1480 Drew Ave. Suite 100
Davis, CA 95618

530.753.6400
530.753.7030 fax

www.lwa.com

Technical Memorandum

LARRY WALKER ASSOCIATES

DATE: January 4, 2019

TO: Matt Parker and Elizabeth Nielsen
Flood Control and Water Conservation District
Siskiyou County

Prepared by: Larry Walker Associates

Brad. T. Gooch, Ph.D.

William Rice, P.G.

Steffen Mehl, Ph.D.

Laura Foglia, Ph.D.

Tom Grouvhoug, P.E.

SUBJECT: **California Department of Water Resources Bulletin 118 Basin Boundary Modification Denial, Shasta Valley Basin (#1-004), Technical Response**

The following technical memorandum provides data and analyses in response to the California Department of Water Resources (DWR) denial dated November 29, 2018 of Siskiyou County Flood Control and Water Conservation District's (the District) request as the Groundwater Sustainability Agency of the basin for a Basin Boundary Modification (BBM) of DWR Bulletin 118 (B118; DWR 2003) Shasta Valley Basin (#1-004).

On Dec. 10, 2018, the LWA team, directed by the District, began analyzing the well completion reports (WRCs) for the wells located in the proposed basin area outside of the current Bulletin 118 Shasta Valley groundwater basin (Figure 1 - Map of points and proposed basin boundary & Figure 1a - Map of points and proposed basin boundary with surface geology overlay). This effort was undertaken to provide DWR with <u>hydrogeologic data to support</u> the District's

Hydrogeologic Conceptual Model for the BBM of Shasta Valley. Attachment A lists the WCRs for the wells of interest – outside of the current Bulletin 118 Shasta Valley groundwater basin boundary but inside the proposed BBM and not including wells in the Western Cascade Volcanics (Tv).

We analyzed the WCRs by correlating the drillers' lithologic description with the screened or perforated intervals of the wells. If no screened or perforated interval was provided on the WCR, then the lithology at and after the depth of first water was noted. Through this process, we have assessed whether the lithology of the relevant screened, perforated, or otherwise saturated interval of the well is sedimentary, in accordance with the definition of an "aquifer" contained within the DWR SGMA Basin Boundary Regulations: *a three-dimensional body of porous and permeable sediment or sedimentary rock that contains sufficient saturated material to yield significant quantities of groundwater to wells and springs*.

Reference: California Code of Regulations; Title 23. Waters; Division 2. Department of Water Resources; Chapter 1.5. Groundwater Management; Subchapter 1. Groundwater Basin Boundaries; Article 2. Definitions; (f).

The sedimentary nature of the interflow deposits that exist within the various, successive volcanic deposits (such as Pluto's Cave Basalt; see Figure 1a - Map of points and proposed basin boundary with surface geology overlay) in the proposed Shasta Valley groundwater basin is represented in the well completion reports. Attachment B is a collection of WCR examples that contain this type of lithology (i.e. sedimentary and volcaniclastic). Below is the procedure we used to analyze the WCRs and correlate the production zones of the basin's aquifer(s) with the recorded lithology of the wells. Attachment C contains the District's WCR analyses and findings. We have combined all WCR locations outside of the current B118 boundary but within the proposed boundary, including locations in the Western Cascade Volcanics (Tv; see Figure 1 - Map of points and proposed basin boundary).

Detailed Procedure for Determination of Screened/Perforated Well Interval Aquifer Lithology in Attachment C:

1. Open WCR PDF via weblink in Column D; if no PDF link is available, mark N/A in Column E ('Screened/perforation/saturated interval lithologies')

2. Check if well report is for an abandoned or destroyed well; if so, mark N/A in Column E

3. Check if well is dry or if no lithology is listed; if so, mark N/A in Column E

4. Check Columns H ('TopOfPerforatedOrScreenedInterval_OR_DepthToFirstWater') and I ('BottomofPerforatedOrScreenedInterval') for the screened interval; if an interval is listed, then all lithologies listed in the pertinent interval in the WCR are entered into Column E ('Screened/perforation/saturated interval lithologies'). If screened intervals are not provided, then update the intervals or depth to water in Columns H and I,

appropriately. Lithologic descriptions in the WCRs often contain hydrogeologically relevant information for this memorandum's specific purpose: to distinguish sedimentary lithologies from volcanic fractured rock materials. Note: Original versions of Columns G, H, and I are included in Columns J, K, and L, respectively. Usage of "/" means that both cases are present as a short hand for usage of parentheses (e.g. un/fractured basalt means (un)fractured basalt for both fractured and unfractured basalt being present).

