Idaho Department of Water Resources

Open File Report

REVIEW OF HYDROGEOLOGIC CONDITIONS LOCATED AT AND ADJACENT TO THE SPRING AT RANGEN INC.

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TABLE OF CONTENTS

INTRODUCTION

GENERAL GEOLOGY

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

This report provides a hydrogeologic review from new information for the area located at and adjacent to the Rangen Inc. spring Gooding County, Idaho. Geological controls for groundwater movement in the area include three main hydrostratigraphic units. An upper basalt overlies mostly Tertiary clastic sediments that were deposited on a deeper basalt. Groundwater flows through the upper and lower basalt as well as the sediments.

Acknowledgements

The staff at Rangen Inc. has been very helpful and cooperative with allowing access to property and spring areas for geologic inspection and GPS surveying. They also provided useful information about the character of the spring discharge patterns, Curren Tunnel, confirming wells with well drilling reports and general social and agricultural perspectives.

Frank Erwin, a long time resident of the Hagerman Valley for more than half a century and also the local water master, is one of the most valuable sources of information that I have encountered from my research in the Hagerman Valley since 1996. Without Frank's help, confirming well locations would have been much more difficult. Frank was aware of my geologic investigations and from his keen sense of geologic knowledge he discovered and brought to my attention a new Glenns Ferry Formation outcrop on the east side of the Hagerman Valley during the summer of 2008 which I refer to as the 'Erwin Outcrop'.

I would also like to thank all of the local residents that I spoke with about well locations, and agreeable disposition allowing me to GPS wells and collect water levels.

I thank the Idaho Department of Water Resources for their continued support, dedication and commitment to gaining additional information to assist with defining the aquifer systems to a greater degree of detail; Dr. Virginia Gillerman with the Idaho Geological Survey for review and editing; and Dr. Allan Wylie with IDWR for review and editing.

Problem, Purpose and Objectives

There is a need for a greater understanding of the aquifer systems near the springs located at Rangen Inc.. For example, does the aquifer that provides water to the Rangen spring area, flow through basalt, sediments or some combination of both? The purpose of the field work was to add to the body of existing knowledge in order to gain a better understanding of the hydrologic data from spring flow rates and groundwater levels. The geologic controls were looked at more closely from outcrop inspection, newly published geologic maps and a new monitor well located 588 feet east of Rangen. The objective of this report is to provide a synthesis of data and information gained from field work and present a hydrostratigraphic flow model with a possible application to numerical groundwater flow models and aquifer recharge.

Geographic Setting

The Hagerman Valley is located 90 miles southeast of Boise. It has been formed within a major geologic transition boundary between the eastern and western Snake River Plain (Figure 1). The springs at Rangen are located on the east side of the Hagerman Valley (Figure 2) within the Eastern Snake River Plain which is dominated by volcanic rock types. The Western Snake River Plain geology is dominated by clastic sediments (Bonnichsen and Breckenridge, 1982). The legal land location for the Rangen spring area is Gooding County, Township 7 south, Range 14 east, section 32, SW1/4 of the NW1/4. The US Geological Survey (USGS) topographic map elevation shows the plateau immediately above Rangen is about 3,220 feet in elevation above mean sea level (MSL), GPS records the elevation of the spring water at the Curren Tunnel at 3,145 feet with a lower spring discharge zone of about 3,100 feet (Figure 3).

The city of Hagerman is about 2,975 feet, Lower Salmon Falls Reservoir at 2,800 feet and the Upper Salmon Falls Reservoir at Sligars Hot Springs is 2,876 feet elevation. Well vegetated talus slopes and numerous landslides occur along the hill side below the rim on the east side of the valley. Vegetation patterns can act as the surface expression, or tracer, to underlying geologic lithology and aquifer discharge (Farmer and Nagai, 2004).

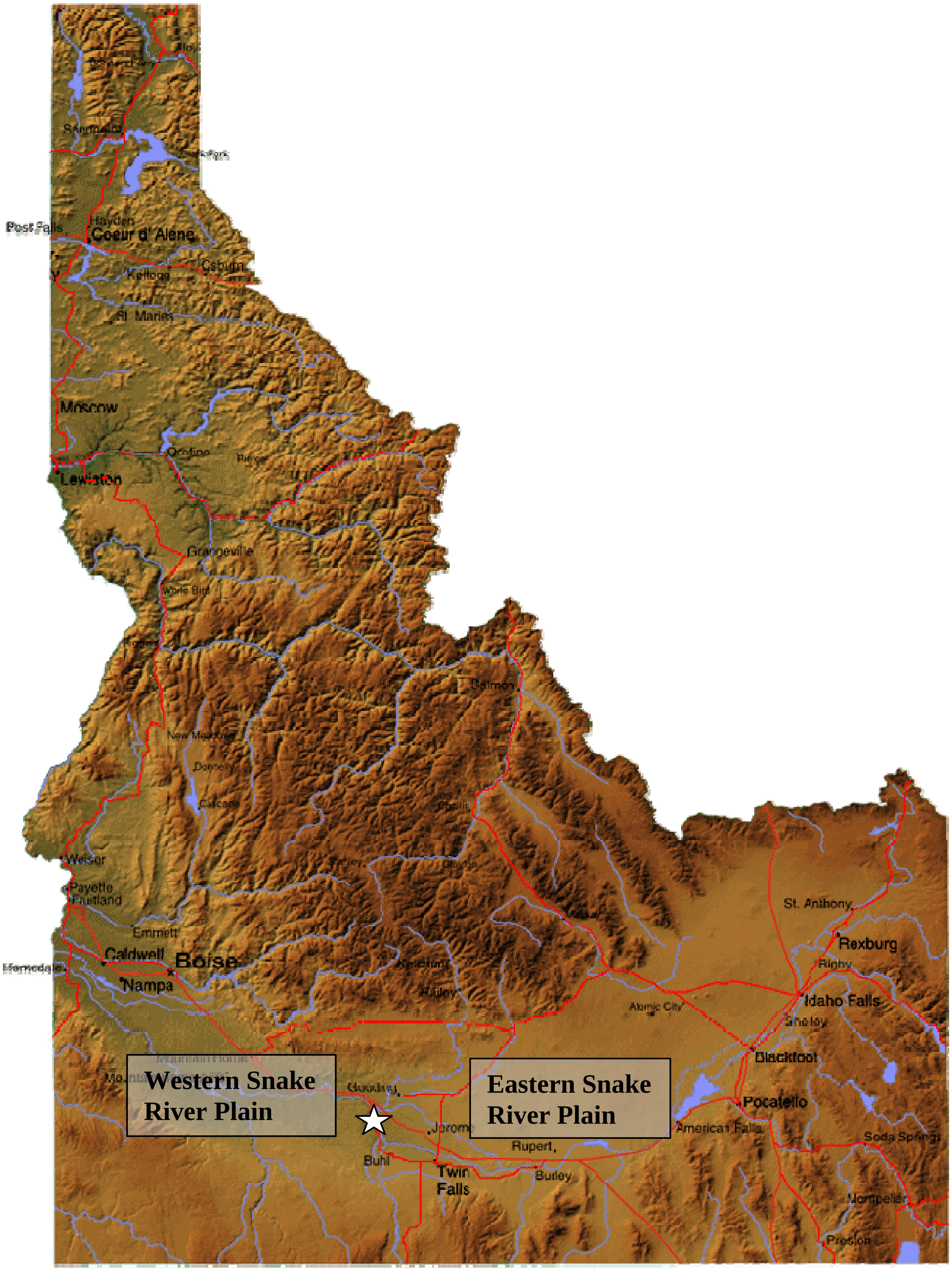


Figure 1. General locations of the eastern and western Snake River Plain with a transition zone between the two geologic provinces located in the Hagerman area noted by the star.

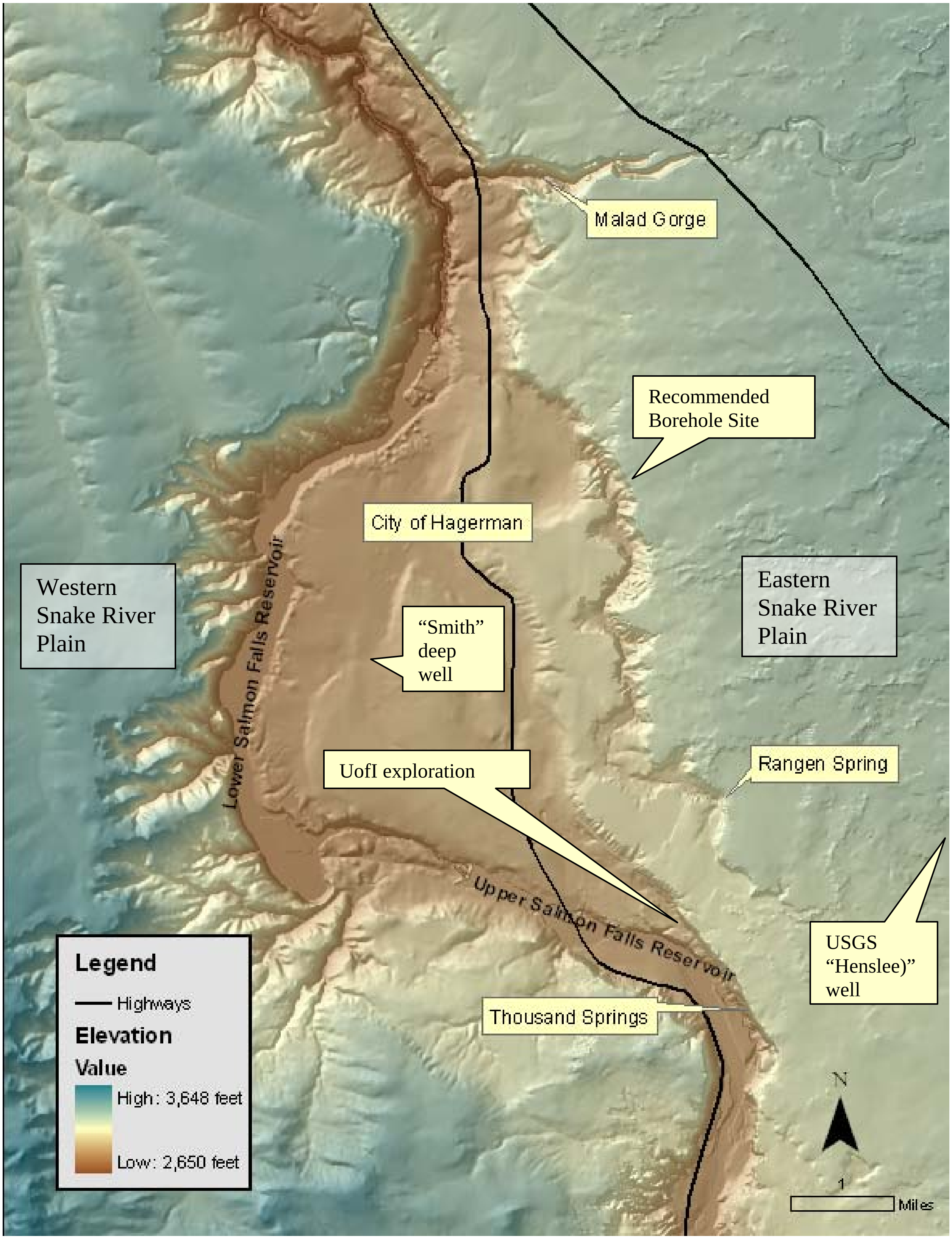


Figure 2. Shaded elevation relief map of the Hagerman Valley.

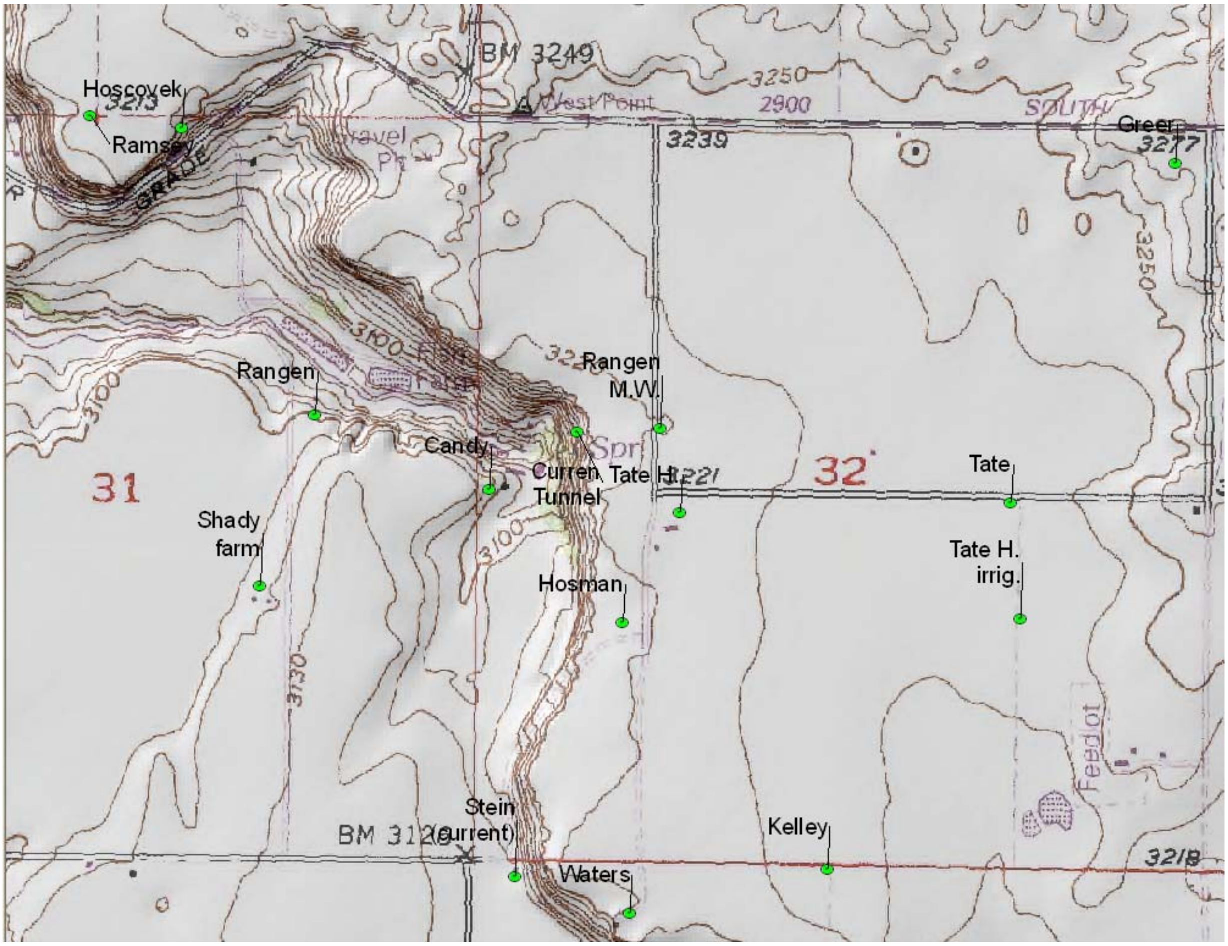


Figure 3. 1:24,000 scale USGS topographic shaded relief map with 10 foot contour line intervals showing the square mile section 32 and east half of section 31. The locations of the Curren Tunnel at Rangen and nearby wells are noted as green circles.

