sets refer to errors when opening, limited metadata available	NA	ArcMap Drawing Errors when opening. Data deficiency could be corrected through research regarding data origin and procedures.

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56	Unknown	Deep Percolation Model (Directory)	Yes	Contains hydrogeologic data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Assumed to be associated with ID. No. 7. Data deficiency could be corrected through research regarding data origin and procedures.
57	Pritchard, McCollum (?)	Faults, Pritchard McCollum 2012 (Directory)	Yes	Contains geologic data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Assumed to be associated with ID. No. 3. Deficiency potentially could be corrected through research regarding data origin and procedures.
58	Unknown	Geochemistry (Directory)	Yes	Contains GIS and geochemistry data specific to West Plains	Uncertain	No metadata available, no QAPP associated with geochemical results	No	Relevant; uncertain credibility, no metadata available	NA	Data appears to be associated with multiple reports and studies. Pritchard XRF data file described under ID. No. 2. Deficiency potentially could be corrected through research regarding data origin and procedures.
59	Unknown	Grande Ronde-Wanapum GW contours (Directory)	Yes	Contains geologic data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Data deficiency could be corrected through research regarding data origin and procedures.
60	Unknown	Grande Ronde Flow Member Contours (Directory)	Yes	Contains geologic data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Data deficiency could be corrected through research regarding data origin and procedures.
61	City of Airway Heights / Blue Star Enterprises NW	Misc pumping test info (Directory)	Yes	Contains lithology and pumping test data for a well within the West Plains area	NA	NA	Yes	Relevant; contains data specific to West Plains; well log prepared by licensed well driller	NA	
62	Pritchard	Paleodrainage Contours, Pritchard 2013 (Directory)	Yes	Contains data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Appears to be associated with ID. No. 4. Data deficiency could be corrected through research regarding data origin and procedures.
63	Various	Water Level Data (Directory)	Yes	Contains data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Data appears to be associated with multiple reports and studies. Data deficiency could be corrected through research regarding data origin and procedures.
64	Unknown	West Plains Geologic Database Project - Rockworks (Directory)	Yes	Contains data specific to West Plains	NA	NA	No	Relevant; no dataset documentation/metadata available	NA	Appears to be associated with ID No. 6. Data deficiency could be corrected through research regarding data origin and procedures.

Bibliography Identification	Author	Report/Dataset Title	Relevance	Basis for Relevance	Apparent Credibility	Basis for Credibility	Suitability Result	Basis for Suitability	Report-Identified Gaps	Comments
65	Unknown	West Plains Hydrogeologic Database Raster Data Set (Directory)	Yes	Contains data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Appears to be associated with ID. No. 6. Data deficiency could be corrected through research regarding data origin and procedures.
66	Unknown	West Plains Water Level Monitoring (Directory)	Yes	Contains data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Data deficiency could be corrected through research regarding data origin and procedures.
67	Unknown	WP Climate data (Directory)	Yes	Contains data specific to West Plains	NA	NA	Yes	Txt files include station information.	NA	
68	Unknown	gw_elevation_study_area (multiple GIS files)	Yes	Contains data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Data deficiency could be corrected through research regarding data origin and procedures.
69	McCollum (?)	McCollum basement outcrop, McCollum basement outcrop_poly (multiple GIS files)	Yes	Contains data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Data deficiency could be corrected through research regarding data origin and procedures.
70	Unknown	modified_Deobald_Paleochannel (multiple GIS files)	Yes	Contains data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Data deficiency could be corrected through research regarding data origin and procedures.
71	Unknown	Seepage Run Data Analysis.xlsx	Yes	Contains seepage run data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Appears to be associated with ID. No. 12. Data deficiency could be corrected through research regarding data origin and procedures.
72	Unknown	West Plains Hydrogeologic Database 10-24-13.xlsx	Yes	Contains borehole, geologic, and hydrogeologic data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Appears to be associated with ID. No. 6. Data deficiency could be corrected through research regarding data origin and procedures.
73	Unknown	West Plains Study Area Water demand.xlsx	Yes	Contains water demand forecast data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Appears to be associated with ID. Nos. 30 and 31. Data deficiency could be corrected through research regarding data origin and procedures.
74	Unknown	WP Rockworks 9-16-13 (multiple GIS files)	Yes	Contains data specific to West Plains	NA	NA	No	Relevant; no metadata available	NA	Data deficiency could be corrected through research regarding data origin and procedures.

Bibliography Identification	Author	Report/Dataset Title	Relevance	Basis for Relevance	Apparent Credibility	Basis for Credibility	Suitability Result	Basis for Suitability	Report-Identified Gaps	Comments
75	Derkey, R.F, M.M. Hamilton and D.F. Stradling	Geologic Map of the Airway Heights 7.5-minute Quadrangle, Spokane County, Washington	Yes	Contains surficial and subsurface geologic information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, geologic interpretation is unique.	NA	
76	Hamilton, M.M., R.F. Derkey, and D.F. Stradling	Geologic Map of the Four Lakes 7.5-minute Quadrangle, Spokane County, Washington	Yes	Contains surficial and subsurface geologic information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, geologic interpretation is unique.	NA	
77	Derkey, R.F and M.M. Hamilton	Geologic Map of the Four Mound Prairie 7.5-minute Quadrangle, Spokane and Stevens Counties, Washington	Yes	Contains surficial and subsurface geologic information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, geologic interpretation is unique.	NA	
78	Derkey, R.F, M.M. Hamilton and D.F. Stradling	Geologic Map of the Nine Mile Falls 7.5-minute Quadrangle, Spokane and Stevens Counties, Washington	Yes	Contains surficial and subsurface geologic information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, geologic interpretation is unique.	NA	
79	Derkey, R.F, M.M. Hamilton and D.F. Stradling	Geologic Map of the Spokane Northwest 7.5-minute Quadrangle, Spokane County, Washington	Yes	Contains surficial and subsurface geologic information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, geologic interpretation is unique.	NA	
80	Hamilton, M.M., R.F. Derkey, and D.F. Stradling	Geologic Map of the Spokane Southwest 7.5-minute Quadrangle, Spokane County, Washington	Yes	Contains surficial and subsurface geologic information specific to West Plains	NA	NA	Yes	Nomenclature is contemporary, geologic interpretation is unique.	NA	
81	Unknown	Various Geologic Maps attributed to EWU, including maps entitled; Deep Creek Quadrangle; Edwall and Waukon Quadrangles; Little Falls and Long Lake Quadrangles; Medical Lake and Four Lakes Quadrangles; and Reardan East and Reardan West Quadrangles. An accompanying file entitled "Unit descriptions used on the quadrangle maps submitted by EWU" appears to provide a Legend for these maps.	Yes	Contains surficial and subsurface geologic information specific to West Plains	NA	NA	No	Nomenclature is contemporary, geologic interpretation appears unique. However, documentation is incomplete and it is unclear if these represent a final work product.	NA	Data deficiency could be corrected through research regarding data origin and procedures.

Acronyms:
CRBG = Columbia River Basalt Group
CRPAS = Columbia River Plateau Aquifer System
DPM = Deep Percolation Model
FAFB = Fairchild Air Force Base
GIS = Geographic Information System
NA = Not Applicable
NDMA = N-Nitrosodimethylamine
NOAA = National Oceanic and Atmospheric Administration
NWS = National Weather Service
QA/QC = Quality Assurance/Quality Control
QAPP = Quality Assurance Project Plan
RASA = Regional Aquifer System Analysis
TCE = Trichloroethylene
TEM = Transmission Electron Microscopy
USDA = U.S. Department of Agriculture
USGS = U.S. Geological Survey
VOC = Volatile Organic Compound
WRIA = Water Resource Inventory Area

Appendix B

Drilling Completion Report for the West Plains Hydrogeologic Framework Project

GSI Water Solutions, Inc.