5. Once Column E is completely filled out, assign in Column F ('Sedimentary lithology present in screened and/or water-saturated interval?') a "y" for Yes a sedimentary feature is present in the interval (intervals can contain a mixture of different lithologies but any sedimentary lithology is all that is required for a "Yes"), a "n" for No sedimentary features are present in the interval, a "na" for Not applicable WCR, and a "u" for intervals with lithological descriptions that are unable to demonstrate a "Yes" or a "No." A rubric for making these decisions is included below.

Interval Rubric Table (included in Attachment C):

Sedimentary	**Non-sedimentary**	**Undeterminable Lithologies**
Alluvial	Andesite	Bedrock
Ash	Basalt	Boulders
Cinders	Diorite	Formation
Clay	Granite	Rock Chips
Claystone	Lava Rock	Rock(s)
Cobble	Quartzite or Quartz vein	
Conglomerate	Schist	
Decomposed Igneous Rock*	Serpentinite	
Gravel	Volcanic Rock	
Mudstone		
River Rock		
Sand		
Sandstone		
Shale		
Silt		
Tuff		

*Decomposed and weathered adjectives indicate a sedimentary lithologic material, based on field observations and communications from well drillers operating in the area.

6. Upon completion of all WCRs, use GIS methods to sample and record surface geology from the California Geologic Survey's (CGS) 1987 Weed Quadrangle for each WCR location in Column M ('CGS Weed Quadrangle 1987 Surface Geology').

