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Southern Nevada Water Authority

Geologic Data Analysis Report for Monitor Well 182W906M in Delamar Valley

October 2007

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SOUTHERN NEVADA WATER AUTHORITY

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SOUTHERN NEVADA WATER AUTHORITY
Groundwater Resources Department
Water Resources Division
snwa.com

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Acronyms

API GR	American Petroleum Institute gamma ray unit
BLM	Bureau of Land Management
RGU	regional geologic unit
SNWA	Southern Nevada Water Authority
TD	total depth
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Abbreviations

°C	degrees Celsius
amsl	above mean sea level
bgs	below ground surface
cps	counts per second
ft	foot
gpm	gallons per minute
gru	API gamma ray unit
I.D.	inside diameter (of casing)
in.	inch
lb	pound
m	meter
Ma	million years
mi	mile
min	minute
µs	microsecond
mS	millisiemens
mV	millivolt
O.D.	outside diameter (of casing)
ppm	parts per million
psi	pounds per square inch
rpm	revolutions per minute

1.0

INTRODUCTION

In support of the Southern Nevada Water Authority's (SNWA) Clark, Lincoln, and White Pine Counties Groundwater Development Project, SNWA drilled 10 monitor wells in five hydrographic areas in Lincoln County, Nevada, between February and December 2005 (Figure 1).

Monitor Well 182W906M is located in southeastern Delamar Valley in Section 19, T7S, R64E, at an elevation of approximately 4,802 ft amsl (Figure 2). The site is approximately 17 mi east of Alamo, Nevada, and is accessed from U.S. Highway 93 by the Alamo Canyon Road. This site is on the west side of the Delamar Mountains, northwest of Gregerson Basin.

1.1 PURPOSE AND SCOPE

The purpose of this report is to describe the geologic, geophysical, and hydrologic data collected for Monitor Well 182W906M. The scope involves evaluation and comparison of borehole cuttings, drilling statistics, borehole geophysical logs, and hydraulic properties of the well. Geophysical data are compared to the borehole lithology to evaluate the geophysical response to geologic and hydrologic conditions, including the geologic units, geologic structures (fractures and faults), and hydrogeology. The drilling statistics are also correlated with the borehole lithology and geophysical logs. A discussion of hydrogeology is included to describe water levels, groundwater flow into the well, and geologic units and structure that provide this groundwater flow.

1.2 OBJECTIVES OF THE MONITOR WELL PROGRAM

The objectives for the 10 monitor wells are to:

- Further refine the distribution of regional aquifers and interbasin flow interpretations of those aquifers through the collection of additional hydrologic and geologic data, general groundwater chemistry and water quality data, and water level data.

- Provide long-term monitoring points for baseline depth-to-water levels, observe future pumping influences and climatic effects, and provide an accurate and timely assessment of groundwater conditions.