Technical Memorandum

To: Mike Hermanson

CC: Joseph Abbott

From: Kevin Lindsey

Date: 09 June 2014

Re: Drilling Completion Report for the West Plains Hydrogeological Framework Project

Dear Mr. Hermanson:

GSI Water Solutions, Inc. (GSI) is pleased to provide Spokane County with this letter report documenting GSI's work to investigate mapped areas as basement outcrops on 2004 surface geologic maps of the West Plains region published by the Washington Department of Natural Resources. Geotechnical boreholes were recently drilled between the Spokane International Airport and the City of Airway Heights in Spokane County to try to determine if mapped areas of basement outcrops are actual outcrops or glacial/fluvial deposits. This letter report contains the following elements:

1. A brief narrative describing fieldwork associated with each geotechnical boring.
2. A site map (Attachment A).
3. Geologic logs (Attachment B).

A total of three geotechnical boreholes were drilled. These wells are designated B-1, B-2, and B-3, and located as shown in Attachment A. Drilling began on 5 June 2014 and was completed on the same day. All boreholes were plugged with bentonite after drilling was completed. A rock sample was separated from said outcrop for comparison with samples collected from drilling. The sample collected is a light gray to black, medium grained, porphyritic, biotite hornblende granite.

Geotechnical Borehole Drilling

All boreholes were drilled using an auger/coring drilling rig operated by GeoEngineers, Inc. under subcontract to GSI. The drilling crew also completed the boreholes under the direction of GSI staff. Geologic logs compiled for each of the boreholes were based on GSI's examination and interpretation of drill cuttings and cores collected during the course of drilling. Drill cuttings were collected in the field as each auger boring was advanced, until contact with rock capable of producing cores. Two inch cores were collected as each core barrel advanced. Cuttings and cores collected during drilling are inventoried at GSI's Kennewick office. The geologic logs, see Attachment B, summarize observations made in the field during drilling and sample collection, and subsequent more detailed evaluation of the samples done in the office. Field collected notes are reproduced in Attachment C.

B-1

Drilling of B-1 began at 8:00 AM and ended at 9:30 AM. The drill rig was located at 47°36'28.37" N/117°33'33.35"W, approximately 25 feet northwest of the mapped outcrop west of Spokane International Airport. In general, sand and gravel sediments were present to 4.5 feet below land surface (ft bls) where contact with basalt and weathered sediments were made to a total depth of 18 ft bls. No contact with basement rock was made.

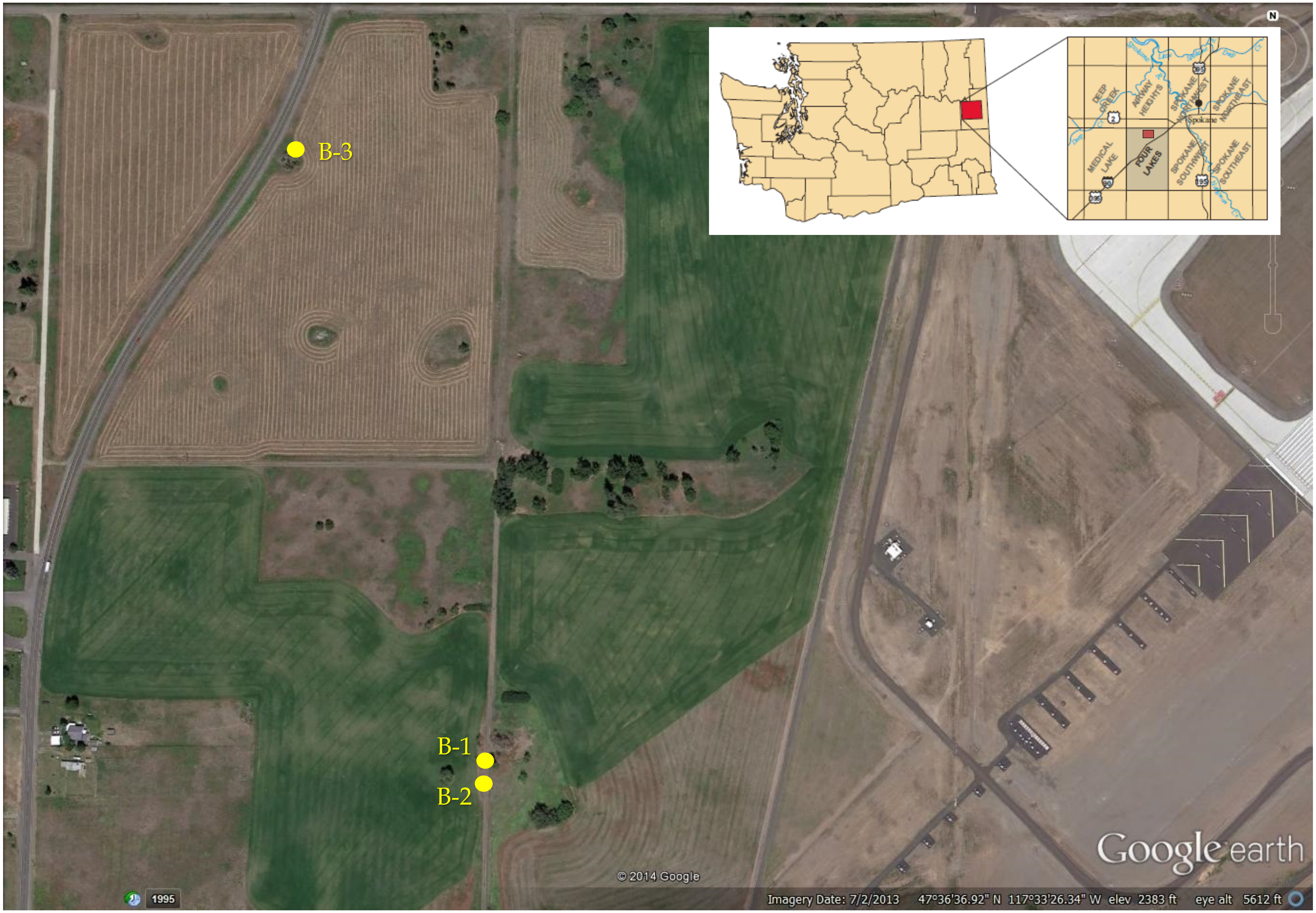
B-2

Drilling of B-2 began at 10:45 AM and ended at 11:45 AM. The drill rig was located 47°36'28.19" N/117°33'33.35"W, approximately 15 feet west of mapped outcrop and 10 feet south of B-1. In general, granitic rubble was penetrated to a depth of 4 ft bls where contact with basalt was made to a total depth of 14 ft bls. No contact with basement rock was made.

B-3

Drilling of B-3 began at 12:50 PM and ended at about 1:45 PM. The drill rig was located 47°36'45.59" N/117°33'41.84W, approximately 10 feet north of mapped outcrop adjacent to South Hayford Road. In general, sand and gravel sediments were penetrated to a depth of 18 ft bls where contact with basalt was made to a depth of 24 ft bls. No contact with basement rock was made.

If you have any questions about this letter report and/or the work that was done during the drilling of the boreholes or interpretation of findings please contact me in our Kennewick, Washington office at (509) 378-3284 at your convenience. It has been a pleasure working for Spokane County on this project.



Spokane West Plains Site Map | **ATTACHMENT A**

B-1 Borehole Geologic Details

Formation	Depth Interval (feet)	Component	Lithology
	0 – 4.5	Gravelly Sand	Sand – 50/50 mafic to felsic, some reddish weathered grains. Gravel –95/5 mafic to felsic.
	4.5 – 6	Basalt	Dark gray to black, fine grained.
	6 – 7.1	Basalt	Dark gray to black, fine grained, vesicular.
	7.1 – 18	Basalt	Dark gray to black, fine grained.