GENERAL GEOLOGY

Geologic Setting

The east side of the Hagerman Valley is located at the western edge of the eastern Snake River Plain in southern Idaho. The valley is an approximately six square mile expanse of Snake River flood plain bounded by steep canyon walls on the west and basalt cliffs on the east. The fine-grained flood-plain sediments of the Glenn's Ferry Formation (GFF) dominate the stratigraphy on the west side of the valley, acting as impediments to ground water flow, with intercalated basalt lavas and buried fluvial channel facies acting as hosts for preferential ground water flow within the low-permeability sediments (Farmer, 1999).

“In addition to the impacts of outcrop and larger-scale heterogeneity seen in the basalt-dominated ESRP aquifer, groundwater flow is controlled by even larger-scale heterogeneity, such as where the fine-grained, low permeability GFF sediments interfinger with the highly permeable basalts on the east side of the Hagerman valley shown in Figure 14 cross-section A-A'. As well as being a zone of lithologic and stratigraphic change, the Snake River has downcut and exposed the ESRP groundwater flow system in the Hagerman Valley, creating some of the largest natural springs in the U.S. collectively known as the Thousand Springs area, but comprising many individual spring complexes such as Ten Springs, Thousand Springs, Malad Gorge Springs, etc.. The valley is a topographic depression displaying outcrops that suggest it may be structurally controlled and the geomorphic expression of the interplay between weathering, fluvial erosion and volcanism. The GFF sediments impart a striking hydraulic contrast to the basalts' high permeability and, like almost all sedimentary interbeds intercalated within the aquifer's basaltic stratigraphy, they have a marked effect on groundwater flow.” (Welhan, 2008)

A series of sediments named the Idaho and Snake River Groups have been deposited non-conformably on the Idavada volcanics (Figure 4). The Idaho Group is composed of seven formations identified by Malde and Powers (1962), and covers several thousand square miles in a wide area of the western Snake River Plain. The Glenns Ferry and possibly the Tuana Formations crop out at Vader Grade road cut ¾ of a mile northwest of Rangen (Figure 5). These Cenozoic sediments are a combination of lake, stream and flood plain deposits inter-bedded with an occasional basalt flow, silicic volcanic ash and basaltic pyroclastic deposits.

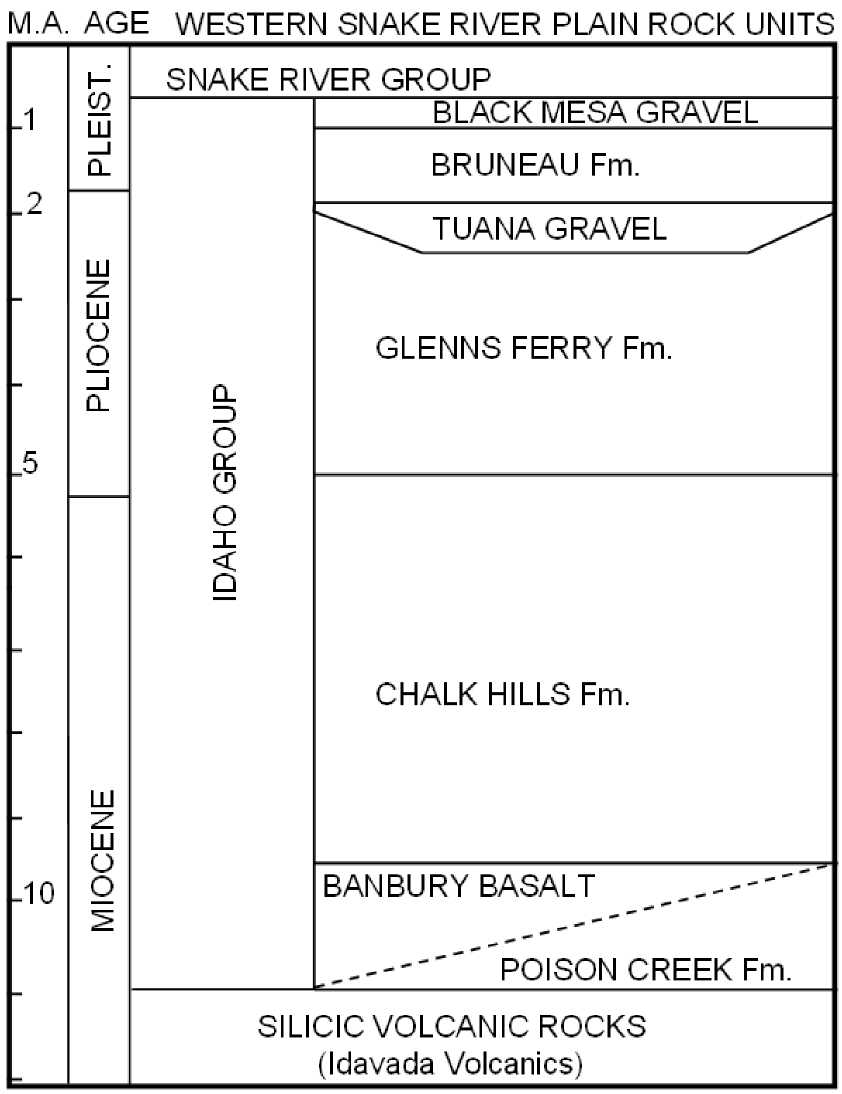


Figure 4. Sequence of upper Cenozoic rocks in the western Snake River Plain, Owyhee County, Idaho (modified from Malde, 1991)

Figure 5. Fresh exposure of GFF (A) at Vader Grade road cut (B) and fossil willow leaves (C&D) and a bivalve (E). Note the darker horizontal banding above and left of the pickup truck from groundwater flowing through the GFF but not from the overlying basalt at this location. The top panorama photo is looking west from Rangen area with the Vader Grade in the foreground and the Hagerman Fossil Beds in the distance.

The Snake River Plain is a major late Cenozoic tectonic/volcanic feature in the northern portion of the Basin and Range geologic region. The plain extends across southern Idaho for roughly 300 miles in a crescent shape. It is divided into two main sections identified as the western and eastern Snake River Plain. The western portion is about 40 miles wide, bounded by normal faults and has a northwest-southeast trend. Malde and Powers (1958) recorded at least 9,000 feet of displacement between the highlands to the north and the elevation of the plain today and concluded about 5,000 feet of displacement occurred in the early and middle Pliocene. The displacement started about 17 million years ago by rifting and down warping of the plain. The subsequent stretching of the crust produced a basin that began filling with sedimentary and volcanic rocks of considerable thickness during the Miocene, Pliocene and Pleistocene (Malde, 1991).

Malde and Powers (1962) divided the Idaho Group into seven formations ranging in age from 11 million to 700,000 years old. In ascending order they are Poison Creek/Banbury Basalt, Chalk Hills, Glenns Ferry, Tuana Gravel, Bruneau and Black Mesa Gravel (Figure 4). These formations are composed of clastic sedimentary lithologies and inter-bedded olivine basalt flows, silicic volcanic ashes and basaltic pyroclastic material with an aggregate thickness up to 1500m (Malde and Powers, 1962). Most of the sediments are poorly consolidated and range in texture from clay to gravel. The GFF (and possibly the Tuana Gravel Fm. (TGF)) and Quaternary age basalt of the Idaho Group are mapped at Rangen. Figure 6 illustrates a generalized geologic map in the vicinity of the study area based on a map by Malde (1972a) and updated by the Idaho Geological Survey in 2005 (Gillerman et al, 2005). Complete descriptions of the mapped geologic units are located in Appendix 1 but a brief overview for the GFF is provided in the following.

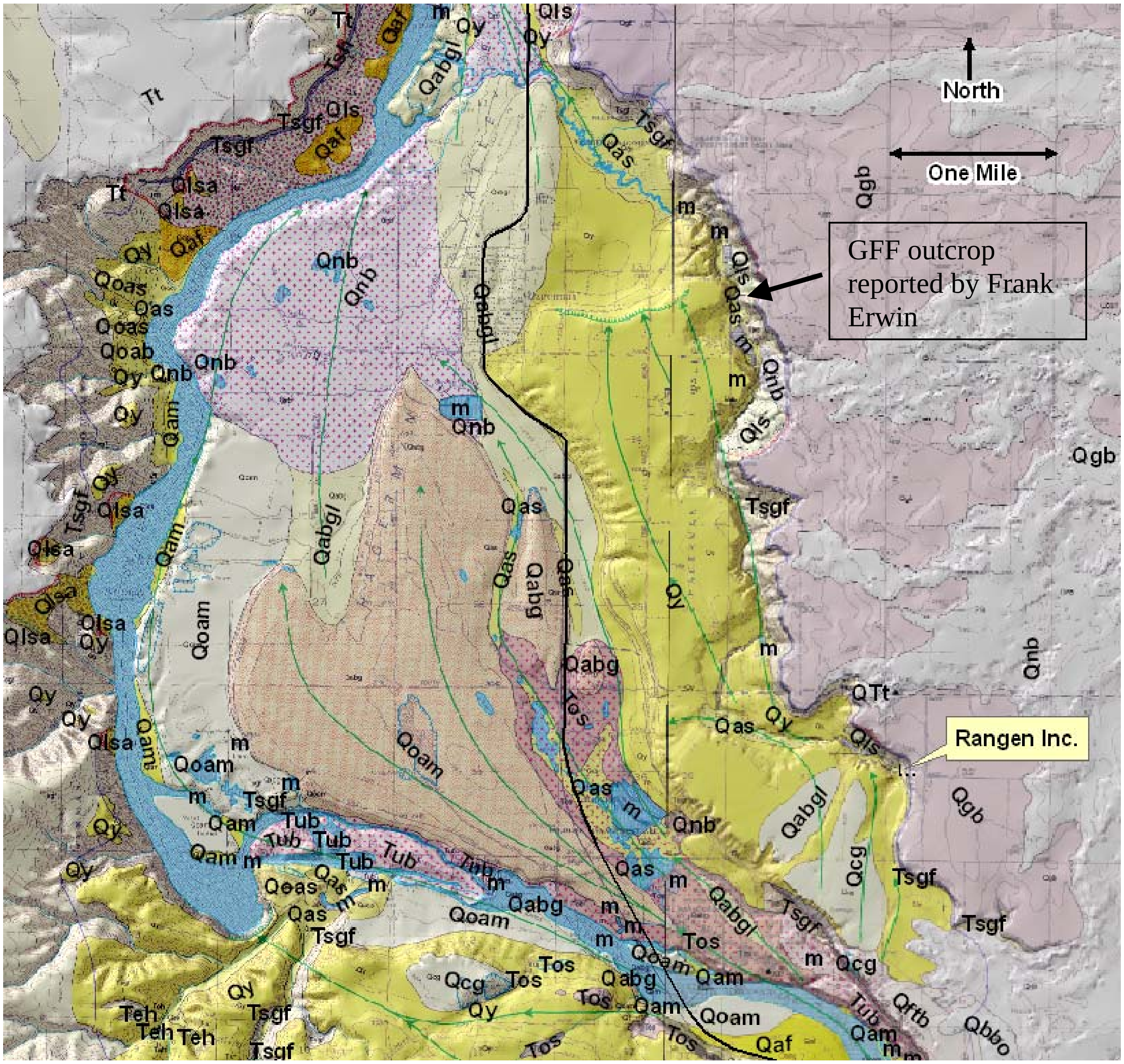


Figure 6. Shaded relief geologic map of the Hagerman Valley (modified for display from Gillerman et al, 2005). The Hagerman and Tuttle Quads are shown and see appendix for geologic descriptions.

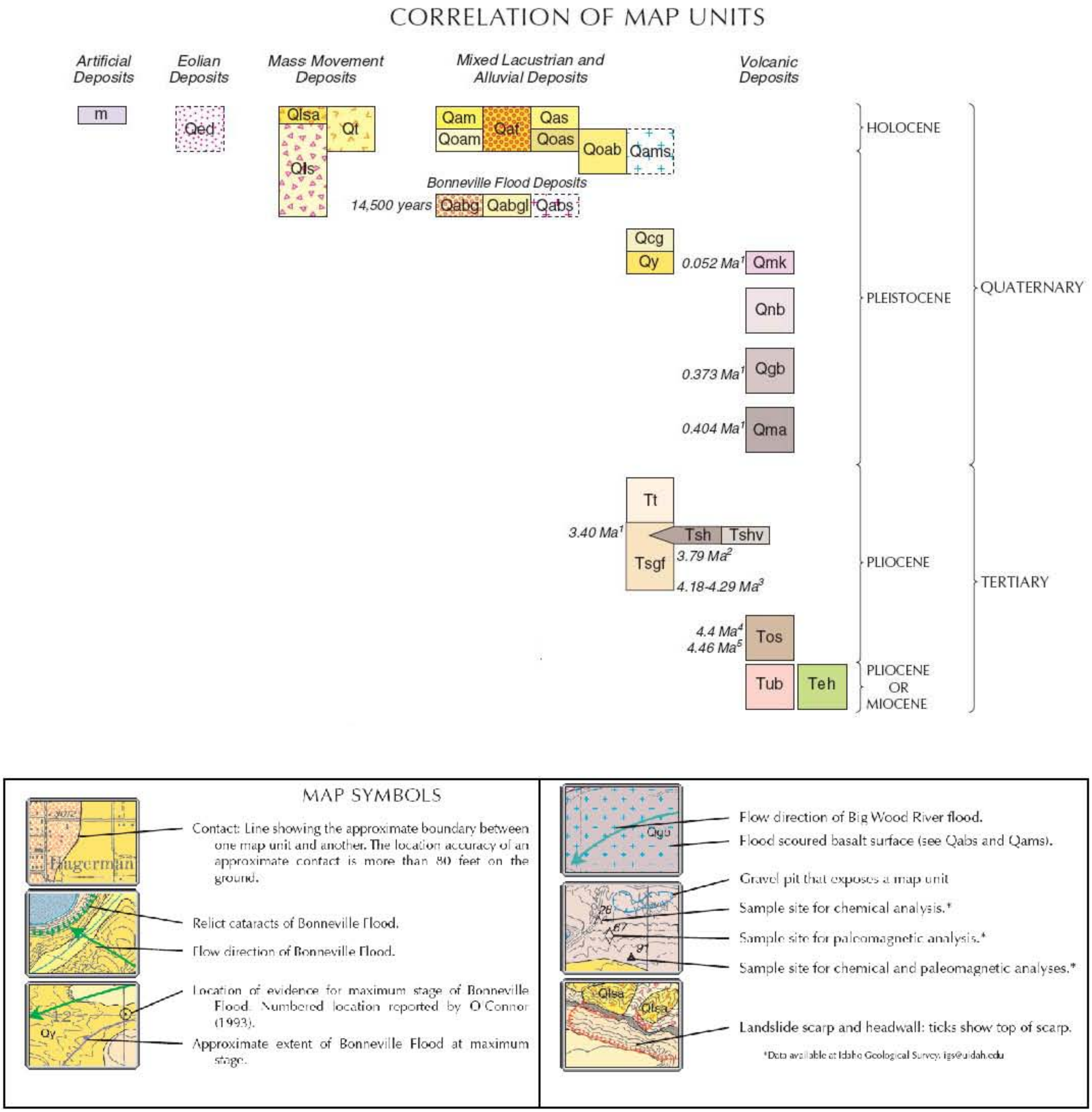


Figure 7. Map symbols and correlation of geologic map units (from Gillerman et al, 2005).