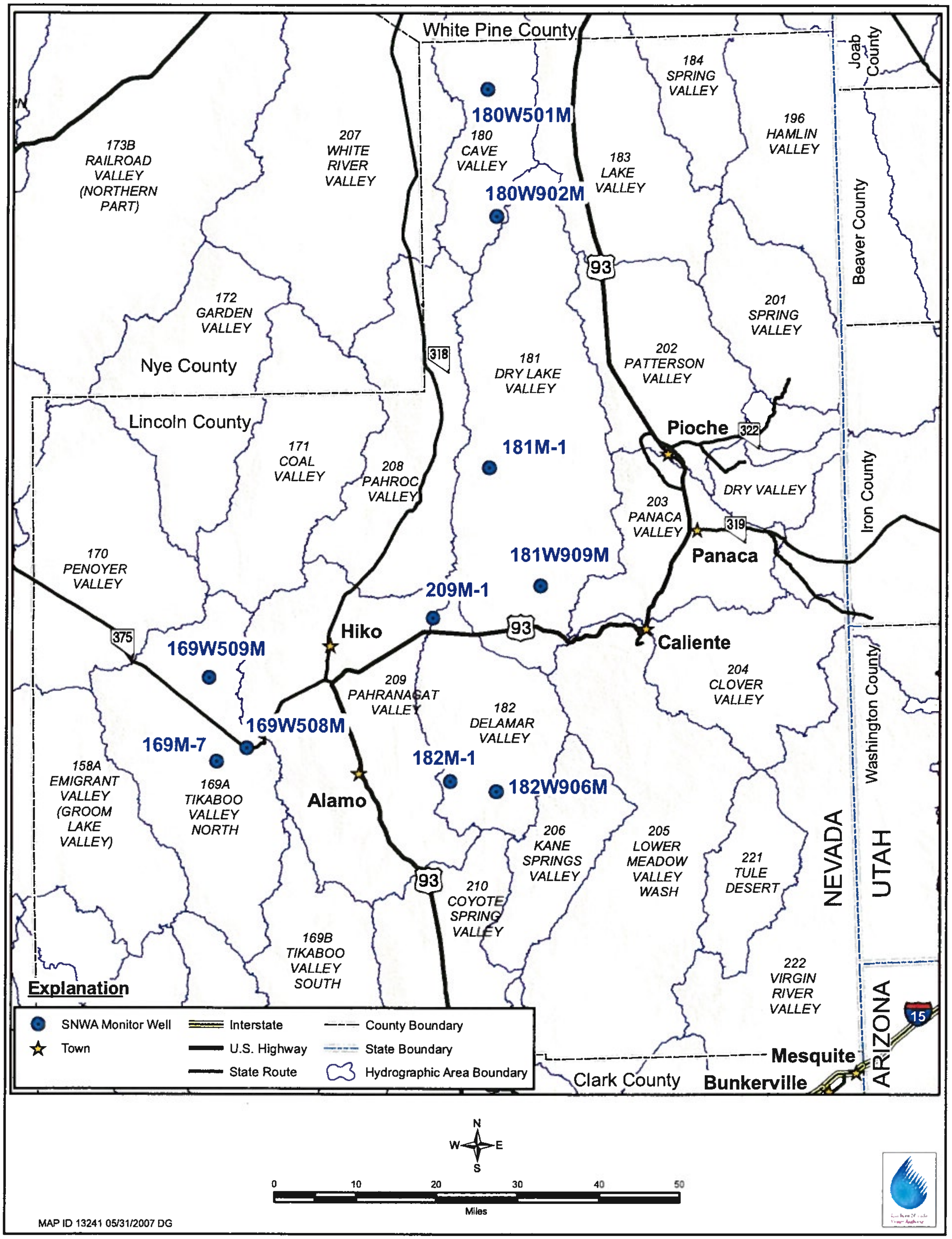
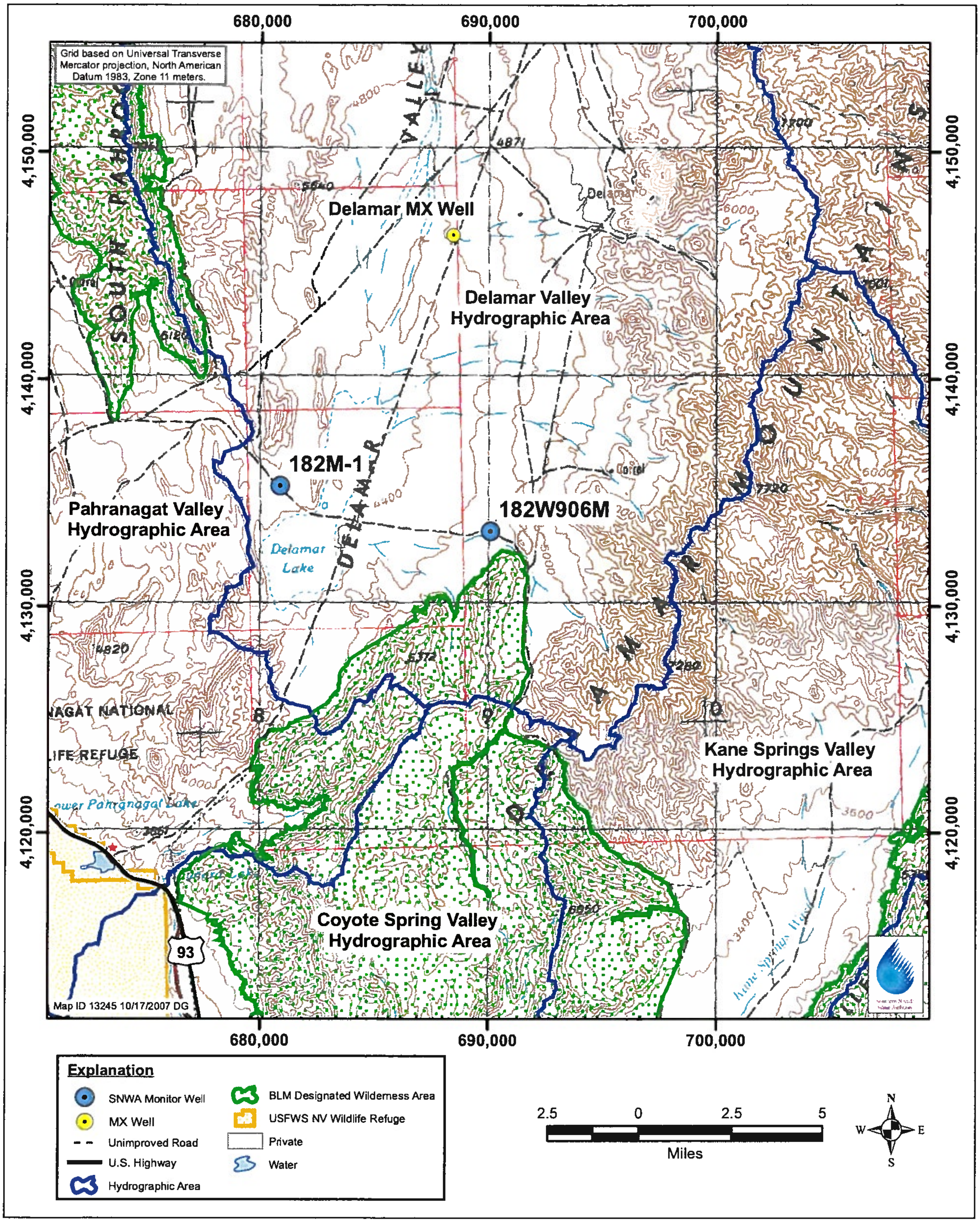


FIGURE 1
SNWA MONITOR WELL LOCATIONS, LINCOLN COUNTY, NEVADA



Source: USGS 1:250,000 Caliente quadrangle, Nevada-Utah; Land Status based on BLM (2006).