B-2 Borehole Geologic Details

Formation	Depth Interval (feet)	Component	Lithology
	0 – 7	Granite	Light gray to black, medium grained, biotite, hornblende, porphyritic.
	7 – 11	Basalt	Dark gray to black, fine grain.
	11 – 14	Basalt	Dark gray to black, fine grain, vesicular.

B-3 Borehole Geologic Details

Formation	Depth Interval (feet)	Component	Lithology
	0 – 3	Gravelly Sand	Sand – 50/50 mafic to felsic, some reddish weathered grains. Gravel –95/5 mafic to felsic.
	3 – 18	Sandy Gravel	Gravel –95/5 mafic to felsic, weathered, fine grained basalt, some quartzite. Sand – 50/50 mafic to felsic, some reddish weathered grains.
	18 – 24	Basalt	Dark gray to black, fine grained, vesicular.

Appendix C

Project Area Well Stratigraphic Data Table

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
149253	2258	250	-117.3906	47.520078	2258	2228	30	2228	2228	0	NP	2228	2228	0	2228	2228	0	2228	2228	0	2228	2228	0	2228	2228	0	2228	2228	0	2228	2008
149258	2393	88	-117.5638	47.5242	2393	2373	20	2373	2373	0	2373	2373	2305	>70																	
149512	2299	295	-117.5136	47.53861	2299	2288	11	2288	2288	0	2288	2288	2253	35	2253	2253	0	2253	2008	>250											
149531	2239	215	-117.5076	47.53263	2239	2236	3	2236	2236	0	2236	2236	2236	0	2236	2236	0	2236	2024	>200											
149539	2200	385	-117.4796	47.64626	2200	2190	10	2190	2190	0	2190	2190	2100	90	2100	1975	125	1975	1975	0	1975	1975	0	1975	1815	>150				<1815	
149584	2449	225	-117.7785	47.575245	2449	2422	27	2422	2422	0	2422	2422	2214	>200																	
149664	2368	360	-117.4093	47.532218	2368	2182	186	2182	2182	0	2182	2182	2109	73	2109	2109	0	2109	2109	0	2109	2109	0	2109	2109	0	2109	2028	81	2028	2008
149741	2390	140	-117.5228	47.601018	2390	2381	9	2381	2381	0	2381	2381	2250	>120																	
149859	2315	140	-117.447	47.580599	2315	2313	2	2313	2313	0	2313	2313	2245	68	2245	2245	0	2245	2175	>70											
149876	2435	97	-117.5607	47.52415	2435	2393	42	2393	2393	0	2393	2393	2338	>40																	
149934	2356	175	-117.522	47.56173	2356	2341	15	2341	2341	0	2341	2341	2181	>150																	
150021	2510	125	-117.8459	47.584935	2510	2435	75	2435	2435	0	2435	2435	2385	>60																	
150057	2320	300	-117.4348	47.554087	2320	2290	30	2290	2290	0	2290	2290	2175	115	2175	2175	0	2175	2130	45	2130	2130	0	2130	2130	0	2130	2130	0	2130	2020
150120	2385	320	-117.3719	47.476413	2385	2376	9	2376	2376	0	2376	2376	2206	170	2206	2206	0	2206	2065	>150											
150145	2495	150	-117.7371	47.71655	2495	2491	4	2491	2491	0	2491	2491	2357	134	2357	2345	>20														
150256	2319	160	-117.4325	47.577978	2319	2307	12	2307	2307	0	2307	2307	2246	61	2246	2246	0	2246	2159	>100											
150297	2368	400	-117.5206	47.583809	2368	2356	12	2356	2356	0	2356	2356	2317	39	2317	2317	0	2317	2317	0	2317	2317	0	2317	2317	0	2317	2317	0	2317	1968
150380	2326	140	-117.458	47.555228	2326	2322	4	2322	2322	0	2322	2322	2246	76	2246	2223	23	2223	2207	16	2207	2207	0	2207	2207	0	2207	2207	0	2207	2186
150404	2319	410	-117.4387	47.589059	2319	2311	8	2311	2311	0	2311	2311	2198	113	2198	2198	0	2030	1909	121	2137	2030	>100								
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150485	2358	160	-117.5191	47.5667	2358	2323	35	2323	2323	0	2323	2323	2263	60	2263	2225	38	2225	2198	>25											
150565	2346	200	-117.5094	47.5754	2346	2343	3	2343	2343	0	2343	2343	2188	155	2188	2146	>40														
150592	2356	160	-117.4855	47.57887	2356	2354	2	2354	2354	0	2354	2354	2212	142	2212	2196	>20														
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150811	2347	360	-117.4825	47.57445	2347	2347	0	2347	2114	233	2005	2114	2114	0	2114	2114	0	2114	2005	109	2005	1997	8	1997	1987	>10				<1987	
151012	2355	220	-117.56	47.637255	2355	2318	37	2318	2318	0	2318	2318	2166	152	2166	2135	>30														
151082	2356	100	-117.5121	47.57172	2356	2342	14	2342	2342	0	2342	2342	2256	>90																	
151164	2382	85	-117.5282	47.57812	2382	2378	4	2378	2378	0	2378	2378	2307	71	2307	2307	0	2307	2307	0	2307	2307	0	2307	2307	0	2307	2307	0	2307	2297
151281	2286	310	-117.4568	47.596204	2286	2279	7	2279	2279	0	2279	2279	2222	57	2222	2222	0	2222	1976	>200											
151331	2316	380	-117.4736	47.578557	2316	2299	17	2299	2299	0	2299	2299	2196	103	2196	2135	61	2135	1999	136	1999	1993	6	1993	1936	>50				<1936	
151359	2312	260	-117.345	47.46398	2312	2303	9	2303	2303	0	2303	2303	2277	26	2277	2250	27	2250	2052	>200											
151449	2360	85	-117.7035	47.78691	2360	2347	13	2347	2347	0	2347	2347	2275	>80																	
151494	2398	240	-117.3696	47.501183	2398	2397	1	2397	2397	0	2397	2397	2180	217	2180	2180	0	2180	2158	>30											
151546	2346	180	-117.5109	47.56525	2346	2340	6	2340	2340	0	2340	2340	2191	149	2191	2166	>30														
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151985	2406	195	-117.6949	47.595497	2406	2357	49	2357	2357	0	2357	2357	2223	134	2223	2223	0	2223	2211	>10											
152024	2379	440	-117.7556	47.594627	2379	2374	5	2374	2374	0	2374	2374	2319	55	2319	2304	15	2304	1979	>250											
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152550	2379	61	-117.5277	47.57378	2379	2377	2	2377	2377	0	2377	2377	2318	>50																	
152705	2356	445	-117.5226	47.55957	2356	2189	167	2189	2189	0	2189	2189	2168	21	2168	2071	97	2071	2071	0	2071	2071	0	2071	2071	0	2071	2071	0	2071	1911
152754	2443	271	-117.7004	47.58195	2443	2406	37	2406	2406	0	2406	2406	2290	116	2290	2272	18	2272	2172	>100											
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152806	2468	335	-117.5488	47.52735	2468	2432	36	2432	2432	0	2432	2432	2376	56	2376	2245	131	2245	2133	>100											
153087	2434	580	-117.5316	47.5303	2434	2164	270	2164	2164	0	NP	2164	2164	0	2164	2164	0	2164	2164	0	2164	2164	0	2164	2164	0	2164	2164	0	2164	1854
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153315	2425	382	-117.3647	47.46707	2425	2424	1	2424	2424	0	2424	2424	2210	214	2210	2210	0	2210	2045	>150											
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153408	2305	280	-117.5008	47.56503	2305	2221	84	2221	2221	0	2221	2221	2221	0	2221	2221	0	2221	2025	>200											
153504	2311	125	-117.5259	47.5301	2311	2307	4	2307	2307	0	2307	2307	2254	53	2254	2243	11	2243	2186	>50											
153792	2355	200	-117.5196	47.56249	2355	2353	2	2353	2353	0	2353	2353	2235	118	2187	2155	>30														