The age of the GFF is broadly constrained from Pliocene to early Pleistocene or 5 to 1.5 MA. (Malde, 1991). It exhibits four major environments including sandy fluviatile, muddy flood plain, lacustrine and valley border facies (Malde, 1972b). Primarily fluviatile and flood plain environments were observed in outcrop at Vader Grade road cut, Malad Gorge, Bliss Grade and a new outcrop reported by the local water master Frank Erwin after a wildfire burned off the vegetation and exposed the sediments at Indian Springs (NW, SW, sec. 18,T7S R14E) during the summer of 2008. It is unknown if the outcrop is in-situ due to landslides in this area. The flood plain deposits of the Hagerman area are marginal to and east of the lacustrine facies that crop out near the town of Glenns Ferry and continue westward as illustrated in Figure 8 (Malde, 1972b;

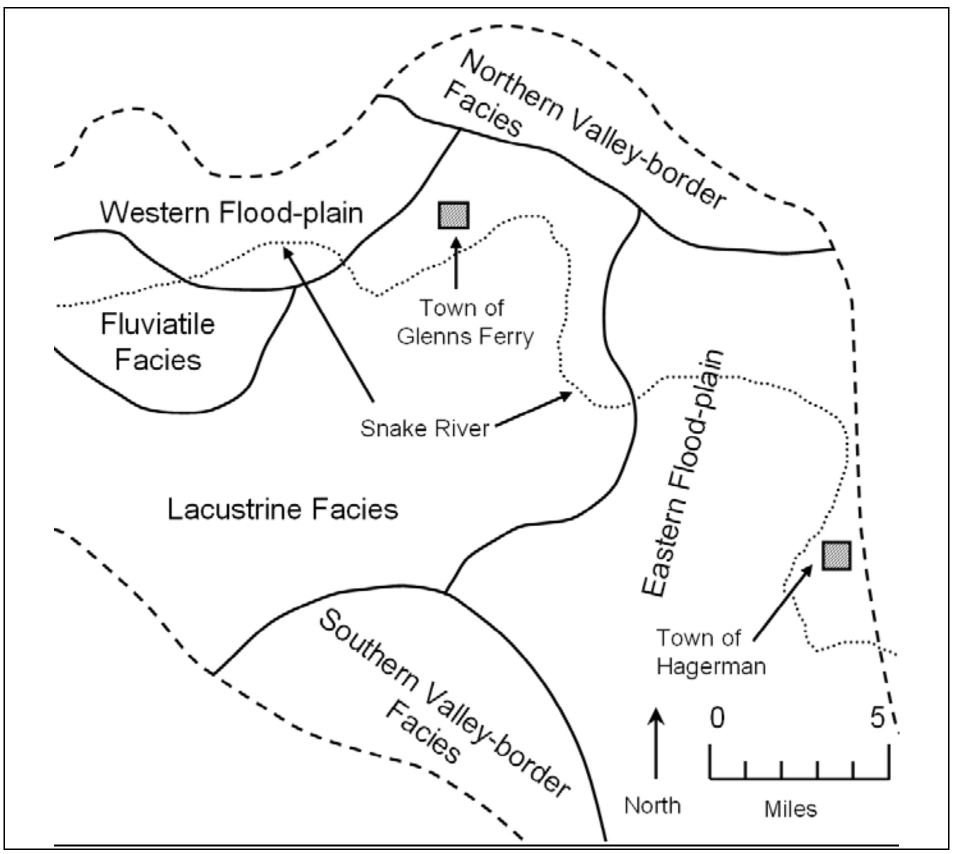


Figure 8. Distribution Glenns Ferry Formation sedimentary facies in the Glenns Ferry/Hagerman area (after Malde, 1972b).

Malde, 1991). Lacustrine deposits consist of massive tan silt and fine-grained sand forming monotonous outcrops and were deposited in ancient "Lake Idaho". The outcrops of fluvial facies are predominately found east of the town of Glenns Ferry (Figure 8). Coarse-grained arkosic sands and cobble gravels of the valley border facies are present at both the northern and southern margins of the western Snake River Plain (Malde, 1972b).

Malde (1972b) describes the depositional setting as a highly sinuous meandering stream and flood plain which formed the delta plain marginal to a perennial lake to the west. The climate was predominately humid but also semi-arid at times.

> "... the river flowed in a wide valley marked by temporary lakes and by broad stretches that were seasonally flooded. As the river shifted its course, the sedimentary environments changed correspondingly. Even so, the persistence of rather uniform environments in certain areas is shown by surprisingly thick sequences of fairly uniform deposits (Malde, 1972b, page D13)."

Lee (1995) recognized two lithofacies associations, sandy and muddy. These are equated to represent a channel and flood plain environment within a meandering stream system. Sandy associations make up about 25% of the GFF at the northern end of the Hagerman Fossil Beds National Monument (Lee, 1995). The sandy fluviatile association contains lithofacies of gravely sand, trough cross-bedded sand, ripple-marked and scour-fill sand generally arranged in upward-fining successions. These are interpreted to represent point bar deposits in a mixed-load, highly sinuous meandering stream system. Bjork (1968) described these channel sands as grey, micaceous quartz sand that is uniformly fine-grained.

Muddy facies sequences with local organic rich and pedogenic facies make up about 75% of the Glenns Ferry Formation (Lee, 1995). The muddy facies association accumulated vertically in flood plains periodically inundated by water from floods in the fluvial system and consists mainly of pale olive colored silty clays and clayey silt beds arranged in upward fining cycles at a scale of decimeters to meters (Lee, 1995). These deposits are commonly characterized by monotonous fine-grained, graded, calcareous, pale-olive silt beds from one to three feet thick capped with a dark, carbonaceous clay from one to several inches thick (Malde, 1965).

The Tuana Gravel Formation rests on the GFF and Saddler (1997) describes the composition of the Tuana Gravels as coarser grained sediments in the silt, sand and gravel fractions. Thickness of the gravel varies up to 200 feet but is commonly about 50 feet thick within the study site (Bjork, 1968). Malde (1965) describes the Tuana as gradually rising in elevation and thickening southward and suggests that the ancestral Snake River deposited the gravels across the valley. The exposed base of the Tuana Gravel exhibits cut and fill stream channels in the underlying silts and clays of the Glenns Ferry Formation. These stream channels are commonly filled with fine sand.

Geologic Model

A three layer geologic model (Figure 9) for the east side of the Hagerman Valley is proposed and it provides the foundation for the hydrostratigraphic model. The model is based on literature review, examination of geologic outcrops and geologic units within the plateau were inferred from drill report logs. Figure 9 shows the three main hydrostratigraphic units on the east side of the valley located near Rangen Inc. spring area consisting of Quaternary basalt overlying Glenns Ferry Fm. overlying Tertiary basalt. The west side of the valley is well defined from excellent geologic exposures and drill logs from within the plateau (Farmer, 1999). Groundwater tracer tests were performed at the Bell Rapids Irrigation District area by Farmer and Larson (2001) and Dallas (2005) within a perched aquifer flowing through a brown colored

Tertiary Basalt flow that is one unit intercalated within the GFF about 200 feet below the plateau surface. Results from dye tracer tests document a highly permeable Tertiary Basalt that does not exhibit in outcrop, drill logs or video logs pillow features or water affected characteristics which can increase permeability. This one basalt and subsequent tracer tests demonstrate that older brown colored Tertiary age basalt may be highly permeable which is a typical characteristic of Quaternary basalt. Although the Tertiary basalt tested may be a localized anomaly, the studies document the potential does exist for highly permeable Tertiary basalts.

The geologic outcrops along the Thousand Springs complex on the north side of the river located in the southeast part of the Hagerman Valley show that geologic structure is playing a significant role controlling groundwater flow. Where the Rangen Spring (and probably other springs north from Rangen up to Malad Gorge) has a strong component of paleo-topographic lows controlling flow characteristics, the Thousand Springs complex does not. Presented by Farmer (2008) at the Idaho Water Resources Research Institute “Groundwater Connections” conference and forthcoming in a report, the Thousand Springs zone of discharge is dominated by a structural geologic “ramp” that is faulted and dips into the Hagerman Valley at approximately 8-10 degrees. Groundwater is flowing down this ramp structure through a pillow zone and contact between Quaternary basalt flows.

Geologic Transition Zone of the Eastern and Western Snake River Plain

(Conceptual Model)

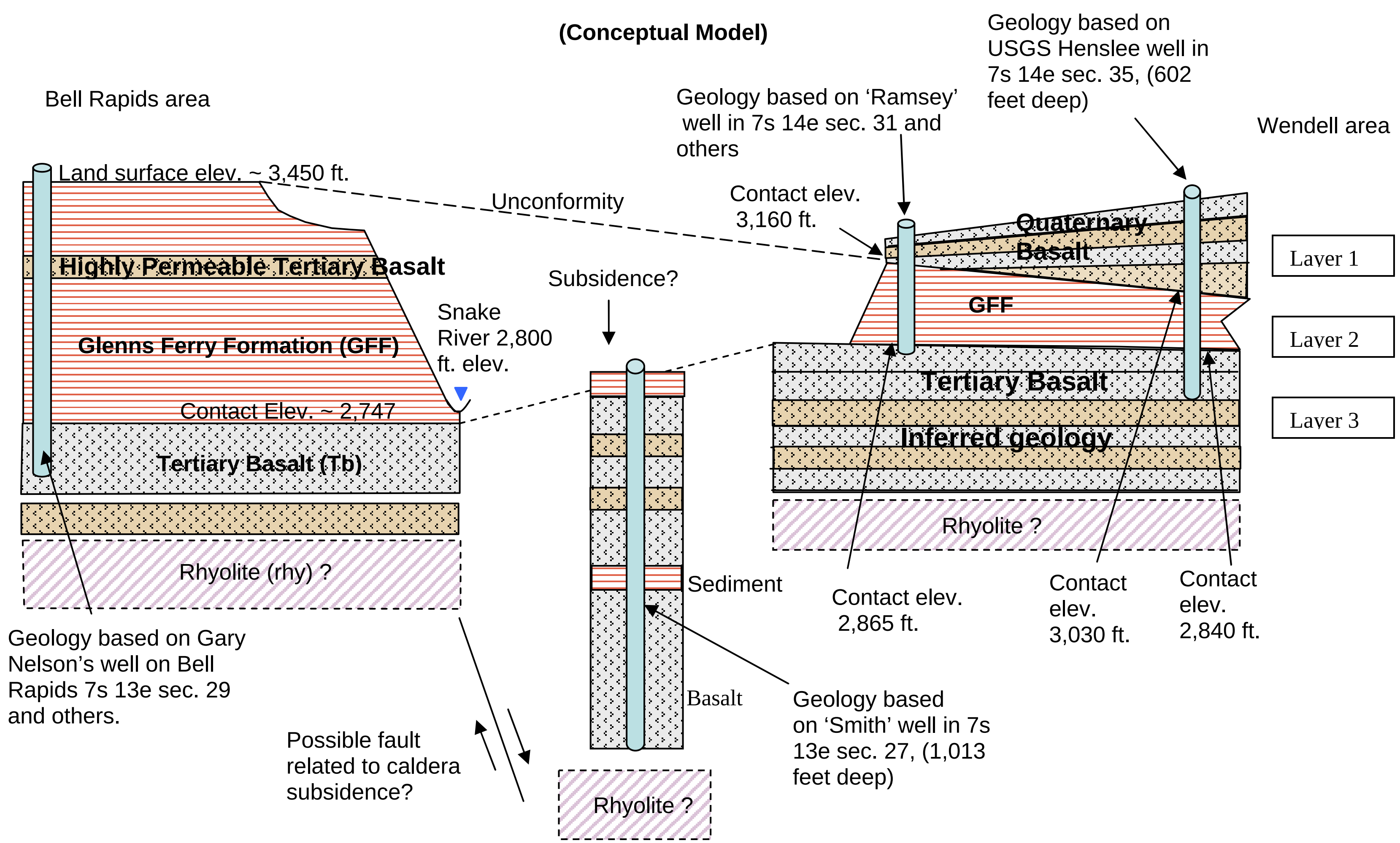


Figure 9. Conceptual 3-layer model of east Hagerman Valley (not to scale). The Tb/rhy contact may not have been horizontal and the Qb/GFF contact is erosional.

Discussion of Rangen Area Geology

A geologic exploration test hole was drilled and completed as a monitoring well 588 feet east of Curren Tunnel on August 5, 2008 (Figure 10). The short-term goal was to allow for collection of rock samples to provide for a better understanding of the subsurface geology. The long-term goal was to collect water levels to facilitate evaluation of water level trends. Figure 11 shows the geologic log, most recent water level and well construction for the monitor well.