FIGURE 2
LOCATION OF MONITOR WELL 182W906M, LINCOLN COUNTY, NEVADA

1.3 SUMMARY OF MONITOR WELL CONSTRUCTION

Monitor Well 182W906M was completed in two stages. An initial (pilot) hole was completed on March 24, 2005, to a depth of 1,640 ft bgs as a 5.625-in. borehole inside 9.875-in. O.D. surface casing. The monitor well was drilled from July 18 to 28, 2005, to a depth of 1,735 ft bgs. On September 2, 2005, the monitor well was completed with 20-in. O.D. conductor casing to a depth of 58 ft bgs and 6.625-in. O.D. (6-in. I.D.) well casing from 2 ft above land surface to 1,702.9 ft bgs using a casing advance system with a slotted interval from 1,275.4 to 1,677.6 ft bgs. The monitor well was initially drilled using air-foam and flooded reverse circulation drilling techniques with a borehole diameter of 12.25 in.

Due to sloughing borehole conditions, the 12.25 in. borehole was reamed to 17.5 in. to a depth of 130 ft bgs, and 14-in. O.D. intermediate casing was set to 133 ft bgs (Stoller, 2005b) on July 30, 2005. Continuing problems with unstable borehole conditions led to the installation of 10.75-in. O.D. intermediate casing to 672 ft bgs (Stoller, 2005b) using a casing advance system on August 17, 2005, within the 12.25 in. borehole.

Figure 3 presents a photograph of the well site taken on April 17, 2007. For additional information on the well construction, refer to Stoller (2006).

Note: View is approximately along the northeast-trending Pahranagat shear zone.

FIGURE 3
VIEW OF MONITOR WELL 182W906M SITE, LOOKING SOUTHWEST

2.0

DATA ANALYSIS

This section analyzes the lithology, geophysical logs, and drilling statistics to evaluate the geology encountered in Monitor Well 182W906M.

2.1 GEOLOGIC SETTING

Delamar Valley is a fault-block basin within the Great Basin subprovince (Fenneman, 1931) formed during the regional extension during the late Tertiary Period (Rowley and Dixon, 2001). The southern end of the valley is marked by a northeast-trending Pahranagat shear zone that was formed by differential extension within the Great Basin region. To the east are the Caliente caldera complex and the Kane Springs Wash caldera, both of which have expelled large amounts of volcanic material in the Delamar Valley area. These calderas appear to have formed during an earlier extensional phase during the Miocene where extension "was expressed more by the emplacement of voluminous calc-alkalic, shallow intrusions … than by faults" (Rowley and Dixon, 2001).

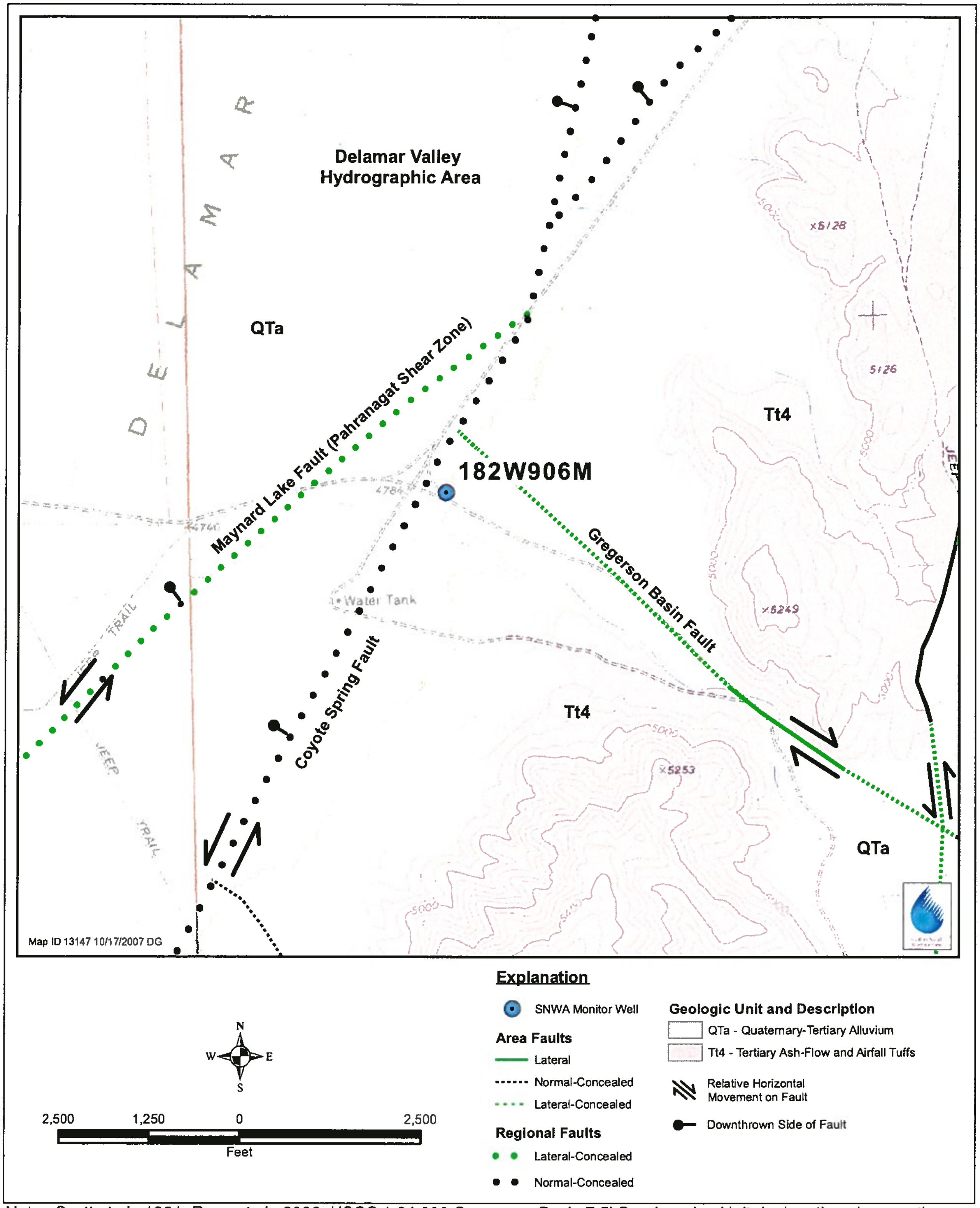
Monitor Well 182W906M is situated near the southern end of the Delamar Valley Hydrographic Area (Figure 1). The surface geology at the well site is of Quaternary and Tertiary alluvium with Tertiary volcanics making up the hills to the south and east (Scott et al., 1991). Important fault zones cut through the area of the monitor well site, including the Pahranagat shear zone, the Coyote Spring Fault, and the Gregerson Basin Fault. The surface geology is displayed on Figure 4.