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
153793	2358	150	-117.5216	47.56234	2358	2355	3	2355	2355	0	2355	2355	2208	>150																	
153822	2387	480	-117.7757	47.611495	2387	2384	3	2384	2384	0	2384	2384	2207	177	2207	2207	0	2207	1932	275	1932	1932	0	1932	1907	>20				<1907	
153858	2382	320	-117.7427	47.602874	2382	2363	19	2363	2363	0	2363	2363	2210	153	2210	2210	0	2210	2012	>200											
153872	2391	320	-117.7237	47.78775	2391	2380	11	2380	2380	0	2380	2380	2331	49	2331	2326	5	2326	2093	233	2093	2093	0	2093	2093	0	2093	2071	>20	<2071	
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155755	2359	600	-117.5317	47.56127	2359	2346	13	2346	2346	0	2346	2346	2278	68	2278	2236	42	2236	2236	0	2236	2236	0	2236	2236	0	2236	2236	0	2236	1759
155784	2366	240	-117.4296	47.506371	2366	2365	1	2365	2365	0	2365	2365	2209	156	2209	2209	0	2209	2126	>80											
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156750	2318	145	-117.4405	47.529096	2318	2316	2	2316	2316	0	2316	2316	2256	60	2256	2250	6	2250	2173	>80											

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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156888	2289	190	-117.5166	47.54145	2289	2286	3	2286	2286	0	2286	2286	2265	21	2265	2265	0	2265	2146	119	2146	2146	0	2146	2146	0	2146	2108	38	2108	2099
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156999	2213	283	-117.4016	47.56632	2213	2204	9	2204	2204	0	2204	2204	2204	0	2204	2204	0	2204	1945	259	1945	1930	>15								
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157980	2374	320	-117.5254	47.57813	2374	2304	70	2304	2304	0	NP	2304	2304	0	2304	2304	0	2304	2304	0	2304	2304	0	2304	2304	0	2304	2304	0	2304	2054
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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161033	2218	300	-117.49	47.532197	2218	2212	6	2212	2212	0	2212	2212	2212	0	2212	2212	0	2212	1953	259	1953	1953	0	1953	1918	>20				<1918	
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161442	2345	500	-117.525	47.55907	2345	2203	142	2203	2203	0	2203	2203	2189	14	2189	2035	154	2035	2035	0	2035	2035	0	2035	2035	0	2035	2035	0	2035	1845
161503	2059	423	-117.4709	47.571845	2059	2004	55	2004	2004	0	NP	2004	2004	0	2004	2004	0	2004	2004	0	2004	2004	0	2004	2004	0	2004	2004	0	2004	1624
161515	2184	140	-117.4782	47.56783	2184	2154	30	2154	2154	0	2154	2154	2154	0	2154	2154	0	2154	2044	>100											
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161749	2399	320	-117.383	47.47207	2399	2319	80	2319	2319	0	2319	2319	2209	110	2209	2209	0	2209	2079	>150											
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162480	2450	220	-117.8095	47.600134	2450	2447	3	2447	2447	0	2447	2447	2230	>110																	
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162602	2321	160	-117.469	47.593694	2321	2318	3	2318	2318	0	2318	2318	2190	128	2190	2161	>60														
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162922	2426	180	-117.6643	47.58291	2426	2422	4	2422	2422	0	NP	2422	2422	0	2422	2422	0	2422	2422	0	2422	2422	0	2422	2422	0	2422	2422	0	2422	2246
162927	2349	360	-117.6801	47.7248	2349	2348	1	2348	2348	0	2348	2348	2348	0	2348	2348	0	2348	1989	>350											
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163049	2401	301	-117.6467	47.6791	2401	2395	6	2395	2395	0	2395	2395	2244	151	2244	2191	53	2191	2100	>90											
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163132	2390	100	-117.5652	47.60385	2390	2382	8	2382	2382	0	2382	2382	2290	>100																	
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
163518	2370	120	-117.6318	47.7259	2370	2364	6	2364	2364	0	2364	2364	2250	>120
163541	2398	120	-117.7076	47.6312	2398	2398	0	2398	2368	30	2368	2368	2278	>100
163547	2102	395	-117.533	47.699452	2102	2102	0	2102	1867	235	1867	1867	1867	0	1867	1867	0	1867	1867	0	1867	1867	0	1867	1712	155	1712	1702	>10	<1702	
163557	2390	260	-117.6246	47.66428	2390	2390	0	2390	2235	155	2235	2235	2235	0	2235	2235	0	2235	2130	>100
163558	2405	105	-117.6244	47.65927	2405	2373	32	2373	2373	0	2373	2373	2295	>80
163578	2519	225	-117.8534	47.686081	2519	2517	2	2517	2517	0	2517	2517	2294	>200
163598	2411	380	-117.6479	47.55341	2411	2405	6	2405	2405	0	NP	2405	2405	0	2405	2405	0	2405	2405	0	2405	2405	0	2405	2405	0	2405	2405	0	2405	2031
163606	2465	400	-117.691	47.614678	2465	2432	33	2432	2432	0	2432	2432	2245	187	2245	2245	0	2245	2065	>180
163647	2396	360	-117.797	47.626928	2396	2348	48	2348	2348	0	2348	2348	2236	112	2236	2236	0	2236	2036	>200
163676	2427	150	-117.69	47.56001	2427	2425	2	2425	2425	0	2425	2425	2277	>140
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163745	2420	103	-117.6894	47.805383	2420	2418	2	2418	2418	0	2418	2418	2317	>100
163758	2363	260	-117.7339	47.6287	2363	2362	1	2362	2362	0	2362	2362	2223	139	2223	2213	10	2213	2103	>100
163781	2214	94	-117.6894	47.6591	2214	2214	0	2214	2154	60	2154	2154	2154	0	2154	2154	0	2154	2120	>30
163836	2375	160	-117.6638	47.57481	2375	2369	6	2369	2369	0	NP	2369	2350	19	2350	2350	0	2350	2350	0	2350	2350	0	2350	2350	0	2350	2350	0	2350	2215
163881	2350	182	-117.7236	47.62094	2350	2330	20	2330	2330	0	2330	2330	2239	91	2239	2231	8	2231	2168	>60
163899	2430	400	-117.7244	47.69035	2430	2409	21	2409	2409	0	2409	2409	2213	196	2213	2207	6	2207	2030	>170
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163950	2418	225	-117.6714	47.56521	2418	2417	1	2417	2417	0	2417	2417	2286	131	2286	2272	14	2272	2193	>80
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164066	2334	360	-117.7116	47.67295	2334	2331	3	2331	2331	0	2331	2331	2224	107	2224	2224	0	2224	1974	>150
164166	2418	160	-117.6524	47.65718	2418	2388	30	2388	2388	0	2388	2388	2258	>120
164168	2424	120	-117.6566	47.65097	2424	2397	27	2397	2397	0	2397	2397	2304	>90
164203	2332	50	-117.7114	47.67305	2332	2329	3	2329	2329	0	2329	2329	2282	>40
164246	2417	223	-117.6081	47.57321	2417	2417	0	2417	2397	20	2397	2397	2231	166	2231	2215	16	2215	2194	>20
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164287	2281	340	-117.5116	47.660677	2281	2277	4	2277	2277	0	2277	2277	2161	116	2161	2085	76	2085	1941	>140
164291	2400	320	-117.67	47.6661	2400	2343	57	2343	2343	0	2343	2343	2197	146	2197	2166	31	2166	2080	>80
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164395	2446	200	-117.5933	47.55601	2446	2446	0	2446	2391	55	NP	2391	2391	0	2391	2391	0	2391	2391	0	2391	2391	0	2391	2391	0	2391	2391	0	2391	2246
164463	2368	150	-117.6762	47.7192	2368	2359	9	2359	2359	0	2359	2359	2320	39	2320	2307	13	2307	2218	>80
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164560	2442	452	-117.8277	47.659106	2442	2441	1	2441	2441	0	2441	2441	2215	226	2215	2213	2	2213	1990	>220
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164650	2463	215	-117.6254	47.56971	2463	2456	7	2456	2456	0	2456	2456	2414	42	2414	2414	0	2414	2414	0	2414	2414	0	2414	2414	0	2414	2414	0	2414	2248
164651	2376	239	-117.608	47.59889	2376	2376	0	2376	2335	41	2335	2335	2220	115	2220	2220	0	2220	2137	>100
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164680	2460	265	-117.6657	47.6959	2460	2457	3	2457	2457	0	2457	2457	2223	234	2223	2223	0	2223	2195	>30
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164767	2449	475	-117.6878	47.6975	2449	2448	1	2448	2448	0	2448	2448	2253	195	2253	2253	0	2253	2114	139	2114	2114	0	2114	2114	0	2114	2114	0	2114	1974
164788	2442	312	-117.6969	47.6368	2442	2442	0	2442	2348	94	2348	2348	2224	124	2224	2224	0	2224	2130	>90
164857	1859	277	-117.5819	47.743819	1859	1859	0	1859	1582	>277	<1582
164915	2400	155	-117.5655	47.5958	2400	2392	8	2392	2392	0	2392	2392	2245	>150
164951	2420	141	-117.6129	47.57081	2420	2417	3	2417	2408	9	2408	2408	2279	>120
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164981	2344	440	-117.7162	47.801489	2344	2336	8	2336	2336	0	2336	2336	2276	60	2276	2276	0	2276	1996	280	1996	1975	21	1975	1904	>70				<1904	
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165064	2440	130	-117.6986	47.637	2440	2318	122	2318	2318	0	2318	2318	2310	>10
165083	2383	300	-117.634	47.6724	2383	2359	24	2359	2359	0	2359	2359	2196	163	2196	2196	0	2196	2083	>110
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165132	2390	365	-117.6633	47.67135	2390	2390	0	2390	2227	163	2227	2227	2205	22	2205	2205	0	2205	2025	>180