Figure 10. 1:3,000 scale map showing the Rangen Monitor Well 588 feet due east of Curren Tunnel and a nearby canal.

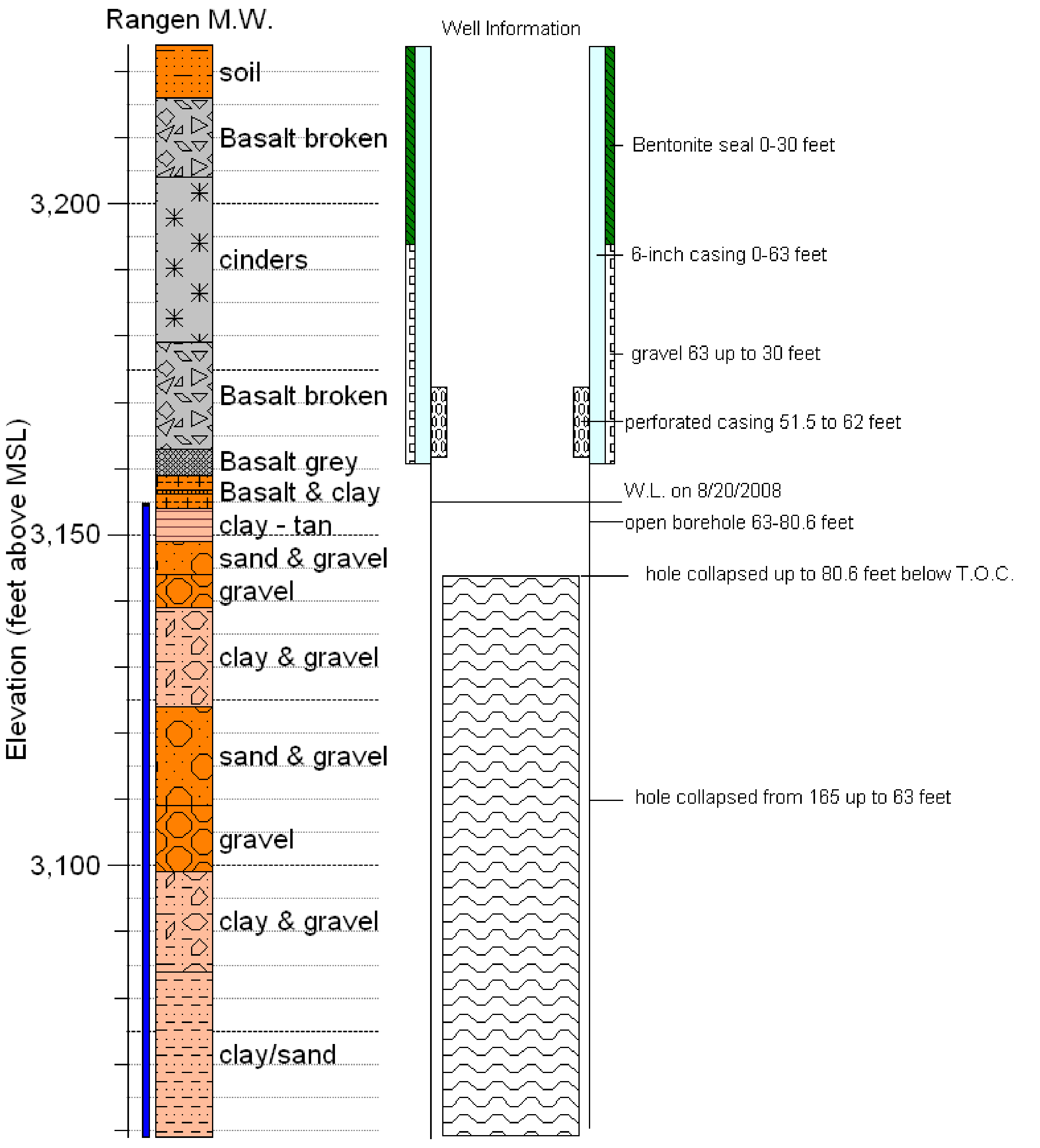


Figure 11. Geologic column and well construction for Rangen monitor well which is 165 feet deep and the base of the basalt starts at 65 foot depth. Tick marks are every 10 feet.

The well was drilled to 165 feet but the sediments collapsed up to about 80 feet below the top of well casing (T.O.C.). Generally, there was 8 feet of soil then basalt was encountered from 8 feet down to about 68 feet (+/- 2 feet) below land surface. The basalt exhibited numerous fractures, rubble zones with cinders and voids. The color is a typical dark grey and contains feldspar laths, vesicles, and some glassy surfaces that indicate fast cooling conditions.

South of Rangen by about one mile is an outcrop showing the Quaternary basalt contact with underlying sediments on the east side of the Hagerman Valley (Figure 12). Clearly observable in outcrop are subaerial clastic sediments of a paleosol directly under a pillow lava rubble zone and the overlying massive portion of the basalt flow which is cliff forming. The contact shows the effects of loading saturated sediment which produces load cast features. It is interpreted that the paleosol was very soft from a wet environment before the lava flow occurred and/or became saturated from flood waters damned by the lava flow prior to loading of the sediments by the ensuing lava flow.

Clastic sediments were encountered from 68 to 165 feet and range in composition from clay, silt, sand and gravel. The geology of the monitor well shown in Figure 11 is consistent with previous conceptual models based on outcrop and adjacent wells (Figure 13 and 14). Samples collected are consistent with known outcrops of GFF and the TGF. Initial observations of the physical character indicate these sediments are from both the GFF and the TGF. However, the upper sand and gravel could be Quaternary in age and may have been deposited on top of Tertiary age sediments of the GFF. The sediments indicate a fluvial depositional environment and the outcrop of pillow basalt at the Curren Tunnel (Figure 15) is consistent with this environment and depositional setting. The tunnel is constructed into a pillow basalt rubble zone of high conductivity. It is likely located within a ‘thalweg’ part of an ancient topographic depression, valley or ravine cut into the GFF. There may have been a stream or small river flowing when the basalt flow entered the depression which produced the pillow basalts when it encountered water. The character of the basalt encountered during drilling of the well, indicates that it has numerous rubble zones, cinders, and voids for most of the thickness and the driller had to case this section to hold back the cinders and maintain circulation. A nearby well log report for "Harvey Tate" dated April 14, 1992, also shows a similar thickness of "black cinders" from 26 to 66 foot depth (Figures 13 and 14). Wells referred to in this report are noted by the last name on the well drilling report. This type of geology is typical of high conductivity

Figure 12. A massive cliff forming basalt overlying a pillow rubble zone which rests unconformably on a paleosol outcrop south of Rangen by one mile. The elevation of the paleosol and pillow zone is 3,162 feet above MSL.

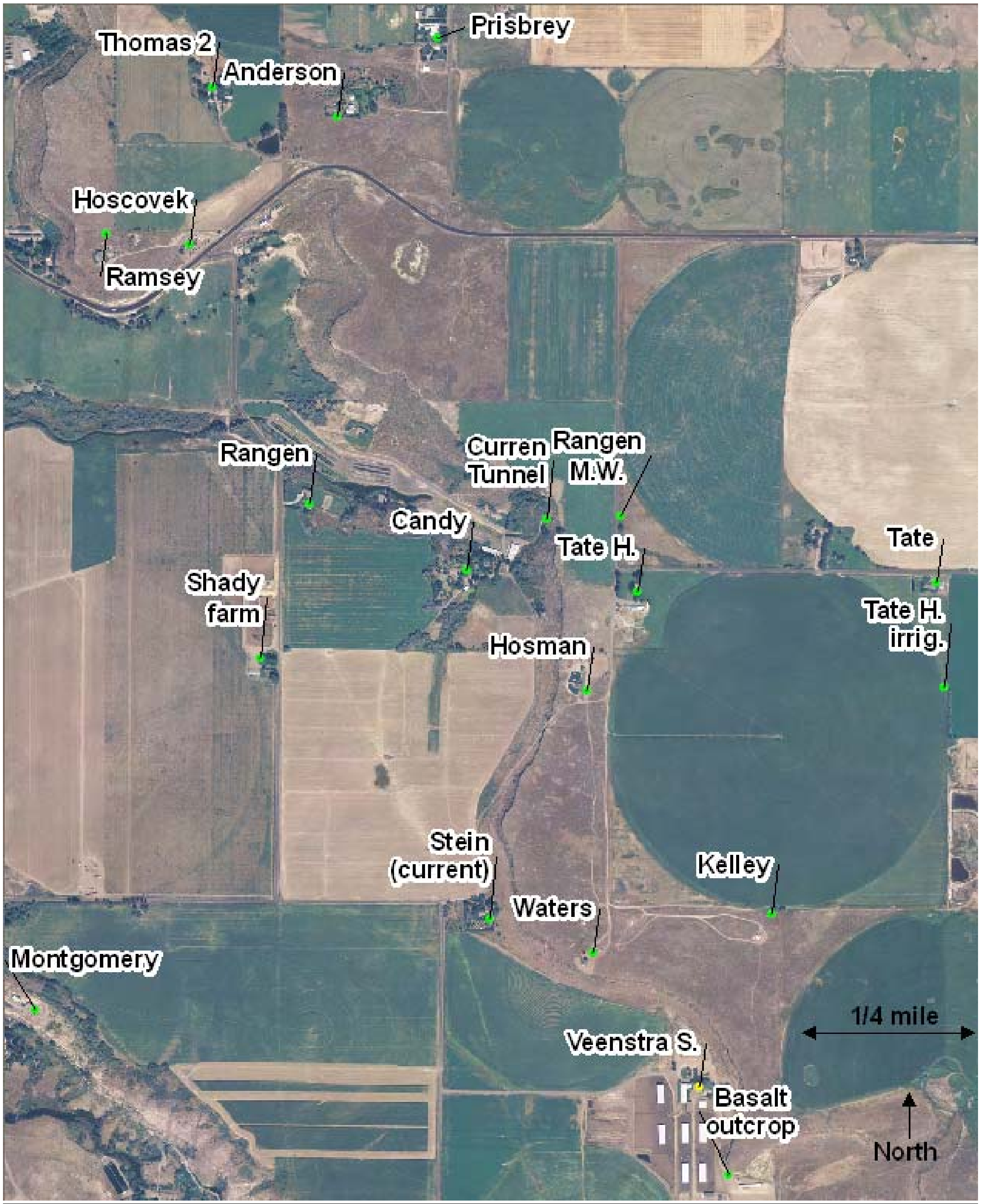
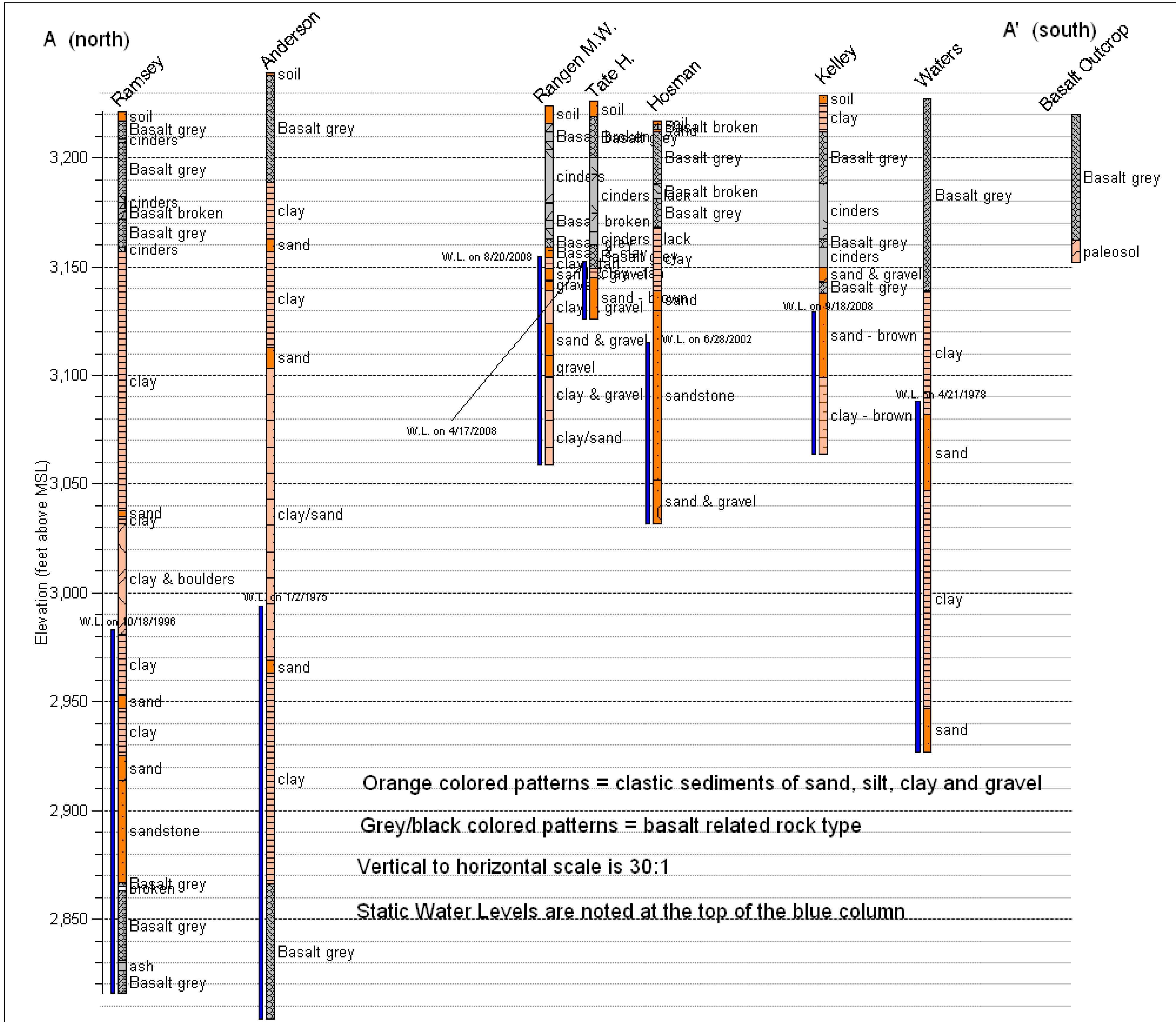


Figure 13. Locations of nearby wells and a geologic outcrop southeast of Rangen by one mile.