2.1.1 GEOLOGIC UNITS ENCOUNTERED AT THE MONITOR WELL

The geologic units encountered in Monitor Well 182W906M consist of alluvial material and Tertiary volcanics, including the Kane Wash Tuff, the Delamar Lake Tuff, and the Hiko Tuff. The alluvial material consists of volcanic detritus eroded from the volcanics to the east and south. This material is part of the "surficial alluvium and basin fill" (QTa) regional geologic unit (RGU) (Dixon et al., 2007). The Kane Wash and Delamar Lake tuffs are part of the "ash-flow tuff and interbedded airfall tuff unit 4" (Tt4) RGU, and the Hiko Tuff is part of the "ash-flow tuff and interbedded airfall tuff unit 3" (Tt3) RGU (Dixon et al., 2007).

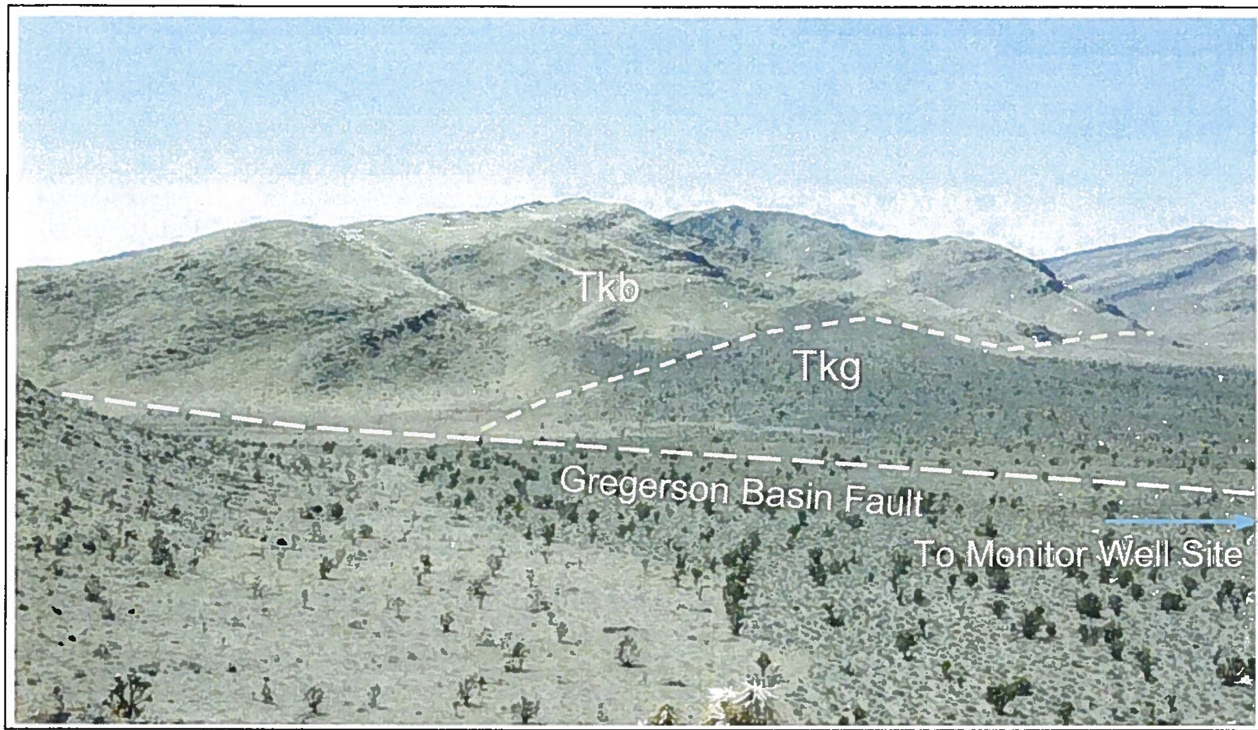
The Kane Wash Tuff consists of rhyolitic ash-flow tuffs, commonly comenditic and with phenocrysts of sanidine, quartz, hedenbergite, and olivine that comprise about 25 percent of the rock (Ekren et al., 1977; Scott et al., 1991 and 1995; Rowley et al., 1995). The sanidine is often adularescent (chatoyant), which distinguishes it from quartz or plagioclase. The Kane Wash Tuff forms the hills to the east and south of the monitor well (Figure 5). The Grapevine Spring member of the Kane Wash Tuff, which is encountered in the well, is exposed south of the well across a wash. A lower zone of this member is densely welded and commonly vitric.