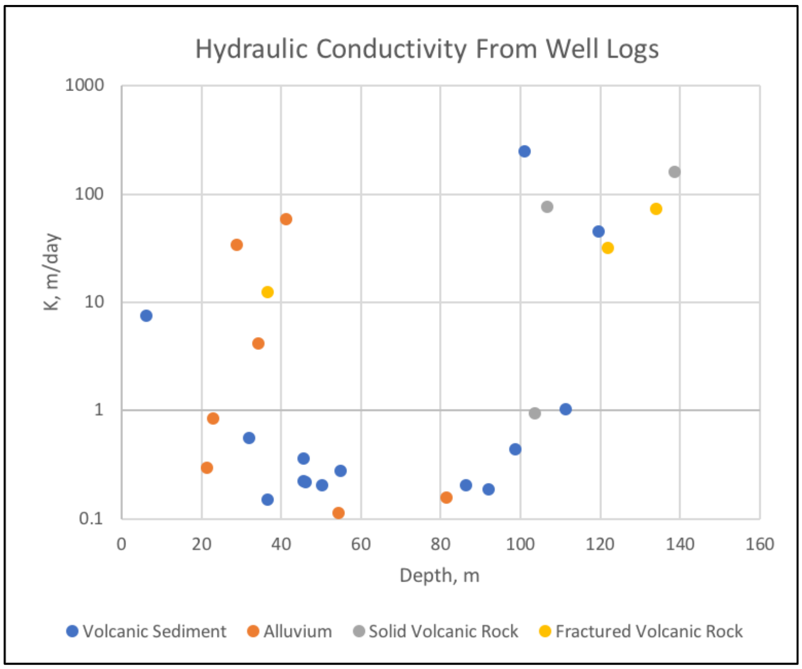
Results

Principal aquifers

There are six major hydrogeologic units in the area: the High Cascade volcanics, the Western Cascade volcanics, the alluvium, the Hornbrook Formation, the Trinity Ophiolite, and a possible Granodioritic fractured rock aquifer (basement). The Western Cascade volcanics are very fractured and have high hydraulic conductivity (DWR 2004). There is a Pleistocene-age landslide that covers the western part of Shasta Valley with a poorly sorted debris flow of Western Cascade sediment containing a high degree of clay (Crandell et al. 1984; DWR 2004; Jeffres 2015). The High Cascade volcanics include the recent Pluto's Cave basalt flow (Mack 1960). Pluto's Cave Basalt, is a highly vesicular formation on the eastern portion of the Shasta Valley, is considered part of the High Cascade volcanics. The interface between individual lava flows, fractures and lava tubes provides preferential flow paths capable of transmitting large quantities of water (DWR 2004). Accordingly, the unit provides substantial quantities of water to wells with yields averaging 1,300 gal/min (80 l/s) and as high as 4,000 gal/minute (250 l/s) (DWR 2004), which is high, even for alluvial aquifers. The interface between the highly fractured and permeable basalt flow and the low permeability debris flow deposits resulted in the issuance of numerous springs (Ward and Eaves 2008). The volcanic flows of Shasta have been mostly andesitic and basaltic, but include some dacite (Williams 1949). Both volcanic units likely have high permeability, however, the eastern High Cascade volcanics are predicted to have higher hydraulic conductivity than the western debris flow volcanics (Buck 2013). Many springs surface at the boundary between these two units (Mount et al. 2010).

WCR Lithologic Cataloging Results

The original basin boundary modification request included a preliminary analysis of well completion reports (including well tests in various aquifer materials) in the Township and Ranges 40N 02W, 40N 03W, and 40N 04W. The analyses indicated that the alluvium and volcanic layers are interspersed, with many cores alternating back and forth between alluvial and volcanic layers and that the hydraulic conductivities of both the alluvium as well as the volcanic rocks are sufficient to support productive wells. The alluvium sampled range from 0.3 ft/d (0.1 m/d) to 192 ft/d (58.6 m/d), while the volcanic rocks range from 0.7 ft/d (0.2 m/d) to 813 ft/d (247.8 m/d), as reported by the well completion reports. The volcanic rocks have a higher hydraulic conductivity if they contain fractures. In the 32 wells analyzed for the original BBM request, 18 of them sampled water that was in either volcanic alluvium (sand- or gravel-sized volcanic rock) or a mixture between volcanic rocks or ash and non-volcanic alluvium.



Hydraulic Conductivity calculated from well completion reports.

The existence of fractures in three of the wells further supports the claim that the volcanic and alluvial aquifers are connected. Fractures tend to act as conduits that enhance permeability and provide pathways for water to flow between different layers. The fractured volcanic rocks have an average hydraulic conductivity of 129 ft/d (39.4 m/d), which is higher than the average hydraulic conductivity of the alluvium (53.5 ft/d, or 16.3 m/d) and the unfractured volcanic rocks (93.5 ft/d, or 28.5 m/d). In addition to well completion reports, the California Statewide Groundwater Elevation Monitoring System (CASGEM) has water level data for 36 wells in the Shasta Valley (State of CA, 2015). The water levels in the alluvium follow the same general head versus elevation trend as the water levels in the volcanic rocks, and there is no significant difference in water levels between the two lithologies. Given this correlation, it is probable that the alluvial and volcanic aquifers are connected.

The new analysis conducted for the present technical memo is presented in the tables below. More than 1,500 well logs have been analyzed and results indicate that the majority of the producing wells in the proposed Shasta Valley groundwater basin have screened intervals, or depth to first water, in porous and permeable sediment or sedimentary rock, derived from volcanogenic, debris-flow, or glacial deposits. The majority of all of the WCR locations are inside mapped surface geology units marked as volcanic versus alluvium as well.

Sedimentary lithology present in screened, perforated, or water-saturated interval?	
Yes	1067
Undeterminable	102
No	219
N/A	125
Total	1513

Total wells	1513
Total - N/A	1388
Yes / (Total - N/A)	77%
No / (Total - N/A)	16%
Undeterminable / (Total - N/A)	7%
Sum of above %'s	100%

Surface Geology (CGS weed Quad. 1987) Sampled at WCR Locations	Count	Percent
Q- Alluvium	303	20.0%
Qg- Glacial deposits	84	5.6%
Qv- Pleistocene Volcanic rocks	415	27.4%
Qvs- Volcanic rocks of Shasta Valley	596	39.4%
SOd- Duzel Formation	3	0.2%
Tv- Western Cascade Volcanics	63	4.2%
“Water”	49	3.2%
Total	**1513**	**100%**

A significant amount of irrigated land outside of the current Bulletin 118 Shasta Valley basin boundary is irrigated by groundwater (Figure 2 - Map of water source and proposed basin boundary). Figure 3 (Map and tables of water sources for Shasta Valley) also shows water sources for Shasta Valley, as described in the 2011 DWR Shasta Valley Groundwater Data Needs Assessment. Much of the irrigated land derives its source water from surface water sources; however, two areas largely use groundwater (annotated on Figure 3 in red circles): Gazelle/Grenada and Pluto’s Cave Basalt. While the Gazelle/Grenada subbasin groundwater-irrigated area is largely included in the current basin boundary, the groundwater-irrigation areas of the Pluto’s Cave Basalt area are not. This area outside of the current basin boundary is of substantial hydrogeologic importance for transmitting large volumes of water through the interconnected aquifer system.