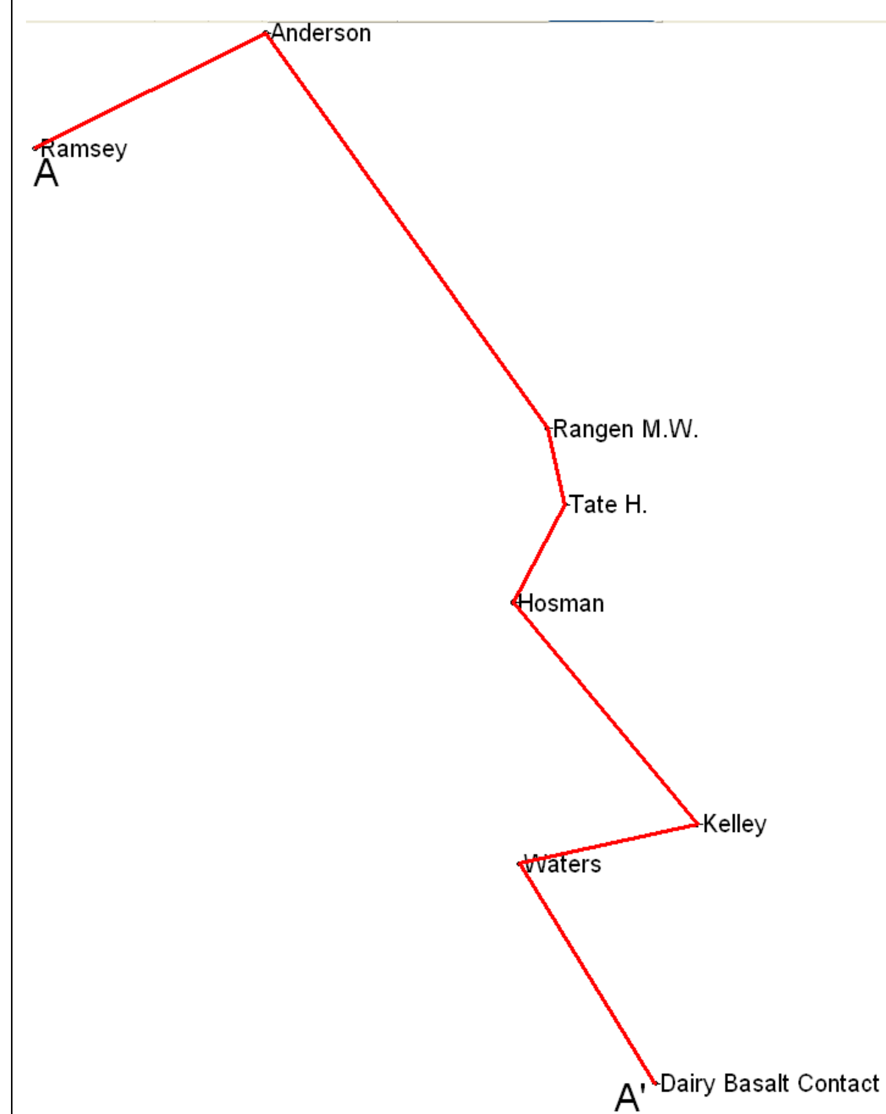


Figure 14. Geologic cross section and location map A (north) to A' (south) for the deepest wells shown in figures and a basalt outcrop south of Rangen. The Ramsey well is 405 feet deep and the Anderson well is 435 feet deep.

Name of Well Owner	Township Range Section	IDTM Easting (meters)	IDTM Northing (meters)	Well Depth (feet)	Depth to Water (feet)	GPS Elevation on T.O.C. (feet above MSL)
Doug Ramsey	T7sR14e31	2429621	1287270	405	238	3221
Warren Anderson	T7sR14e30	2430178	1287549	435	245	3239
Harvey Tate	T7sR14e32	2430901	1286409	100	73.6	3226
Chris Hosman	T7sR14e32	2430776	1286172	185	102	3217
David Kelley	T8sR14e5	2431220	1285636	165	100	3229
Craig Waters	T8sR14e5	2430791	1285541	300	139	3227
Rangen MW	T7sR14e32	2430858	1286592	165	69.27	3237
Basalt outcrop	T8sR14e5	2431116	1285014	n.a.	n.a.	n.a.

Name of Well Owner	USGS Numbering System
Doug Ramsey	7S 14E 31baa
Warren Anderson	7S 14E 30ddb
Harvey Tate	7S 14E 32cab
Chris Hosman	7S 14E 32cbd
David Kelley	8S 14E 5baa
Craig Waters	8S 14E 5bba
Rangen MW	7S 14E 32bdc
Basalt outcrop	8S 14E 5bdd

Table 1. List of general information for wells used in cross section.

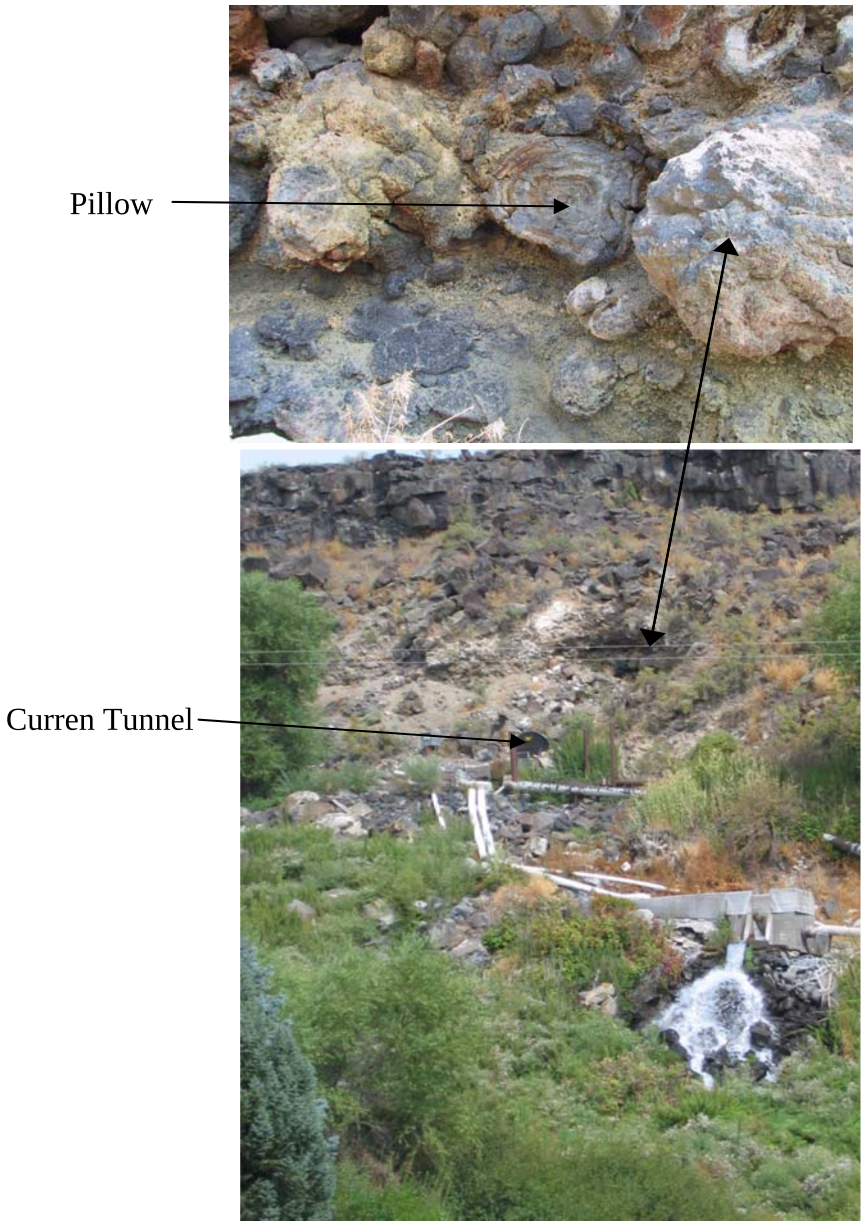


Figure 15. Curren Tunnel and pillow basalt of about 1 foot diameter. Pillow features form when lava flows into water.

zones elsewhere in the Eastern Snake River Plain for example at ‘Ten Springs’ and the Thousand Springs Complex located 2.5 miles south. Pillow features are also present at the Big Springs tunnel adjacent to ‘Vardis Fisher’ Lake north of Rangen and east of the town of Hagerman.

The water level in the monitor well is about 10 feet higher in elevation than the spring water surface discharging from the end of the Curren Tunnel. Water levels in the well are shown in Figure 16 and Table 2.   The spring water elevation where it discharges from the Curren Tunnel is 3,145 feet. The elevation of the water level in the monitor well is 3,155 feet. According to Rangen employee Lonnie Tate, Rangen obtains about 2/3 of its water from spring zones below the Curren Tunnel with a large discharge area just south of the Curren Tunnel 100 to 200 feet that will be noted as the 'lower spring zone'. The remaining 1/3 of their water comes directly out of the Curren Tunnel.

The approximate elevation of the lower spring zone obtained with a GPS is 3,100 feet and a few pieces of subrounded stream gravels of Rhyolite composition were observed as float within the lower spring zone and they appear to be of typical character based on my work with the Tuana Gravel Fm.; but this gravel could be Quaternary age (Qg) gravels eroded from the Tuana Gravel Fm. too. In other words, it is difficult to determine what type and age these gravels are but they are in the correct vertical stratigraphic location for the Tuana Gravel. The lower spring zone and float gravel correlate with gravel encountered during drilling of the monitor well at an elevation between approximately 3,100 and 3,125 feet (Figure 11) and this stratum may represent higher conductivity that the lower spring zone is flowing through. One theory posed is that the actual spring discharge elevation from in-situ geology may be higher than where the spring is visible on the slope due the concept of water flowing out of the in-situ layer (buried beneath the slope material) and then flowing downward through talus and overburden slopes vertically in the subsurface, then flowing laterally again to where it daylights or is visible on the hillside. In my opinion, this phenomenon doesn't occur at Rangen (or other springs north of Rangen up to Malad Gorge) to as great of a degree as other upriver springs such as Crystal or Clear Springs because of the presence of the GFF in this reach and less overburden and talus. As

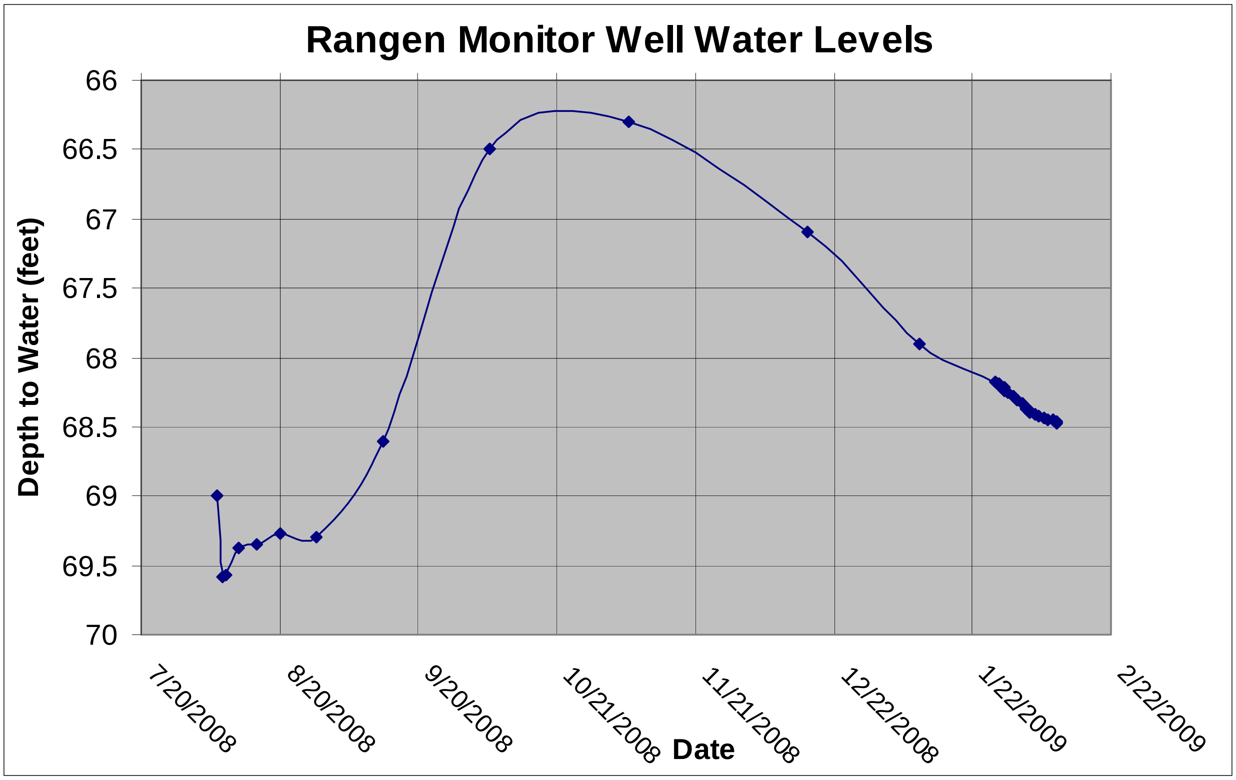


Figure 16. Static water levels for Rangen monitor well.

Date	**Depth to Water** in feet below top of casing (* = well sounding depth)	**Collected by**
8/6/2008*	80*	Neal Farmer - IDWR
8/6/2008	69	Neal Farmer - IDWR
8/7/2008	69.58	Neal Farmer - IDWR
8/8/2008	69.57	Neal Farmer - IDWR
8/11/2008	69.37	Neal Farmer - IDWR
8/15/2008	69.35	Neal Farmer - IDWR
8/20/2008*	80.6*	Neal Farmer & Nathan Erickson - IDWR
8/20/2008	69.27	Neal Farmer & Nathan Erickson - IDWR
8/28/2008	69.3	Neal Farmer & Nathan Erickson - IDWR
9/12/2008	68.6	Nathan Erickson - IDWR
10/6/2008	66.5	Nathan Erickson - IDWR
11/6/2008	66.3	Nathan Erickson - IDWR
12/16/2008	67.09	Dennis Owsley - IDWR
1/10/2009	67.90	Nathan Erickson - IDWR
1/10/2009	80.5*	Nathan Erickson - IDWR

Table 2. Static water levels from the Rangen monitor well measured from the top of casing.

seen in Figure 5, the “talus” or slope overburden can be very shallow with just a few boulders strewn over the surface. Conversely, upstream where the GFF is not present and basalt dominates the canyon walls then the deep boulder talus slopes will have more voids allowing the vertical flow of water downward to daylight at a lower level than the in-situ level the groundwater is flowing through.