The Grapevine Spring member is underlain by the Delamar Lake Tuff, which has a similar lithology but with a lower percentage of phenocrysts and an abundance of elongated pumice fragments and lithophysae (Figures 6 and 7). The Delamar Lake Tuff is exposed almost due east of the well site (Figure 8). Scott et al. (1991) indicate a fault contact of the Kane Wash Tuff with the Delamar Lake Tuff at that location. This tuff unit is also within "ash-flow tuff and interbedded airfall tuff unit 4" (Tt4) of the regional geologic map (Dixon et al., 2007).



Note: Scott et al., 1991; Page et al., 2006; USGS 1:24,000 Gregerson Basin 7.5' Quadrangle. Unit designations in parentheses are the RGUs defined in Dixon et al., (2007).

Figure 4
Preliminary Geologic Map around Monitor Well 182W906M, Southeast Delamar Valley



Note: Tkb = Gregerson Basin Member, Tkg = Grapevine Spring Member, both of the Kane Wash Tuff, dipping ~20° east-southeast (Scott et al., 1991); Miocene, ~14 to 15 Ma. Scattered outcrops of the Grapevine Spring Member are present south of the well site. The Kane Wash Tuff and its members are part of the Tt3 RGU (Dixon et al., 2007).

FIGURE 5
KANE WASH TUFF SOUTHEAST OF MONITOR WELL 182W906M, LOOKING SOUTH

FIGURE 6
OUTCROP OF DELAMAR LAKE TUFF WITH PUMICE FRAGMENTS AND LITHOPHYSAE EAST OF MONITOR WELL 182W906M

FIGURE 7
SAMPLE OF DELAMAR LAKE TUFF, SHOWING PUMICE FRAGMENTS AND LITHOPHYSAE FROM NEARBY OUTCROP EAST OF MONITOR WELL 182W906M

Note: Tkb = Gregerson Basin Tuff (brown); Tdl = Delamar Lake Tuff (gray); Qco = colluvium (Scott et al., 1991); east of Monitor Well 182W906M. Yellow line is a fault, an offshoot of the Gregerson Basin Fault (Scott et al., 1991). For this figure and Figures 6 and 7, the Gregerson Basin and Delamar Lake tuffs are part of the Tt3 RGU, and the colluvium is part of the QTa RGU (Dixon et al., 2007).

FIGURE 8
DELAMAR LAKE TUFF FAULTED AGAINST THE GREGERSON BASIN MEMBER OF THE KANE WASH TUFF, LOOKING EAST

Beneath the Delamar Lake Tuff is the Hiko Tuff, a non-welded to densely welded ash-flow tuff with abundant phenocrysts. The percentage of phenocrysts is generally 30 to 40 percent and can be as low as 15 percent to as much as 50 percent (Ekren et al., 1977; Scott et al., 1991 and 1995; Rowley et al., 1995). Compositionally, the Hiko Tuff appears to be a quartz latite or rhyodacite and is distinguished from overlying units by the presence of abundant plagioclase and biotite.

In the Gregerson Basin quadrangle geologic map, the Hiko Tuff has limited exposure, particularly within a few miles of the monitor well (Scott et al., 1991). The thickness of the Hiko Tuff appears to vary from about 800 or 900 ft to the southwest of the monitor well (Scott et al., 1993, Cross section B—B') to 3,000 ft or more to the northeast (Scott et al., 1991). Individual units and mineralogic variations within the Hiko Tuff are taken from other sources, such as Scott et al. (1993), Scott et al. (1995), and Rowley et al. (1995). These descriptions are helpful in correlating with individual members of the Hiko Tuff unit within the borehole.

In the Delamar Lake quadrangle, the Hiko Tuff is divided into four members: an upper moderately to densely welded tuff with about 40 percent phenocrysts and with pumice and lithic fragments, a lower unit of similar composition, a vitrophyric unit similar to the lower Hiko Tuff, and a partly welded tuff with fewer phenocrysts and more lithic fragments (Scott et al., 1993). Plagioclase and mafic minerals appear to be more abundant in the upper member (Scott et al., 1995; Rowley et al., 1995). The vitrophyric unit is considered to thin eastward. The partly welded tuff is also described as occurring in the southwest portion of the Gregerson Basin quadrangle (Scott et al., 1991), and it was noted in outcrop to the northeast of Monitor Well 182W906M.

2.1.2 GEOLOGIC STRUCTURE AT THE MONITOR WELL SITE

The Maynard Lake Fault, a primary strand of the Pahranagat shear zone, is a left-lateral strike-slip fault and is present northwest of the monitor well site (Figure 4). Another more northerly oriented fault, the Coyote Spring Fault, cuts through the area of the well site (Figures 4 and 9). This fault appears to be a left-lateral strike-slip fault as well, associated with the shear zone but striking more north–south. A third fault, the Gregerson Basin Fault, trends northwest from Gregerson Basin (Figure 5). This fault is a right-lateral strike-slip fault (Scott et al., 1991) and trends to a short distance north of the well site. None of these faults are present in outcrop in the vicinity of the well site, but all are indicated by offsets of units and/or by linear trends in topography (Figures 2 and 4). The Maynard Lake and Coyote Spring faults do have surface expression to the southwest in the Delamar Lake geologic map (Scott et al., 1993).