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
165149	2352	80	-117.7309	47.63685	2352	2350	2	2350	2350	0	2350	2350	2272	>80																	
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165178	2421	82	-117.6647	47.65127	2421	2382	39	2382	2382	0	2382	2382	2339	>40																	
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165247	2405	400	-117.6024	47.55271	2405	2385	20	2385	2385	0	NP	2385	2385	0	2385	2385	0	2385	2385	0	2385	2385	0	2385	2385	0	2385	2385	0	2385	2005
165250	2440	120	-117.6894	47.6296	2440	2375	65	2375	2375	0	2375	2375	2320	>45																	
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165333	2239	400	-117.579	47.775265	2239	2224	15	2224	2224	0	2224	2224	2224	0	2224	2224	0	2224	1989	235	1989	1922	67	1922	1839	>90				<1839	
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165357	2420	300	-117.6676	47.65108	2420	2420	0	2420	2370	50	2370	2370	2233	137	2233	2233	0	2233	2120	>110											
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165425	2521	300	-117.5826	47.54791	2521	2442	79	2442	2442	0	2442	2442	2338	104	2338	2338	0	2338	2338	0	2338	2338	0	2338	2338	0	2338	2338	0	2338	2221
165462	1957	215	-117.5651	47.748961	1957	1957	0	1957	1742	>215	<1742																				
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165793	2400	131	-117.6461	47.56651	2400	2383	17	2383	2383	0	NP	2383	2383	0	2383	2383	0	2383	2383	0	2383	2383	0	2383	2383	0	2383	2383	0	2383	2269
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165995	2393	182	-117.7071	47.63525	2393	2342	51	2342	2342	0	2342	2342	2211	>120																	
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166500	2342	280	-117.6242	47.68937	2342	2342	0	2342	2158	184	2158	2158	2158	0	2158	2158	0	2158	2062	>80											
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166542	2370	415	-117.6288	47.5949	2370	2364	6	2364	2364	0	2364	2364	2180	184	2180	2180	0	2180	1955	>180											

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
166559	2380	85	-117.6298	47.6725	2380	2363	17	2363	2363	0	2363	2363	2295	>80																	
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166712	2437	320	-117.7045	47.6307	2437	2437	0	2437	2383	54	2383	2383	2242	141	2242	2242	0	2242	2117	>120											
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166848	2289	730	-117.5824	47.705553	2289	2281	8	2281	2281	0	2281	2281	2281	0	2281	2281	0	2281	1919	362	1919	1854	65	1854	1559	>300				<1559	
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166994	2326	560	-117.6067	47.725739	2326	2300	26	2300	2300	0	2300	2300	2263	37	2263	2231	32	2231	1986	245	1986	1986	0	1986	1986	0	1986	1766	>220	<1766	
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167068	2581	540	-117.6234	47.56511	2581	2578	3	2578	2578	0	NP	2578	2578	0	2578	2578	0	2578	2578	0	2578	2578	0	2578	2578	0	2578	2578	0	2578	2041
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167073	2174	275	-117.5254	47.69905	2174	2171	3	2171	2171	0	2171	2171	2171	0	2171	2171	0	2171	1984	187	1984	1984	0	1984	1899	>80				<1899	
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167107	2343	105	-117.7067	47.788603	2343	2334	9	2334	2334	0	2334	2334	2283	51	2283	2283	0	2283	2238	>50											
167117	2367	160	-117.6085	47.6106	2368	2354	14	2354	2354	0	2354	2354	2208	>150																	
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167345	2391	85	-117.5689	47.6036	2391	2384	7	2384	2384	0	2384	2384	2306	>80																	
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167628	2459	150	-117.6891	47.6199	2459	2405	54	2405	2405	0	2405	2405	2309	>100																	
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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168468	2331	275	-117.6415	47.691128	2111	1912	199	1912	1912	0	1912	1912	1912	0	1912	1912	0	1912	1903	9	1912	1912	0	1912	1912	0	1903	1899	4	1899	1800
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168735	2401	102	-117.5631	47.52352	2401	2399	2	2399	2399	0	2399	2399	2299	>100																	
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169420	2192	460	-117.5211	47.676444	2192	2192	0	2192	2033	159	2033	2033	2033	0	2033	2033	0	2033	1908	125	1908	1892	16	1892	1732	>160				<1732	
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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169741	1984	310	-117.5094	47.68245	1984	1982	2	1982	1970	12	1970	1970	1970	0	1970	1970	0	1970	1970	0	1970	1970	0	1970	1674	>300				<1674	
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169773	2449	500	-117.6608	47.59071	2449	2439	10	2439	2439	0	NP	2439	2439	0	2439	2439	0	2439	2439	0	2439	2439	0	2439	2439	0	2439	2439	0	2439	1949
169790	2412	200	-117.6821	47.56311	2412	2405	7	2405	2405	0	2405	2405	2222	183	2222	2212	>10														
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169889	2423	250	-117.7123	47.61861	2423	2323	100	2323	2323	0	2323	2323	2173	>160																	
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170052	2448	170	-117.5919	47.54061	2448	2446	2	2446	2446	0	2446	2446	2304	142	2304	2278	>30														
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170121	2256	405	-117.69	47.6659	2256	2239	17	2239	2239	0	2239	2239	2239	0	2239	2239	0	2239	1981	258	1981	1981	0	1981	1851	>100				<1851	
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170714	2445	240	-117.6229	47.56961	2445	2368	77	2368	2368	0	NP	2368	2368	0	2368	2368	0	2368	2368	0	2368	2368	0	2368	2368	0	2368	2368	0	2368	2205
170731	2555	500	-117.5775	47.54931	2555	2445	110	2445	2445	0	NP	2445	2445	0	2445	2445	0	2445	2445	0	2445	2445	0	2445	2445	0	2445	2445	0	2445	2055
170739	2320	460	-117.5967	47.67447	2320	2242	78	2242	2242	0	2242	2242	2242	0	2242	2242	0	2242	2037	205	2037	1935	102	1935	1860	>90				<1860	
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171094	2300	382	-117.5431	47.671172	2300	2291	9	2291	2291	0	2291	2291	2233	58	2233	2191	42	2191	1999	192	1999	1988	11	1988	1918	>70				<1918	