A small canal or large ditch is located nearby (Figure 10) and during a discussion with Lonnie Tate he noted the canal isn’t used much any more since the conversion from furrow/flood irrigation to sprinkler technology. This site could be explored as a possible small scale or ‘pilot’ aquifer recharge by injection site but it might only benefit the Rangen Spring complex area. The basalt at this site is permeable and conducive to receiving recharge water and there is a power line at this location.

Fluorescent dye tracer tests need to be performed by injecting either Fluorescein or Rhodamine into the monitor well and then monitor the springs to determine the location of dye discharge, time of first arrival and total time-of-travel. The dyes are certified by ANSI/NSF for Standard 60 potable water supplies and approved by the EPA for public drinking water supply systems. They can be detected in extremely low concentrations of 1 part per billion or lower which is well below the visual concentration of about 1,000 ppb. IDWR staff currently has the dye, equipment and expertise to implement the tracer test at a very low cost. The dye test would also help with interpreting and correlating the long-term water monitoring data sets with the spring flows as well as making a quantified determination of some aquifer parameters. Some spring owners have already agreed to allow tests to occur at their location.

Additional exploratory boreholes drilled near this site, would be useful to locate the paleo-topographic low contact. An additional geologic exploration borehole is recommended east of the Hagerman Water Users spring complex by 350 feet and north of Big Springs by 1,400 feet (T7S R14E, section 18, SW of the NW, see Figure 2) to confirm the Quaternary and Tertiary (Q/T) contact at this location.

There is an apparent downward hydraulic gradient within the GFF as illustrated in the wells “Rangen M.W.”, “Hosman” and “Waters” that show water levels dropping as the wells are completed at deeper depths (Figure 14). But, the Ramsey and Anderson wells might have an upward hydraulic gradient from the underlying deep basalt aquifer located beneath the GFF. Better evidence of this upward hydraulic gradient is recorded from a USGS “Henslee” monitor well (Figure 18) located due east of Rangen by 2.9 miles (T7S R14E, section 35, SW SW). The well was screened within the deep basalt aquifer from an elevation of 2,720 up to 2,840 feet and then sealed up to land surface. There are sediments noted in the log between 2,840 and 3,030 feet elevation and it is probable to conclude these sediments are an eastward extension of the GFF (Figure 9). The driller notes ‘black sand’ at the bottom of the well which is interpreted to be volcanic related.

The bottom hole temperature at 602 feet below land surface (elevation = 2,680 feet) is 69^{o} Fahrenheit which was measured using a HOBO temperature logger. Typical spring water temperatures of the ESPA are about 58 degrees, therefore, the deeper aquifer is about 10 degrees warmer than the shallow groundwater temperature which may be evidence that it is a separate aquifer system. A shallow domestic well located south of the USGS well by 60 feet is completed in the ESPA to a depth of 123 feet and it has a static water level of 83.4 feet (elevation = 3,197.6 feet) below top of casing on May 2, 2008 which is <u>lower</u> than the water level in the USGS well at 78-79 feet below top of casing (WL elevation = 3,202.5 feet) or approximately 5 foot difference. The hydrograph in Figure 17 for the USGS “Henslee” well indicates a slight downward trend during the short time period of data recording. There is no known pumping well withdrawing water from this deeper aquifer within the general area of Wendell, Malad Gorge, to Crystal Springs and the overlying GFF sediments would insulate the effects of pumping from the deep aquifer from the upper ESPA.

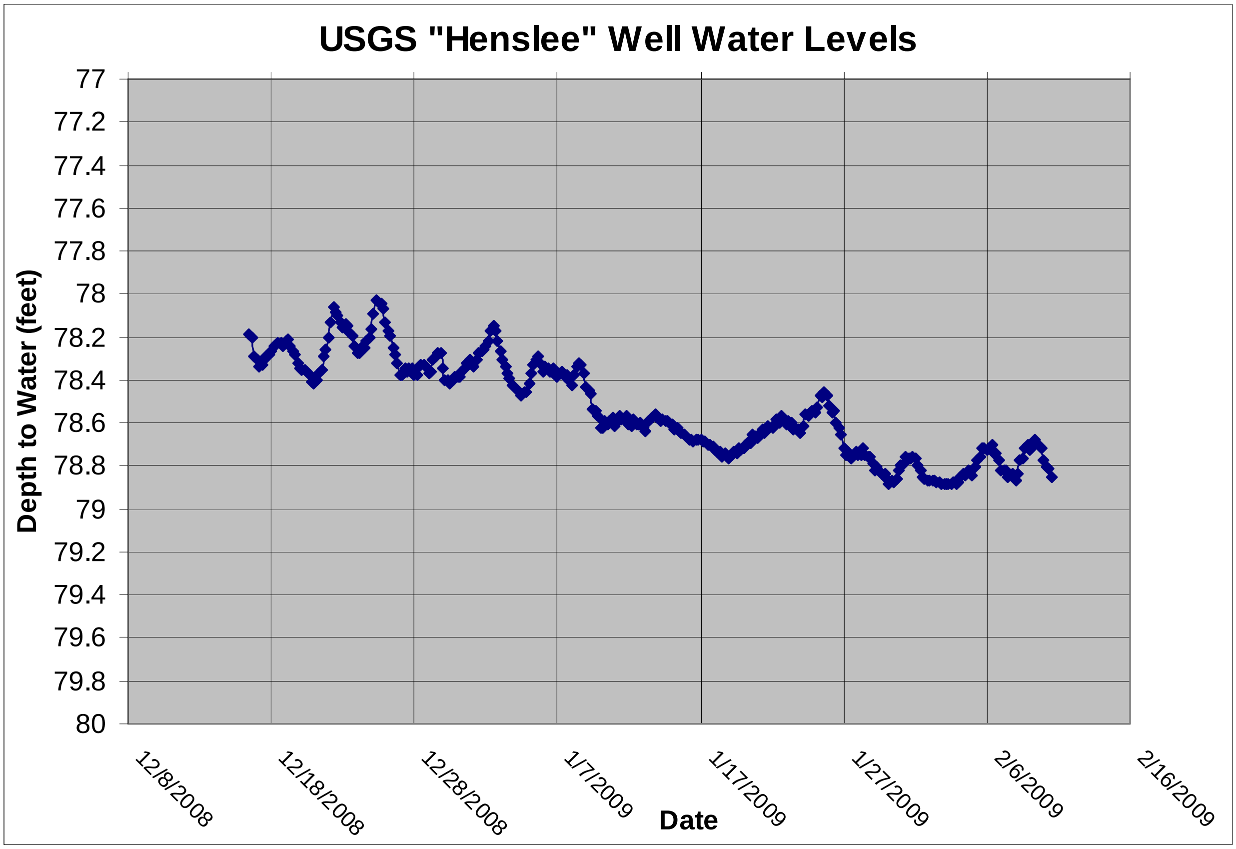


Figure 17. Hydrograph for USGS "Henslee" well.

A recent geologic exploration borehole was drilled to a depth of 700 feet at the University of Idaho (UofI) Fish Aquaculture Research Station located at T8S R14E, section 6, SE ¼ on August 20, 2008 (Figure 2). Borehole geophysics were performed and the report is in progress but the preliminary temperature log shows a shift from about 61 degrees Fahrenheit from 220 feet and then a sharp increase to 66 degrees from 220 down to 240 feet with a temperature high of 68 degrees at a depth of 350 feet. The hole collapsed below this depth. The temperature level and shift indicate an aquifer that is not dominated by upper elevation springs or river water and may be from the deep basalt aquifer system noted in the previously discussed wells.

The groundwater temperature from both the USGS "Henslee" well and the UofI Exploratory Well are almost exactly the same with only a 40 foot elevation difference in elevation between levels where the temperature was recorded in each well. It is conceivable the 'warm' water from both of these wells is from a common source or aquifer system.

Another well that is completed to a depth of 1,013 feet is located west by northwest of Rangen by 3.8 miles in T7S R13E, section 27, NW of the NE (Figure 18). It is artesian with a well head elevation of 2,900 feet or about 100 feet above the level of the Lower Salmon Falls Reservoir (elevation 2,800 feet); and 24 feet higher than the Snake River (2,876 feet) at Sligars Hot Springs. The last name for this well is "Smith" and the water temperature is about 70 degrees Fahrenheit at the well head indicating an aquifer that is not dominated by colder river water or spring water. Discussion of these and other distant wells is somewhat out of scope for the purposes of this report but it is important to note the context.

Based on an evaluation from the wells noted in this document, as well as over 100 other wells in the area and geologic outcrops, there are numerous groundwater flow paths and a deep aquifer system beneath the Glenns Ferry Formation that is not being used; but more information is needed to further refine the hydrogeology of the area. A detailed discussion about the greater hydrogeologic context for the area from Bliss, to Wendell to Thousand Springs and the Hagerman Valley is in progress and forthcoming.

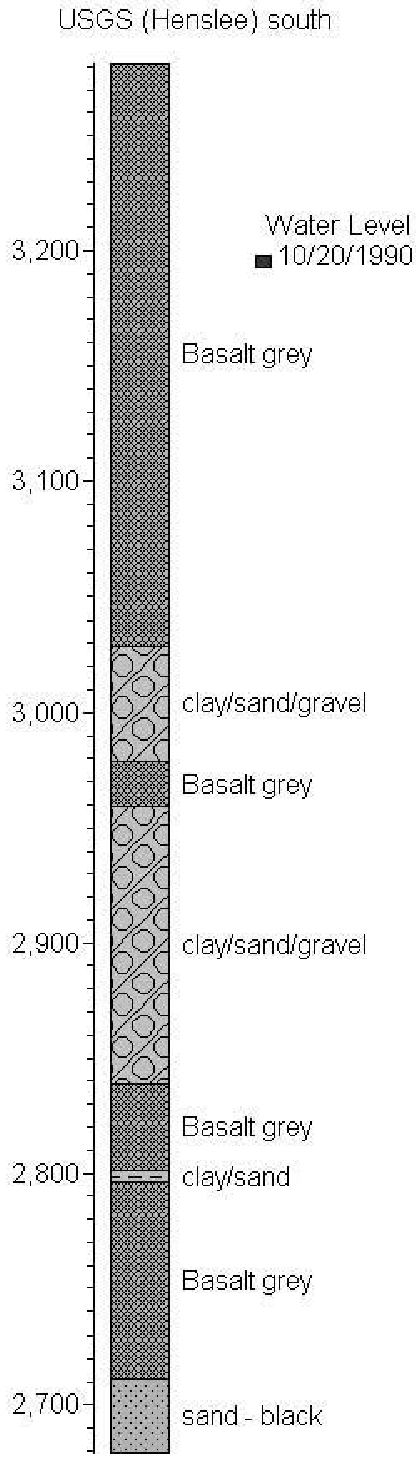


Figure 18. U.S. Geological Survey monitor well located at T7S R14E, section 35, SW SW east of Rangen by 2.9 miles (Figure 2). The total depth of the well is 602 feet with a bottom-hole temperature of 69° F.

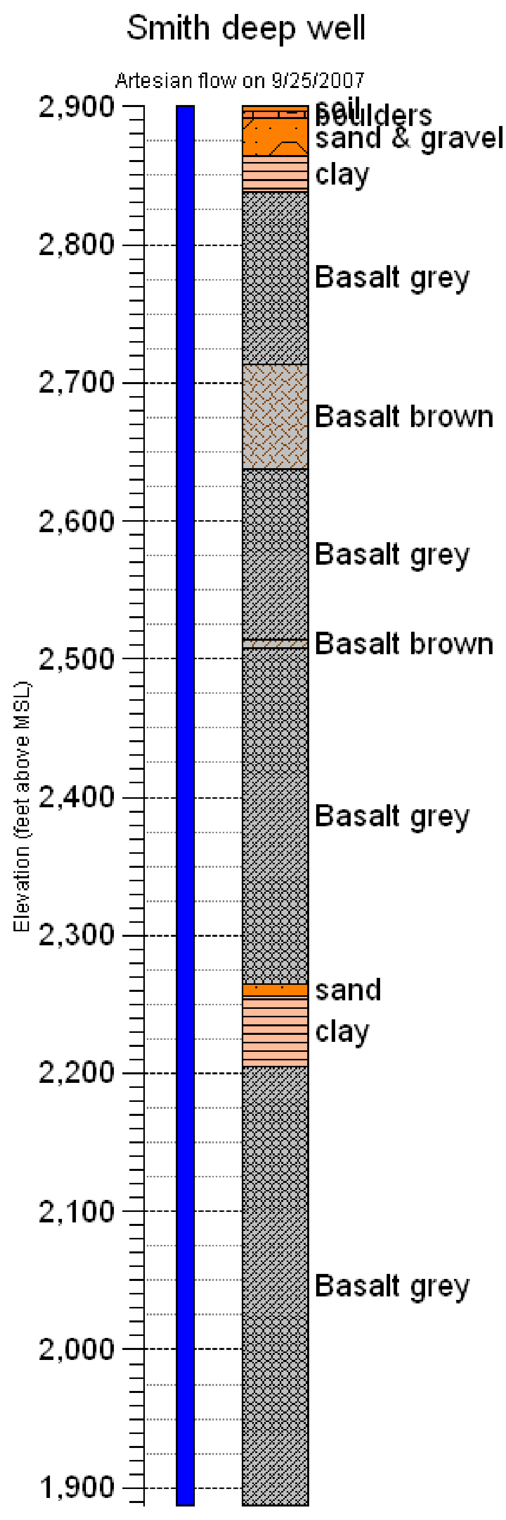


Figure 19. "Smith" deep well located in the Hagerman Valley (Figure 2). The well is artesian with a surface water temperature of about 70 degrees Fahrenheit. Note the extensive grey colored basalt underlying the brown basalt and the total depth is 1,013 feet.

HYDROSTRATIGRAPHIC MODEL

Two hydrologic models are proposed; the first one is larger scale that crosses the Hagerman Valley with an east/west orientation. The second is more localized for the Rangen spring area with a north/south orientation. The models demonstrate how water moves through the hydrostratigraphic units. The "Hagerman Valley Model" focuses on the east side of the valley with three main geologic units that groundwater is flowing through, the upper Quaternary basalt flows that host the Eastern Snake River Plain Aquifer, the Tertiary Glenns Ferry Formation of clastic sediments that contains aquifers with a downward hydraulic gradient, and the deep basalt aquifer that indicates an upward hydraulic pressure gradient. Lastly, the "Smith" artesian well located in the floor of the valley (Figure 2) provides evidence for an upward hydraulic gradient that may allow groundwater (possible from a low temperature geothermal system) to flow up into the base of the Snake River accounting for some of the reach gains. The GFF likely forms a wedge of clastic sediments eastward from Rangen towards Wendell and may create vertically divergent groundwater flow paths with a deep path flowing through basalts underlying the GFF (Figure 20).