2.2 MONITOR WELL 182W906M

Monitor Well 182W906M was drilled in a single pass. An initial borehole was drilled near the completed well and is considered in order to provide additional details, but the primary focus of this section is on the completed well. For this report, the well cuttings were logged, and the geology encountered is discussed.

2.2.1 LITHOLOGY

Lithologic cuttings were collected for Monitor Well 182W906M at 10-ft intervals during the drilling process using SNWA internal procedures. These cuttings were described and the lithologic units

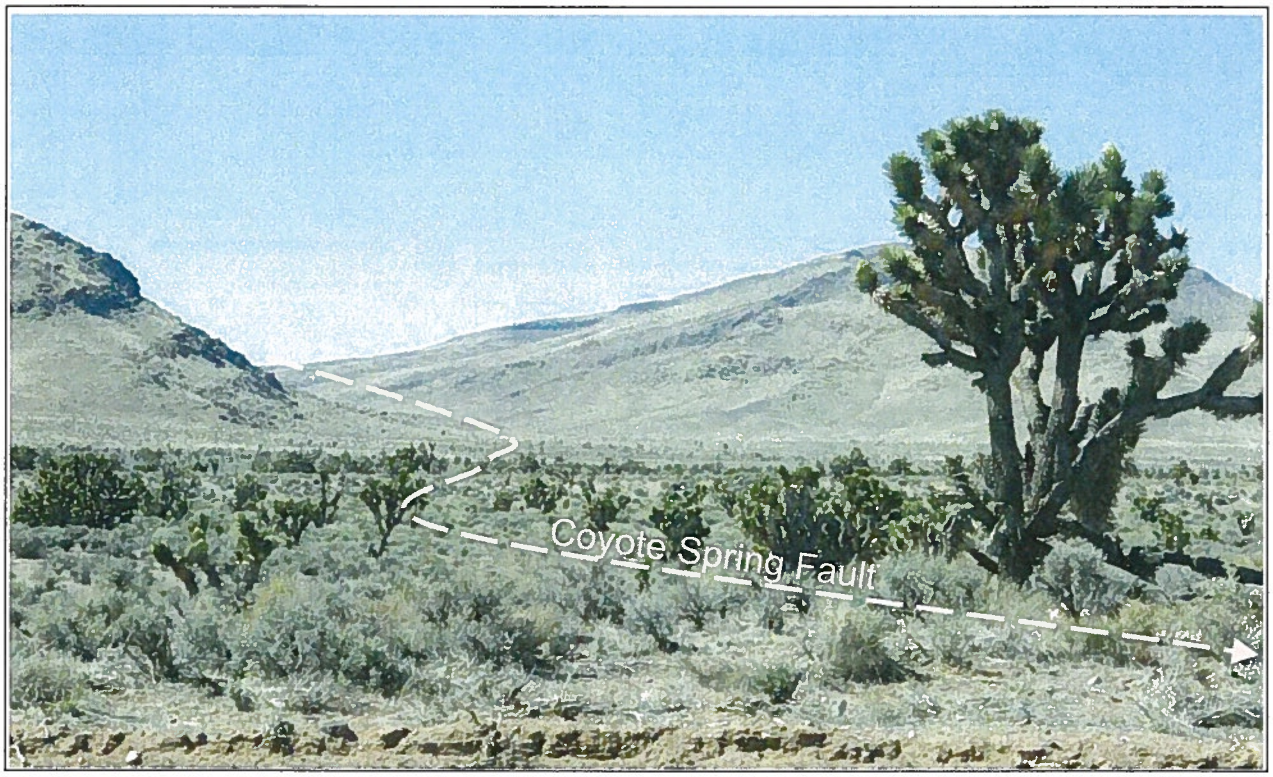


FIGURE 9
VIEW SHOWING THE APPROXIMATE LOCATION OF THE COYOTE SPRING FAULT FROM MONITOR WELL 182W906M, LOOKING SOUTH-SOUTHWEST

encountered by drilling were identified based on descriptions by Scott et al. (1991, 1993, and 1995), Rowley et al. (1995), and from samples collected from nearby outcrops. A summary of the lithologic log is included in Table 1.

Based on the cuttings and a video of the borehole, the upper 170 ft of the well is of surficial and older alluvial material. The Grapevine Spring member of the Kane Wash Tuff is present beneath the alluvium and consists of two types of tuff: a moderately to partly welded ash-flow tuff, from 170 to 280 ft bgs, and a lithic ash-flow tuff, from 280 to 350 ft bgs, for a total thickness of 180 ft. Phenocrysts in the Grapevine Springs member are dominated by sanidine and quartz and almost no plagioclase. Mafic minerals are dominated by pyroxene and hornblende and no biotite. In the initial hole, a vitrophyre is present at the base of the Grapevine Springs unit from 340 to 350 ft bgs, which is presumed to be part of that unit. A vitrophyre in this unit is indicated by Scott et al. (1991). In the completed hole, some evidence of the vitrophyre is present but to a lesser degree.