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
171100	2453	475	-117.6851	47.6982	2453	2452	1	2452	2452	0	2452	2452	2206	246	2206	2206	0	2206	1997	209	1997	1991	6	1991	1978	>20				<1978	
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171112	2462	110	-117.6678	47.7	2462	2454	8	2454	2454	0	2454	2454	2352	>100																	
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171350	2401	180	-117.6797	47.65285	2401	2314	87	2314	2314	0	2314	2314	2221	>80																	
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171950	2483	260	-117.6255	47.56881	2483	2476	7	2476	2476	0	NP	2476	2476	0	2476	2476	0	2476	2476	0	2476	2476	0	2476	2476	0	2476	2476	0	2476	2223
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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174533	2370	242	-117.5709	47.628746	2370	2370	0	2370	2294	76	2295	2295	2204	91	2204	2204	0	2204	2147	57	2147	2128	>20								
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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175069	2407	225	-117.6037	47.55371	2407	2394	13	2394	2394	0	NP	2394	2394	0	2394	2394	0	2394	2394	0	2394	2394	0	2394	2394	0	2394	2394	0	2394	2182
175078	2364	245	-117.659	47.57351	2364	2363	1	2363	2363	0	NP	2363	2363	0	2363	2363	0	2363	2363	0	2363	2363	0	2363	2363	0	2363	2363	0	2363	2119
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175450	2436	340	-117.6659	47.76374	2436	2434	2	2434	2434	0	2434	2434	2341	93	2341	2341	0	2341	2341	0	2341	2341	0	2341	2341	0	2341	2237	104	2237	2096
175454	1863	295	-117.531	47.723929	1863	1594	269	1594	1594	0	1594	1594	1594	0	1594	1594	0	1594	1594	0	1594	1594	0	1594	1563	>30				<1563	
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175569	2329	255	-117.6711	47.6706	2329	2309	20	2309	2309	0	2309	2309	2204	105	2204	2204	0	2204	2074	>130											
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175727	1999	370	-117.5063	47.68595	1999	1997	2	1997	1997	0	1997	1997	1997	0	1997	1997	0	1997	1997	0	1997	1997	0	1997	1634	363	1634	1629	>5	<1629	
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175730	2260	287	-117.5339	47.67321	2260	2260	0	2260	2220	40	2220	2220	2182	38	2182	2114	68	2114	1945	>180											
175739	1872	197	-117.4845	47.681142	1872	1832	40	1832	1832	0	1832	1832	1832	0	1832	1832	0	1832	1832	0	1832	1832	0	1832	1675	>150				<1675	

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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175817	2424	160	-117.6652	47.58141	2424	2415	9	2415	2415	0	NP	2415	2415	0	2415	2415	0	2415	2415	0	2415	2415	0	2415	2415	0	2415	2415	0	2415	2264
175819	2422	200	-117.6838	47.6496	2422	2422	0	2422	2345	77	2345	2345	2222	>110																	
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175931	2330	380	-117.5961	47.67333	2330	2012	318	2012	2012	0	2012	2012	2012	0	2012	2012	0	2012	1960	52	1960	1950	>10								
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176105	2293	420	-117.6252	47.7131	2293	2287	6	2287	2287	0	2287	2287	2223	64	2223	2165	58	2165	1890	275	1890	1868	>20								
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176121	2490	300	-117.732	47.6997	2490	2485	5	2485	2485	0	2485	2485	2474	11	2474	2474	0	2474	2474	0	2474	2474	0	2474	2474	0	2474	2474	0	2474	2190
176186	2420	80	-117.6284	47.64601	2420	2415	5	2415	2415	0	2415	2415	2340	>70																	
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176607	2382	400	-117.622	47.6787	2382	2378	4	2378	2378	0	2378	2378	2252	126	2252	2222	30	2222	1982	>240											
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176823	2431	172	-117.6216	47.57035	2431	2429	2	2429	2291	138	NP	2291	2291	0	2291	2291	0	2291	2291	0	2291	2291	0	2291	2291	0	2291	2291	0	2291	2259

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
176824	2308	120	-117.5329	47.65806	2308	2305	3	2305	2298	7	2298	2298	2243	55	2243	2243	0	2243	2188	>60											
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25/41-25A1-Sceva	2350	1,224	-117.5622	47.641293	2350	2338	12	2338	2338	0	2338	2338	2179	159	2179	2137	42	2137	1937	200	1937	1870	67	1870	1640	230	1640	1256	384	1256	
25/41-28L1-Sceva	2432	312	-117.643	47.631641	2432	2429	3	2429	2357	72	2357	2357	2315	42	2315	2289	26	2289	2120	>169											
25/42-29R1-Sceva	2320	400	-117.5141	47.631521	2320	2320	0	2320	2320	0	2320	2320	2176	144	2176	2137	39	2137	1925	212	1925	1910	>15								

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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25/42-32R1-Sceva	2370	152	-117.5191	47.614575	2370	2358	12	2358	2358	0	2358	2358	2218	>140																	
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253286	2333	600	-117.5327	47.55888	2333	2327	6	2327	2327	0	NP	2327	2327	0	2327	2327	0	2327	2327	0	2327	2327	0	2327	2327	0	2327	2327	0	2327	1733
253440	2405	500	-117.6566	47.5882	2405	2400	5	2400	2400	0	NP	2400	2400	0	2400	2400	0	2400	2400	0	2400	2400	0	2400	2400	0	2400	2135	265	2135	1905
253443	2359	80	-117.6485	47.5758	2359	2350	9	2350	2350	0	2350	2350	2334	16	2334	2334	0	2334	2334	0	2334	2334	0	2334	2334	0	2334	2334	0	2334	2279
253445	2353	280	-117.5117	47.56344	2353	2343	10	2343	2343	0	2343	2343	2183	160	2183	2116	67	2116	2073	>40											
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256943	2366	100	-117.7043	47.50784	2366	2351	15	2351	2351	0	2351	2351	2276	75	2276	2276	0	2276	2276	0	2276	2276	0	2276	2276	0	2276	2276	0	2276	2266
256945	2502	140	-117.8572	47.604183	2502	2492	10	2492	2492	0	2492	2492	2362	>120																	
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
295341	2165	80			2165	2165	0	2165	2087	78	NP	2087	2087	0	2087	2087	0	2087	2087	0	2087	2087	0	2087	2087	0	2087	2087	0	2087	2085
295346	2173	117	-117.5075	47.551837	2173	2173	0	2173	2056	>117	<2056																				
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308841	2440	173	-117.7026	47.7406	2440	2424	16	2424	2424	0	2424	2424	2267	>160																	
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338673	2488	120	-117.8613	47.66994	2488	2482	6	2482	2482	0	2482	2482	2368	>120																	
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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343533	2290	300	-117.4768	47.562391	2290	2245	45	2245	2245	0	2245	2245	2166	79	2166	2145	21	2145	1990	>240											
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347036	2127	420	-117.5347	47.69172	2127	2127	0	2127	1737	390	1737	1737	1737	0	1737	1737	0	1737	1737	0	1737	1737	0	1737	1707	>30				<1707	
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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366366	2346	500	-117.5157	47.55643	2346	2346	0	2346	2148	198	NP	2148	2148	0	2148	2148	0	2148	2138	10	2138	2138	0	2138	2138	0	2138	2127	11	2127	1846
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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385125	2283	360	-117.4154	47.557263	2283	2278	5	2278	2278	0	2278	2278	2251	27	2251	2251	0	2251	2133	118	2133	1959	174	1959	1923	>30				<1923	
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391925	2441	540	-117.3346	47.487726	2441	2411	30	2411	2411	0	2411	2411	2207	204	2207	2207	0	2207	1933	274	1933	1933	0	1933	1901	>30				<1901	
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391996	2104	260	-117.4901	47.557494	2104	2073	31	2073	2073	0	NP	2073	2073	0	2073	2073	0	2073	2060	13	2060	2060	0	2060	2060	0	2060	2046	14	2046	1844
392033	2424	80	-117.5516	47.5359	2424	2414	10	2414	2414	0	2414	2414	2344	>70																	
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406975	2420	140	-117.709	47.746745	2420	2382	38	2382	2382	0	2382	2382	2280	>140																	
406989	2012	287	-117.4641	47.575815	2012	1984	28	1984	1984	0	NP	1984	1984	0	1984	1984	0	1984	1984	0	1984	1984	0	1984	1780	204	1780	1759	21	1759	1725
407021	2442	380	-117.8274	47.597672	2442	2410	32	2410	2410	0	2410	2410	2194	216	2194	2194	0	2194	2062	>130											
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408086	2408	220	-117.5349	47.57216	2408	2376	32	2376	2376	0	NP	2376	2376	0	2376	2376	0	2376	2376	0	2376	2376	0	2376	2376	0	2376	2376	0	2376	2188
408087	2348	220	-117.5286	47.56143	2348	2251	97	2251	2251	0	2251	2251	2239	12	2239	2165	74	2165	2165	0	2165	2165	0	2165	2165	0	2165	2165	0	2165	2128
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408340	2097	365	-117.5164	47.68088	2097	2096	1	2096	1962	134	1962	1962	1962	0	1962	1962	0	1962	1962	0	1962	1962	0	1962	1732	>230				<1732	