The second model is more localized for the Rangen spring area with the main hydrostratigraphic units composed of the upper Quaternary basalts overlying clastic sediments. Groundwater is flowing through both the basalt and the sediments and daylight as springs on the hillside at Rangen. The spatial distribution of vegetation growth patterns at and adjacent to the spring area are similar to the west side of the Hagerman Valley at perched aquifer springs. A study by Farmer and Nagai (2004) identified how geologic lithology, perched groundwater and hydrophilic vegetation growth patterns can be used as a tracer to the underlying aquifer dynamics. Two types of spatial patterns from non-native vegetation are easily discernable at the

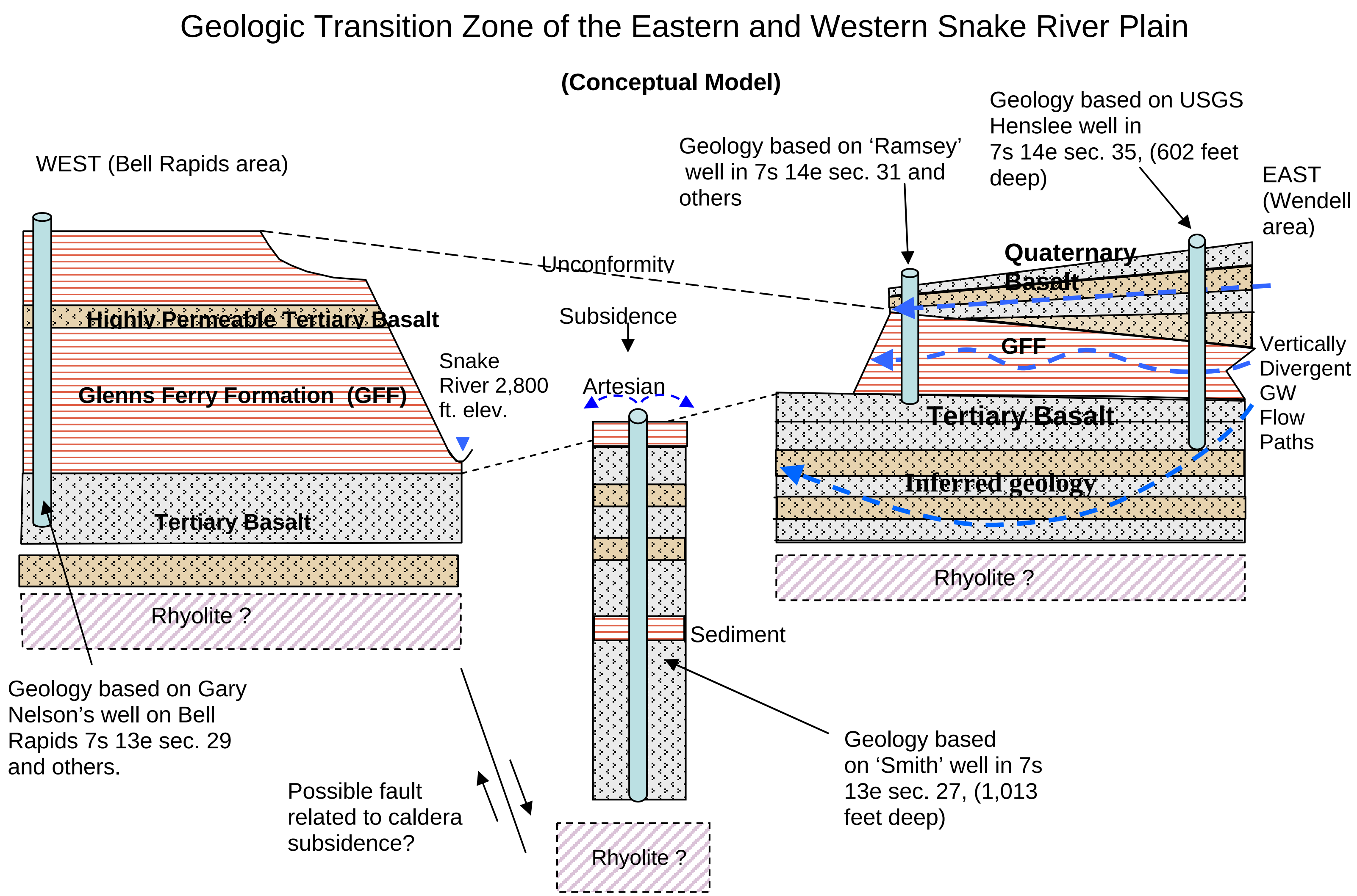


Figure 20. Conceptual model of Hagerman Valley (not to scale).

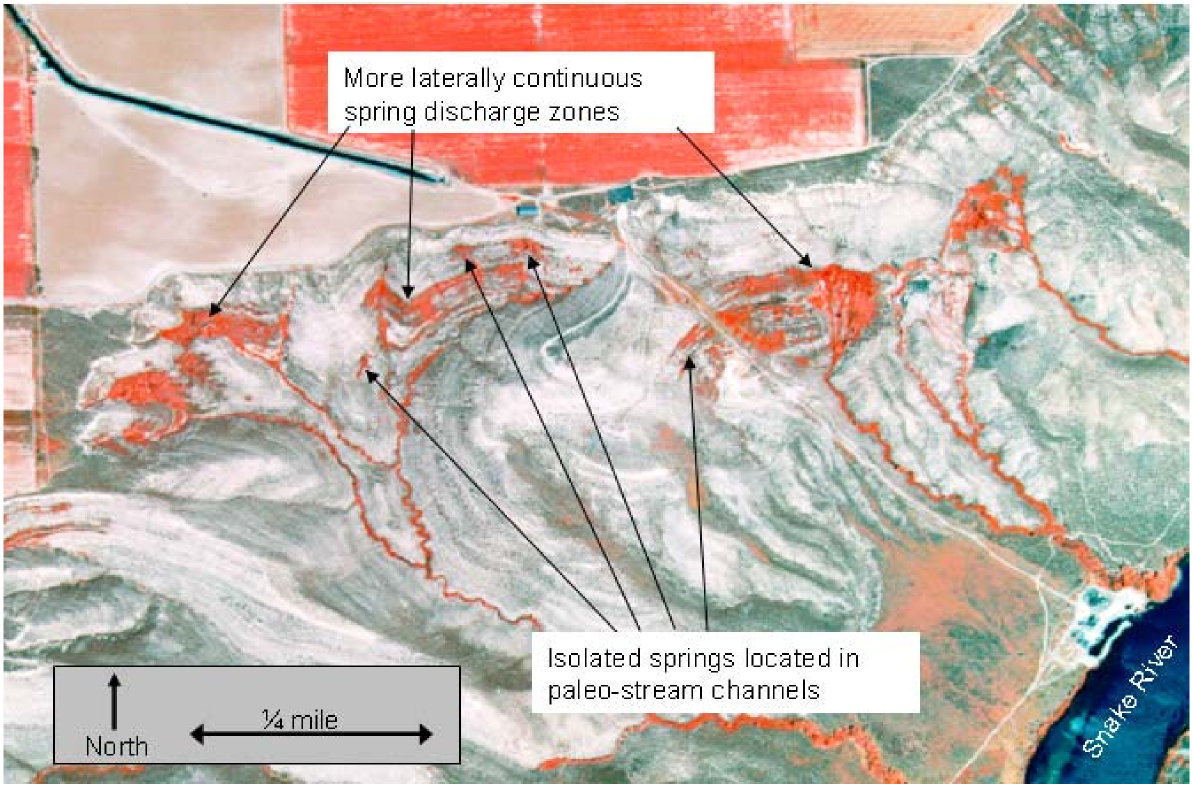


Figure 21. False color infrared air photo of springs at the Hagerman Fossil Beds N.M. (T7S R13E, section 16) showing spatial distribution pattern contrast between non-native and native vegetation which is a function of the geologic lithology and stratigraphy.

Hagerman Fossil Beds National Monument within the GFF and shown in Figure 21. It was determined from onsite outcrop inspection, boreholes and monitor wells using a soil auger, tracer tests and shovels that the isolated springs were paleo lows cut by streams and rivers and later filled with fluvial sand. As seen in Figure 21 immediately adjacent to the channels with springs are dry hillsides with sagebrush but also note the 'banding' of vegetation below the main spring. This is leakage from the channel downward until it encounters a low permeable lithology where it ponds but leaks downward again until another low permeable unit is encountered. Figure 22 is a model for this leakage pattern and the geology was confirmed on site. The laterally continuous spring discharge zones are a function of intercalated basalt flow (which is not present at all locations due to an embayment of the basalt) and sand facies possibly from a shoreline environment. The two center arrows in Figure 21 noting the isolated springs are confirmed to be flowing through the TGF contact with the GFF (top of the GFF) within paleo topographic depressions of cut and fill stream channels.

The Rangen geology is also composed of the GFF and exhibits similar hydrophilic vegetation patterns, as seen in Figure 23, where immediately adjacent to the spring area are 'dry' hill sides with sagebrush and cheat grass. The two isolated springs flowing through the TGF noted in Figure 21 may be an analog for the groundwater flowing through the gravels encountered at Rangen. The stream channels exposed at the Hagerman Fossil Beds N.M. have a bowl or "U" shape or geometry and the Curren Tunnel pillow basalts may have a similar shape. The geologic architecture where the Curren Tunnel is located helps explain the spring discharge

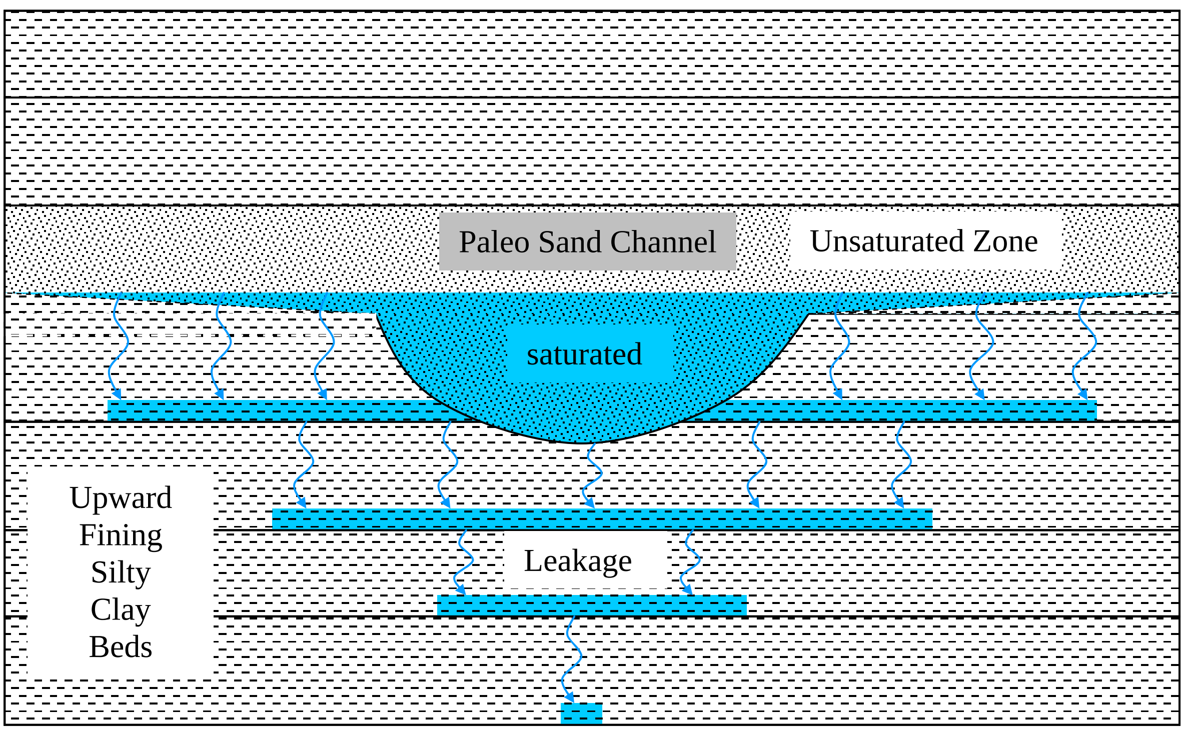


Figure 22. Model for leakage from a paleo stream channel with ponding on top of low permeable lithology and thus vegetation grows along these zones as seen in Figure 20 (Farmer and Nagai, 2004).