Based on the elongated pumice fragments that are common from about 350 to about 400 ft bgs, the Delamar Lake Tuff is present below the Grapevine Springs member. The Delamar Lake Tuff is similar to the Grapevine Springs member of the Kane Wash Tuff, with the dominance of sanidine and quartz phenocrysts but with a greater amount of pumice fragments and fewer phenocrysts. Mafic minerals also included pyroxene and hornblende. Biotite and plagioclase are rare. In both the

TABLE 1
LITHOLOGY OF MONITOR WELL 182W906M
(Page 1 of 3)

Interval Top to Base (ft bgs)	Geologic Unit	General Lithology	Description of Cuttings
0 to 60	QTa	Alluvium	Generally brown clay, silt, sand, and medium to very coarse gravel; poorly sorted angular to subrounded clasts. Clasts are primarily of Kane Wash Tuff with quartz and sanidine phenocrysts. Occ limestone or dolomite clasts to 30 ft bgs. See Note 1 at end of table.
60 to 170	QTa	Alluvium	Pink to gray to brown silt, sand, and medium to very coarse gravel, poor to moderately sorted subangular to subrounded clasts, rounded 160 to 170 ft bgs. Clasts are primarily of Kane Wash Tuff with quartz and sanidine phenocrysts. Some clasts of other volcanic units. Occ limestone or dolomite clasts. Lower contact based on borehole video.
170 to 280	Tkg (Tt4)	Moderately to partly welded ash-flow tuff	Pinkish gray to brown-gray. Quartz-sanidine phenocrysts, about 20%. The sanidine is often adularescent (chatoyant). Mafics, less than 2%, consisting of pyroxene, hornblende, and Fe-Ti oxides most likely magnetite and ilmenite. Occ flow-banded groundmass, often vitric. Occ lithic frags, less than 2%.
280 to 340	Tkg (Tt4)	Moderately welded ash-flow tuff	Pinkish gray to brown-gray. Quartz-sanidine phenocrysts, 15% to 30% as above. Mafics, 1% to 3% as above, rare biotite, usually in lithic frags. Pumice frags noted; 2% to 4% lithic frags, often of carbonate or volcanic material, possibly slough from caving zones in alluvium. Calcite probably as vlts.
340 to 350	Tkg (Tt4)	Vitric tuff	Pink to brown to gray, occ gray-green. Quartz-sanidine phenocrysts, 15% to 20% as above. Mafics less than 2% as above. Vitric frags green to gray-green, more common in the pilot hole. Occ lithophysae and pumice frags.
350 to 400	Tdl (Tt4)	Partly to moderately welded ash-flow tuff	Pinkish to brownish gray to grayish brown. Quartz-sanidine phenocrysts, 15% to 20% as above. Mafics, 1% to 3%, of pyroxene, hornblende, and FeOx as above, commonly oxidized. Banding in tuff. Elongated pumice frags and occ lithophysae. 1% to 2% calcite veinlets.
400 to 600	Thu (Tt3)	Partly to moderately welded ash-flow tuff	Pink to brownish gray to gray, often reddish. Quartz and feldspar phenocrysts, 15% to 30%. Mafics, 2% to 4%, of biotite, FeOx, and occ hornblende and pyroxene. Occ evidence of pumice frags and lithophysae and red-orange to orange flow banding with abundant glass shards parallel to the banding (see Note 2). Calcite on fractures or as alteration of feldspar and mafics.
600 to 780	Thu (Tt3)	Moderately to densely welded ash-flow tuff	Pink to gray to brownish gray, often reddish or orange. Quartz and feldspar phenocrysts, 25% to 35%. Mafics, 2% to 5%, of biotite, FeOx, and occ. hornblende. Occ flow banding of groundmass, generally orange to red-orange. Phenocrysts more abundant in these frags. Occ lithic frags, less than 2%. Calcite as above, and some silica on fractures.
780 to 850	Thu (Tt3)	Partly to moderately welded ash-flow tuff	Pink to gray to reddish gray or brownish gray. Quartz and feldspar phenocrysts, 25% to 35%. Mafics, 2% to 5%, as above. Occ flow banding as above. Cuttings tend to be fine with lots of silt, probably from grinding of partly welded tuff matrix. Calcite as above.

TABLE 1
LITHOLOGY OF MONITOR WELL 182W906M
(Page 2 of 3)