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
408354	2007	320	-117.4857	47.67881	2007	1996	11	1996	1996	0	1996	1996	1996	0	1996	1996	0	1996	1957	39	1957	1957	0	1957	1687	>260				<1687	
408360	2377	180	-117.6089	47.59823	2377	2377	0	2377	2337	40	2337	2337	2197	>150																	
408361	2413	160	-117.8094	47.590985	2413	2390	23	2390	2390	0	2390	2390	2253	>140																	
408367	2448	180	-117.7316	47.775065	2448	2446	2	2446	2446	0	2446	2446	2315	131	2315	2268	>50														
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409886	2418	100	-117.6277	47.64489	2418	2406	12	2406	2406	0	2406	2406	2318	>80																	
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411175	1866	264	-117.4716	47.666129	1866	1857	9	1857	1857	0	1857	1857	1857	0	1857	1857	0	1857	1857	0	1857	1857	0	1857	1703	154	1703	1602	>100	<1602	
411179	2459	460	-117.6889	47.6174	2459	2419	40	2419	2419	0	2419	2419	2249	170	2249	2249	0	2249	1999	>250											
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411766	2337	140	-117.4241	47.583335	2337	2315	22	2315	2315	0	2315	2315	2208	107	2208	2197	>110														
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413063	2474	117	-117.7339	47.587153	2474	2444	30	2444	2444	0	2444	2444	2428	16	2428	2428	0	2428	2428	0	2428	2428	0	2428	2428	0	2428	2370	58	2370	2357
413065	2401	160	-117.6272	47.5778	2401	2398	3	2398	2398	0	2398	2398	2258	140	2258	2241	>20														
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413090	2350	260	-117.7328	47.62613	2350	2338	12	2338	2338	0	2338	2338	2158	180	2158	2158	0	2158	2090	>60											
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413195	2391	420	-117.6804	47.6727	2391	2388	3	2388	2388	0	2388	2388	2210	178	2210	2210	0	2210	1986	224	1986	1986	0	1986	1971	>20				<1971	
413228	2448	300	-117.703	47.6916	2448	2437	11	2437	2437	0	2437	2437	2297	140	2297	2261	36	2261	2148	>80											
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413231	2358	200	-117.5625	47.636706	2358	2358	0	2358	2332	26	2332	2332	2200	132	2200	2200	0	2200	2158	>40											
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417166	2433	110	-117.6884	47.59757	2433	2409	24	2409	2409	0	2409	2409	2335	74	2335	2335	0	2335	2335	0	2335	2335	0	2335	2335	0	2335	2332	3	2332	2323
417168	2378	180	-117.6079	47.5987	2378	2326	52	2326	2326	0	2326	2326	2198	>130																	
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418381	2379	260	-117.6168	47.59	2379	2364	15	2364	2364	0	2364	2364	2199	165	2199	2199	0	2199	2119	>80											
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419529	2258	287	-117.5223	47.65783	2258	2257	1	2257	2166	91	2166	2166	2166	0	2166	2166	0	2166	2063	103	2063	2001	62	2001	1971	>30				<1971	
419534	2373	440	-117.6929	47.51622	2373	2344	29	2344	2344	0	NP	2344	2344	0	2344	2344	0	2344	2344	0	2344	2344	0	2344	2344	0	2344	2344	0	2344	1933
424262	2364	200	-117.7075	47.50968	2364	2358	6	2358	2358	0	2358	2358	2199	159	2199	2199	0	2199	2164	>30											
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428159	2229	367	-117.5432	47.69521	2229	2228	1	2228	2228	0	2228	2228	2197	31	2197	2132	65	2132	1987	145	1987	1987	0	1987	1862	>120				<1862	
428162	2261	323	-117.5254	47.65783	2261	2249	12	2249	2249	0	2249	2249	2165	84	2165	2129	36	2129	1995	134	1995	1942	53	1942	1938	>10				<1938	
428170	2427	160	-117.7253	47.746607	2427	2425	2	2425	2425	0	2425	2425	2267	>160																	
428173	1941	348	-117.5781	47.747894	1941	1787	154	1787	1787	0	1787	1787	1787	0	1787	1787	0	1787	1787	0	1787	1787	0	1787	1593	>180				<1593	
428174	1887	346	-117.5898	47.736987	1887	1568	319	1568	1568	0	NP	1568	1568	0	1568	1568	0	1568	1568	0	1568	1568	0	1568	1568	0	1568	1568	0	1568	1541
428463	2353	180	-117.5117	47.56098	2353	2352	1	2352	2352	0	2352	2352	2208	144	2208	2173	>30														
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432282	2380	100	-117.6925	47.51877	2380	2380	0	2380	2380	0	2380	2380	2280	>100																	
435792	2291	162	-117.6933	47.68325	2291	2290	1	2290	2290	0	2290	2290	2205	85	2205	2205	0	2205	2129	>80											
435794	2402	220	-117.6936	47.64579	2402	2330	72	2330	2330	0	2330	2330	2235	95	2235	2192	43	2192	2182	>10											

Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
435795	2262	811	-117.5792	47.68905	2262	2096	166	2096	2096	0	2096	2096	2096	0	2096	2096	0	2096	2096	0	2096	2096	0	2096	1451	>600				<1451	
437006	2458	155	-117.5523	47.5334	2458	2455	3	2455	2455	0	2455	2455	2303	>140																	
437578	2420	420	-117.7154	47.6184	2420	2256	164	2256	2256	0	2256	2256	2256	0	2256	2256	0	2256	2000	>250											
438376	2365	145	-117.6233	47.68468	2365	2350	15	2350	2350	0	2350	2350	2220	>120																	
439858	2449	360	-117.6964	47.6365	2449	2449	0	2449	2361	88	2361	2361	2229	132	2229	2229	0	2229	2089	>140											
439859	2341	250	-117.7253	47.6312	2341	2340	1	2340	2340	0	2340	2340	2198	142	2198	2198	0	2198	2091	>100											
439862	2365	100	-117.6858	47.686	2365	2364	1	2364	2364	0	2364	2364	2265	>100																	
439863	2427	120	-117.7325	47.745466	2427	2426	1	2426	2426	0	2426	2426	2307	>120																	
441147	1869	235	-117.5903	47.743623	1869	1773	96	1773	1773	0	1773	1773	1773	0	1773	1773	0	1773	1773	0	1773	1773	0	1773	1729	44	1729	1659	70	1659	1634
442420	2337	260	-117.5014	47.5613	2337	2335	2	2335	2335	0	2335	2335	2227	108	2227	2227	0	2227	2077	>130											
443619	2409	300	-117.3882	47.46623	2409	2384	25	2384	2384	0	2384	2384	2239	145	2239	2219	20	2219	2109	>110											
443624	2382	210	-117.4585	47.542835	2382	2381	1	2381	2381	0	2381	2381	2242	139	2242	2242	0	2242	2172	>70											
443628	2358	160	-117.7095	47.6354	2358	2333	25	2333	2333	0	2333	2333	2218	115	2218	2218	0	2218	2198	>20											
443632	2340	245	-117.728	47.62818	2340	2334	6	2334	2334	0	2334	2334	2235	99	2235	2235	0	2235	2090	>140											
443666	1986	436	-117.4536	47.585377	1986	1981	5	1981	1981	0	1981	1981	1981	0	1981	1981	0	1981	1981	0	1981	1981	0	1981	1526	>440				<1526	
443679	2299	380	-117.5531	47.678799	2299	2287	12	2287	2287	0	2287	2287	2234	53	2234	2194	40	2194	1989	205	1989	1954	35	1954	1919	>40				<1919	
445280	2424	140	-117.5561	47.53177	2424	2407	17	2407	2407	0	2407	2407	2284	>120																	
445291	2440	335	-117.7009	47.6364	2440	2440	0	2440	2349	91	2349	2349	2208	141	2208	2208	0	2208	2100	>110											
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445294	2110	390	-117.512	47.6803	2110	2110	0	2110	1778	332	1778	1778	1778	0	1778	1778	0	1778	1778	0	1778	1778	0	1778	1720	>50				<1720	
446897	2448	120	-117.4097	47.511762	2448	2442	6	2442	2442	0	2442	2442	2328	>110																	
446909	2102	440	-117.3891	47.551952	2102	2077	25	2077	2077	0	2077	2077	2077	0	2077	2077	0	2077	1952	125	1952	1952	0	1952	1662	>300				<1662	
446916	2401	420	-117.6898	47.51995	2401	2401	0	2401	2401	0	NP	2401	2401	0	2401	2401	0	2401	2401	0	2401	2401	0	2401	2401	0	2401	2401	0	2401	1981
451214	2421	400	-117.5394	47.589943	2421	2395	26	2395	2395	0	NP	2395	2395	0	2395	2395	0	2395	2395	0	2395	2395	0	2395	2395	0	2395	2395	0	2395	2021
451220	2408	320	-117.7039	47.63865	2408	2408	0	2408	2279	129	2279	2279	2202	77	2202	2191	11	2191	2088	>110											
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454719	2397	70	-117.7066	47.7115	2397	2379	18	2379	2379	0	2379	2379	2327	>50																	
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468689	2416	300			2416	2415	1	2415	2415	0	2415	2415	2182	233	2182	2172	10	2172	2131	41	2131	2131	0	2131	2131	0	2131	2131	0	2131	2116
470133	2370	80	-117.6787	47.51796	2370	2370	0	2370	2370	0	2370	2370	2290	>80																	
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
475423	2329	485	-117.6067	47.6767	2329	2314	15	2314	2314	0	2314	2314	2218	96	2218	2199	19	2199	1958	241	1958	1897	61	1897	1844	>50				<1844	
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484540	2103	490	-117.5178	47.68506	2103	2102	1	2102	2102	0	2102	2102	2102	0	2102	2102	0	2102	1983	119	1983	1983	0	1983	1613	>360				<1613	
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491720	2208	280	-117.5584	47.711428	2208	2208	0	2208	2136	72	2136	2136	2136	0	2136	2136	0	2136	1967	169	1967	1928	>40								
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494595	2199	305	-117.4492	47.60974	2199	2141	58	2141	2141	0	2141	2141	2107	34	2107	2002	105	2002	1962	40	1962	1962	0	1962	1894	>60				<1894	
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
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522544	1937	300	-117.5799	47.7269	1937	1857	80	1857	1857	0	1857	1857	1857	0	1857	1857	0	1857	1857	0	1857	1857	0	1857	1637	>220				<1637	
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544196	2321	500	-117.5946	47.77264	2321	2318	3	2318	2318	0	2318	2318	2281	37	2281	2231	50	2231	2071	160	2071	2051	20	2051	1821	>230				<1821	
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544389	2240	330	-117.5233	47.66165	2240	2224	16	2224	2224	0	2224	2224	2151	73	2151	2101	50	2101	1963	138	1963	1963	0	1963	1910	>40				<1910	
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545161	2326	525	-117.587		2326	2325	1	2325	2325	0	2325	2325	2294	31	2294	2260	34	2260	1986	274	1986	1976	10	1976	1801	>160				<1801	
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545189	2112	480	-117.5219	47.680785	2112	2111	1	2111	2111	0	2111	2111	2111	0	2111	2111	0	2111	1932	179	1932	1795	137	1795	1632	>160				<1632	
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560430	2156	80	-117.5094	47.549614	2156	2156	0	2156	2078	78	NP	2078	2078	0	2078	2078	0	2078	2078	0	2078	2078	0	2078	2078	0	2078	2078	0	2078	2076
560682	2397	160	-117.6041	47.633445	2397	2397	0	2397	2337	60	2337	2337	2237	>100																	
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Borehole Name	Elevation	Total Depth	Longitude	Latitude	Top Qa	base Qa	QA iso	paleo top	paleo base	paleo iso	TOB	top Tw	base Tw	Tw iso	Top L1	base L1	L1 iso	Top Tgsb	Base Tgsb	Tgsb iso	Top N2-R2 IB	Base N2-Rs IB	N2-R2 iso	Top Tgw	Base Tgw	Tgw iso	Top L2	Base L2	L2 iso	Top Basement	Base:basement
616912	2334	380	-117.6213	47.747309	2334	2327	7	2327	2327	0	2327	2327	2310	17	2310	2160	150	2160	1954	>210											
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658244	2525	260	-117.5911	47.51491	2525	2523	2	2523	2523	0	2523	2523	2265	>60																	
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BCF544	2391	255	-117.5932	47.634175	2391	2391	0	2391	2136	>255	<2136																				
MARSH M-1A	2330	212	-117.5114	47.554619	2330	2330	0	2330	2127	203	NP	2127	2127	0	2127	2127	0	2127	2127	0	2127	2127	0	2127	2127	0	2127	2127	0	2127	2118
NWLW-MW9	1870	300	-117.3862	47.567458	1870	1870	0	1870	1650	220	1650	1650	1650	0	1650	1650	0	1650	1650	0	1650	1650	0	1650	1570	>80				<1570	
SCD-MW8	2334	380	-117.5582	47.66105	2334	2334	0	2334	2316	18	2316	2316	2189	127	2189	2124	65	2124	1954	>170											
SCR-MW4	2346	363	-117.5746	47.661397	2346	2340	6	2340	2340	0	2340	2340	2210	130	2210	2166	44	2166	1983	>180											
SCR-MW7	2342	360	-117.5726	47.664186	2342	2342	0	2342	2342	0	2342	2342	2202	140	2202	2160	42	2160	1982	>180											
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25/42-25J1 Sceva	1765	2060	-117.436	47.628662	1765	1642	123	1765	1765	0	1642	1642	1642	0	1642	1642	0	1642	1624	18	1624	1624	0	1624	1624	0	1624	927	697	697	600