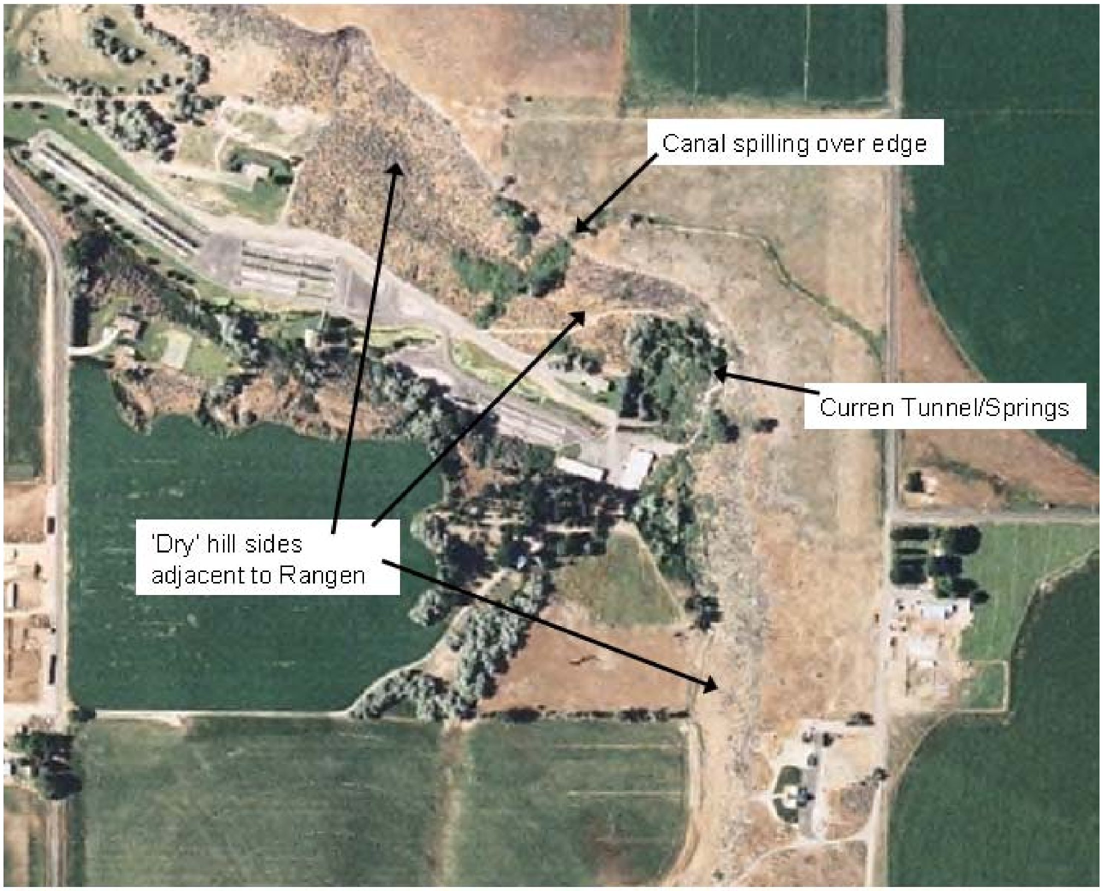


Figure 23. Hydrophilic vegetation isolated by adjacent 'dry' hill sides at Rangen spring area.

patterns as shown in the conceptual model (Figure 24). The hypothetical "U" shape influences a response similar to a V-notched weir, where the discharge is not a linear function with head change. An analog, for demonstration purposes, could be the standard 90 degree V-notch weir discharge curve graphed in Figure 25. The discharge at 1.0 feet of head is 2.49 $ft.^3$/sec. and at about 2 feet of head it is approximately 13.7 $ft.^3$/sec. for a difference of about 5.5 $ft.^3$/sec. (U.S. Bureau of Reclamation 2001). The discharge is not doubled from 1.0 to 2 feet of head but over 5 times more. Therefore, if the basalt aquifer discharge at the Curren Tunnel has similar character as a V-notch weir and the water table was raised in the basalt aquifer then a change in the ratio of discharge from the basalt to the lower spring zone in gravel may occur.

If the water table continues to lower then the ratio may change where most of the spring discharge will be sourced from the lower gravel spring zone and little if any from the Curren Tunnel. If it is determined the Curren Tunnel discharge is highly sensitive to a decrease in the water table then correspondingly it should be highly sensitive to an increase in the water table. The exact geometry of the paleo-topographic depression is unknown but this does demonstrate the non-linear relationship that may exist and help explain the sensitivity of springs to head change for the Curren Tunnel and other springs north of Rangen to Malad Gorge. The underlying gravel and sand aquifers may provide a more stable or constant flow that is insulated, less sensitive and slower to respond to head changes verses the pillow zone aquifer. Tracer tests would be useful for characterizing this further. Also, conversion of the agricultural field east of the Curren Tunnel about 600 feet from sprinkler to flood/furrow irrigation is a possibility to assist with recharge in this area.

The transmissivity of the aquifer at the Curren Tunnel will be more responsive than further east because the saturated thickness is less near Rangen. The geologic model in Figure 20 shows how the ESPA aquifer thickness becomes less as it flows toward the Rangen area due to the effective base of the aquifer with the Glenns Ferry Formation dipping eastward. East of Rangen by 3 miles the upper basalt aquifer (ESPA) at the USGS Henslee well is saturated by about 300 feet. At the Curren Tunnel it is estimated the saturated thickness is approximately 10 feet thick based on the difference in elevation of the Rangen monitor well water level and the base of the Curren Tunnel. For example, if a well about 1 mile east of Rangen has 100 feet of saturated aquifer thickness with a hydraulic conductivity of 100 feet/day then the following relationship would occur given Transmissivity (T) = saturated aquifer thickness (b) multiplied by hydraulic conductivity (K) or $T = bK$. Also, if long-term water levels declined by 5 feet this would reduce the saturated thickness in the aquifer near Rangen by 50% verses just 5% for the area one mile east.

Rangen area aquifer T = (10 ft.) x (100 ft./d) = 1,000 $ft.^2$/day	One mile east of Rangen T = (100 ft.) x (100 ft./d) = 10,000 $ft.^2$/day

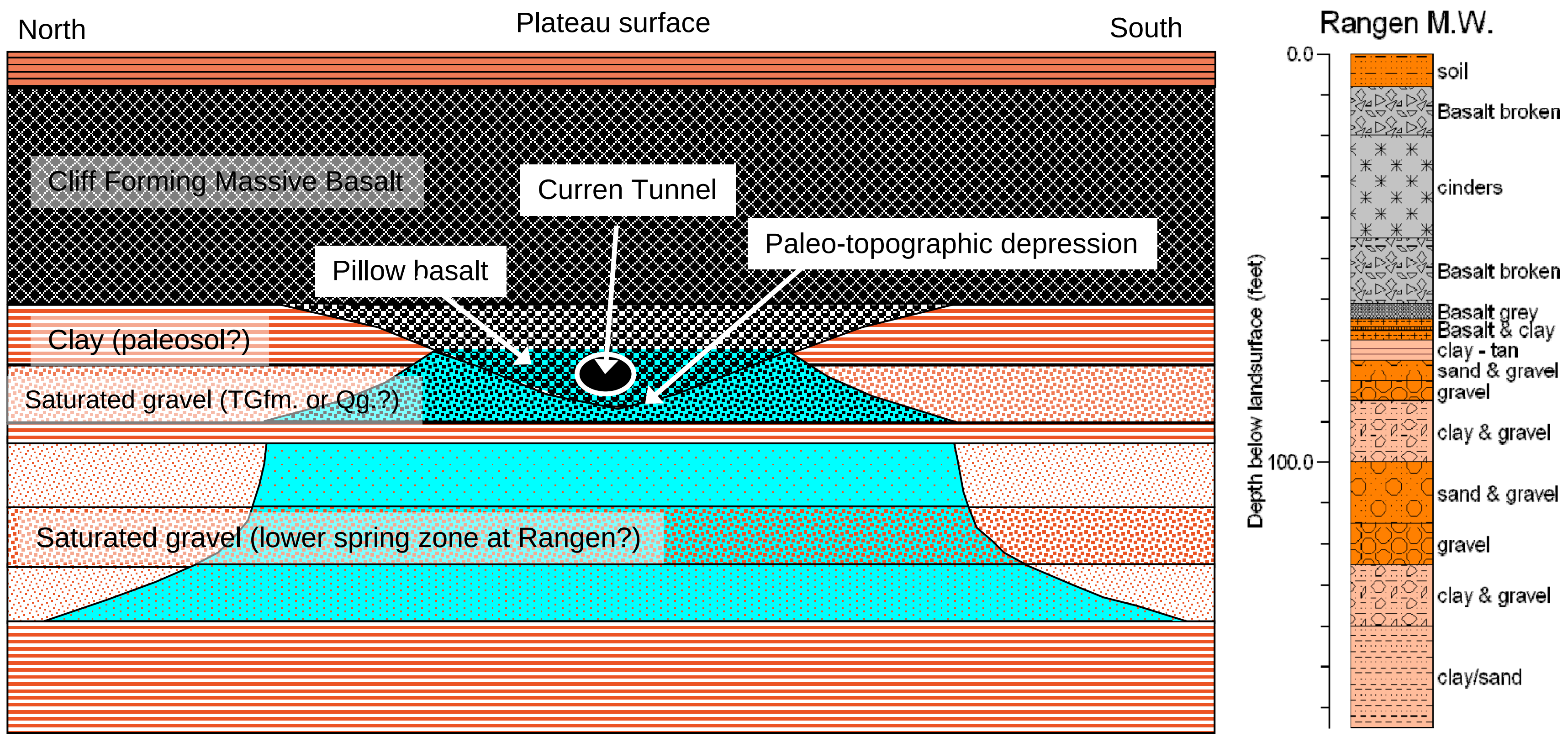


Figure 24. Conceptual hydrostratigraphic model for the Rangen spring area showing the paleo-topographic depression filled with pillow basalts and underlying sediments transporting groundwater.

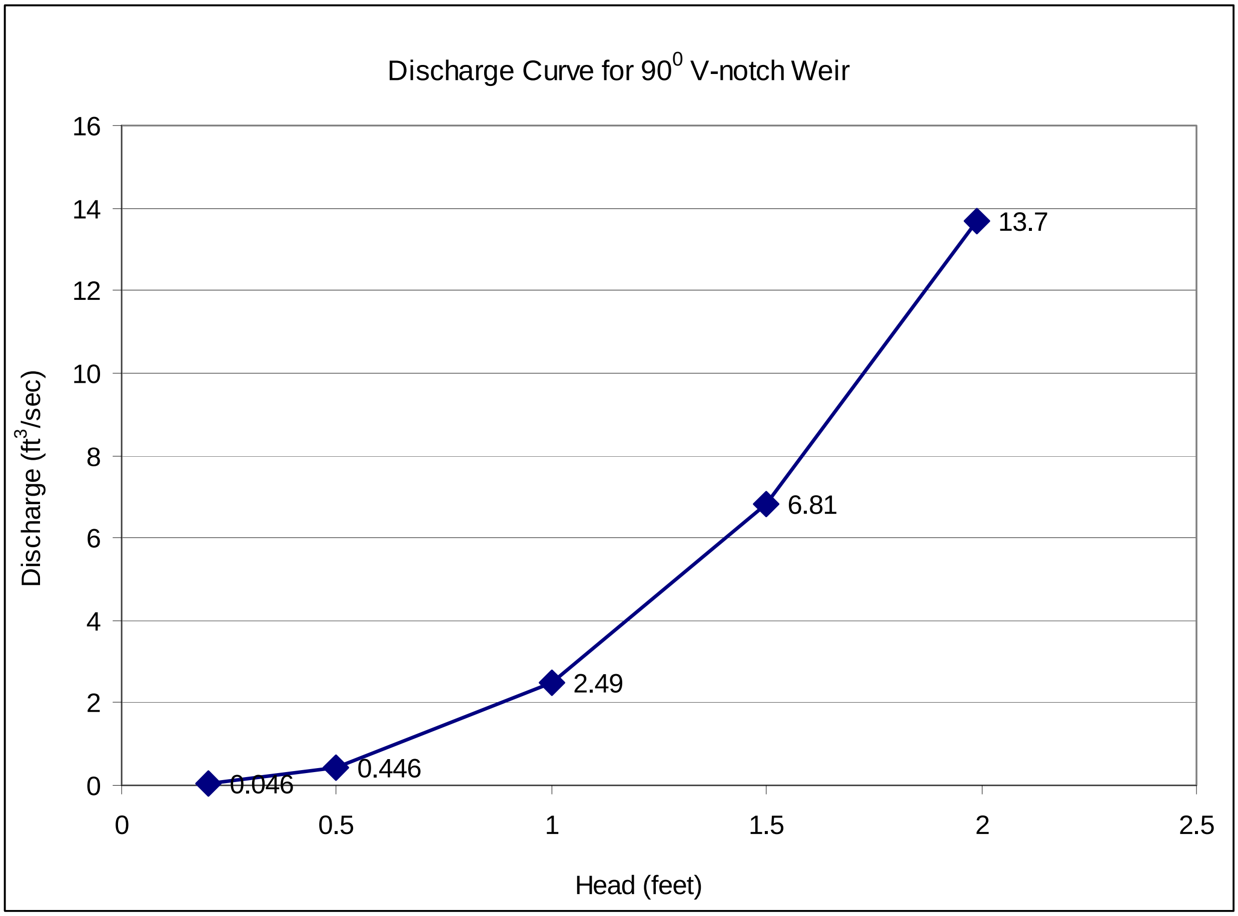


Figure 25. Discharge curve for a standard 90 degree V-notch weir as a possible analog for the Non-linear response of discharge to head change. Data from U.S. Bureau of Reclamation Water Measurement Manual Table A7-4.

CONCLUSIONS AND RECOMMENDATIONS

The Hagerman Valley is formed within a transition zone between two major geologic provinces of the eastern and western Snake River Plain which produces major interbedded lithologic differences such as volcanic rocks with floodplain, fluvial and lacustrine sediments. Aquifer flow paths, spring discharge rates and spring spatial distribution patterns are a direct function of the interplay between aquifer systems flowing through these different lithologies. The sediments of the Glenns Ferry Formation on the west side of the Hagerman Valley are well exposed and easily accessible for observation and study which provides information for interpreting geology on the east side of the valley. A thinner portion of the same sediment formation is exposed on the east side of the valley but conversely it is well covered by vegetation, talus, and landslides.

Between the general triangular shaped area of Wendell and the Thousand Springs to Malad reach, the Glenns Ferry Formation appears to be positioned between basalt thereby creating a thinning eastward extending wedge into the subsurface, which must influence the groundwater flow systems. Essentially all wells have been completed in the upper basalt above the Glenns Ferry Fm. but there is good evidence for a deeper basalt aquifer flowing beneath the Glenns Ferry Fm. To my knowledge there is not one pumping well completed in this plateau area down to the deeper basalt zone; but there are one and perhaps two exploration and monitor wells drilled to this depth. This deeper aquifer may also be flowing up into the base of the Snake River within the Hagerman Valley area contributing flow to the Snake River which would help explain reach gains that currently can not be accounted for. Groundwater is likely flowing within the Glenns Ferry Fm. based on the water levels and geology of the Rangen, Hosman, Kelley, Waters wells and some springs discharge from it in the Hagerman Valley where homeowners such as Larry Littlefair use it for a domestic water supply source (Erwin, 2008).

The subsurface geologic architecture and types of lithologies play important roles for the springs near Rangen Inc. and throughout the Thousand Springs to Malad reach. Additional exploration wells are recommended with tracer tests and long-term water level measurements. I also recommend geophysics be attempted to identify the subsurface topographic low depression that is hosting the pillow basalts and main groundwater flow to the Curren Tunnel. Geophysics may be able to trace the extent of the pillow zone. Then, an additional exploratory well could be drilled into the lowest part of the depression with subsequent tracer tests and long-term water level measurement. The pillow lava rubble zone located at the Curren Tunnel indicates highly conductive basalt versus the very low conductivity basalt encountered and tested at the W-canal aquifer recharge site north east of Wendell.