Conclusion

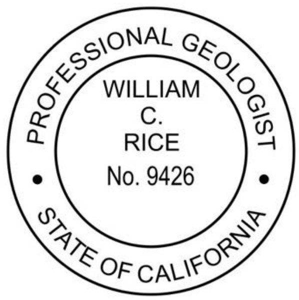
Siskiyou County is requesting a change of the boundary of the groundwater basin: many groundwater aquifers exist in the drainage area, but currently only the narrow, alluvial aquifer nearest the river is designated by the California Department of Water Resources (DWR) as a groundwater basin (DWR 2004). The geological, geophysical, and hydrological evidence support the extension of the current groundwater boundary to include both the alluvial unit and the volcanic units. The units have been shown by the analysis of well logs developed in the present memo, modeling, and mapping to be a part of a connected aquifer system. Numerical models further support this claim (e.g., Buck 2013) which indicates flow across the valley from volcanic to alluvial aquifers. Extending this basin boundary area would provide the ability to better manage the current designated groundwater basin which is heavily impacted by the flows from the groundwater system in the extended area. Quaternary alluvium, terrace, and glacial deposits are scattered over the valley and most of the Quaternary alluvium only occurs in the narrow Shasta River corridor and its tributaries. However, the baseflow of the Shasta River and its tributaries is directly reliant on groundwater contributions from the Western Cascades Volcanics, the High Cascades Volcanics, and the Volcanic Rocks of Shasta Valley. In effect, the vast majority of land use and groundwater pumping that exists outside of the current Bulletin 118 (2003) alluvial basin boundary has direct and indirect impacts on groundwater in the alluvium and the baseflow of streams. Technical studies over the last 60+ years have investigated and documented the hydrology and geohydrology of Shasta Valley's groundwater and surface water; there is consensus that the volcanic deposits and the alluvium define the basin.

In summary, the detailed WCR Lithologic Cataloging Result Tables presented in this technical study further supports the finding of previous studies and shows that 77 percent of the wells analyzed (not including those designated N/A) in the proposed BBM area indicate that these wells are producing groundwater from porous and permeable sediment or sedimentary rock in the screened, perforated, or saturated interval. Furthermore, the proposed BBM area has substantial hydrogeological importance for transmitting large volumes of water from areas of recharge, supporting spring flows, and providing water to agricultural wells. Future work to develop the Groundwater Sustainability Plan (GSP) for the Shasta Valley groundwater basin will refine and confirm the geohydrologic nature of this complex basin. Development of management scenarios that include only the alluvium aquifer will limit considerably the capability of the District to reach sustainability and design groundwater management solutions that can enhance sustainability. Analysis of the entire aquifer system is needed to address SGMA concerns and provide a successful GSP for the Shasta valley.

Sincerely,

Larry Walker Associates

Information, conclusions, and recommendations made by Larry Walker Associates in this document regarding this site have been prepared under the supervision of and reviewed by the licensed professional whose signature appears below.



Brad. T. Gooch, Ph.D.

William Rice, P.G.

Steffen Mehl, Ph.D.

Laura Foglia, Ph. D.

Tom Grouvhoug, P.E.

Attachments:

Figure 1:	Well Locations Investigated in Attachments A & C with
Figure 1a:	Same as in Figure 1 with Additional Surface Geology Overlay
Figure 2:	Map of Water Sources and Proposed Basin Boundary (DWR and SVRCD)
Figure 3:	Map and Tables of Water Sources for Shasta Valley (DWR 2011)

Attachment A:	Well Completion Report Spreadsheet
Attachment B:	Examples of Shasta Valley Well Completion Reports with Sediments and Sedimentary Rock
Attachment C:	Annotated Well Completion Report Spreadsheet

Note: All attachments are included with this technical memorandum.