Interval Top to Base (ft bgs)	Geologic Unit	General Lithology	Description of Cuttings
850 to 940	Thl (Tt3)	Densely welded ash-flow tuff	Red-brown, reddish orange, gray, pink. Quartz and feldspar phenocrysts, 30% to 50%. Mafics, 3% to 6%, of biotite, hornblende, and FeOx. Abundant frags of vitric to devitrified orange to reddish orange flow banded groundmass with up to 60% phenocrysts. Lithic frags, 2% to 4%. Generally coarse cuttings. Calcite as above.
940 to 1,030	Thl (Tt3)	Moderately welded ash-flow tuff	Red-brown, reddish orange, pink, gray. Quartz and feldspar phenocrysts, 30% to 50%, sanidine occ adularine. Mafics, 2% to 5%, as above. Less abundant frags of vitric to devitrified groundmass as above. Lithic frags, 2% to 4%.
1,030 to 1,070	Thv (Tt3)	Moderately welded vitric ash-flow tuff	Quartz, sanidine, and plagioclase, 30% to 45%; Mafics, 2% to 4%, of biotite, hornblende, and FeOx. 1% to 2% frags of very dark gray vitrophyre. Occ frags of vitric to devitrified orange to reddish orange flow-banded groundmass with up to 60% phenocrysts, less common than above. Lithic frags, 1% to 2%. Calcite vlts and calcite alteration, hematite, and occ silica cement in fixed frags.
1,070 to 1,190	Thl (Tt3)	Moderately welded ash-flow tuff	Feldspar and quartz phenocrysts, 35% to 50%, feldspar much greater than quartz. No evidence of sanidine. Mafics, 5% to 7%, of biotite and minor FeOx. Rare lithic fragments and dark gray vitrophyre. Pinkish to reddish gray, brownish gray, and gray. Iron oxidation on fractures with possible faulting at 1,090 to 1,100 ft bgs.
1,190 to 1,230	Thl (Tt3)	Partially altered moderately welded ash-flow tuff	Feldspar phenocrysts with minor quartz, 30% to 40%. Mafics are uncommon, often less than 1% of the rock, and are of biotite, FeOx, and occ hornblende and pyroxene. Gray to red-gray, yellow to orange to reddish orange. Evidence of vitric and pumice frags and lithophysae. The pumice fragments commonly contain small vesicles partly or completely filled with silica. Occ lithic frags. Red-brown clay alteration is evident in the cuttings.
1,230 to 1,280	Thl (Tt3)	Clay altered moderately welded ash-flow tuff	Feldspar phenocrysts with minor quartz, 25% to 45%. Mafics, 1% to 5%, as above. Iron oxidation and clay alteration is common. Generally red-brown to red matrix, occ tan to brown and lt gray to gray.
1,280 to 1,320	Thl (Tt3)	Moderately to densely welded ash-flow tuff	Feldspar phenocrysts with minor quartz, 15% to 35%. Mafics are uncommon, often less than 1% of the rock, and are of biotite, FeOx, and occ hornblende and pyroxene. Gray to red-gray, yellow to orange to reddish orange. Evidence of vitric and pumice frags and lithophysae. The pumice fragments commonly contain small vesicles partly or completely filled with silica. Occ lithic frags.
1,320 to 1,410	Thl (Tt3)	Moderately to densely welded ash-flow tuff	Plagioclase, sanidine, and quartz phenocrysts, 15% to 30%. Mafics are generally less than 1% of the rock and are of biotite, FeOx, and occ hornblende and pyroxene. Pink to reddish gray, orange gray, brownish gray, commonly pale groundmass. Quartz-lined vesicles common, pumice and lithophysae are common. Rare lithic frags. Flow banding is common.
1,410 to 1,430	Thl (Tt3)	Moderately to densely welded ash-flow tuff	Phenocrysts as above, 20% to 35%. Mafics, 1% to 3%, as above. Hematite and clay are common in reddish brown, orange, and brown-gray matrix.

TABLE 1
LITHOLOGY OF MONITOR WELL 182W906M
(Page 3 of 3)

Interval Top to Base (ft bgs)	Geologic Unit	General Lithology	Description of Cuttings
1,430 to 1,700	Thp (Tt3)	Partly to moderately welded ash-flow tuff	Pink to reddish gray, orange-gray, brownish gray, brown, reddish brown. Plagioclase, sanidine, and quartz phenocrysts, 10% to 30%, sanidine often adularescent. Mafics are about 1% to 2% of the rock and are of biotite, FeOx, and occ hornblende and pyroxene. Occ pumice frags and lithophysae. Brown, gray, and dark brownish gray lithics are more common, 3% to 5%. Flow banded groundmass with glass shards is common, orange to pale orange or pale pink. Less common than above.
1,700 to 1,735	Thp (Tt3)	Partly welded ash-flow tuff	Highly fractured zone with tuff as rounded clasts and abundant fines in the cuttings. Tuff is as above with pumice frags, lithophysae, and lithics. Sanidine phenocrysts are coarser and often adularescent. Mafics are about 1% to 4% of the rock and are as above. Rare carbonate and quartzite clasts that may be from within this fault zone. Lithics 5% to 10%, include older tuffs. Hematitic clay, limonite, and MnOx on fractures.

Note 1. Cuttings from the initial hole were used for this interval, 0 to 60 ft bgs, as cuttings for this interval were not collected in the final hole.
Note 2. Flow banding of groundmass is a banding that is generally orange, pale orange, light orangish gray, reddish orange, or pinkish orange. The banding commonly has abundant glass shards and may have up to 60% phenocrysts in fragments of this material and generally has very few mafic minerals. This flow banding appears throughout the Hiko Tuff in varying amounts.

Common abbreviations for the above table:
FeOx - iron oxides usually magnetite and ilmenite
frags - fragments
MnOx - manganese oxide
occ - occasional or occasionally
vlts - veinlets

QTa - includes the surficial and older Quaternary alluvium encountered in this hole.
Tkg and Tdl designate the Grapevine Springs member of the Kane Wash Tuff and the Delamar Lake Tuff.
Th, Thv, and Thp designate the Hiko Tuff and its vitric and partly welded submembers.
RGU designations are given in parentheses where the unit is a subunit of the RGU.
The RGUs are defined in Dixon et al. (2007).

Grapevine Springs member of the Kane Wash Tuff and the Delamar Lake Tuff, mafics rarely comprise greater than 3 percent of the rock, usually less than 2 percent.

The Hiko Tuff was encountered below the Kane Wash Tuff and is distinguished by a high percentage of plagioclase phenocrysts, the presence of biotite, and a greater percentage of mafic phenocrysts. The Hiko Tuff appears to consist of distinct subunits. The upper units, from 400 to 1,030 ft bgs, include a partly to moderately welded ash-flow tuff, a moderately welded ash-flow tuff, and a moderately to densely welded ash-flow tuff. These units contain 25 to 35 percent phenocrysts in the upper part of this interval and up to 35 to 50 percent phenocrysts in the lower part. A moderately welded, vitric tuff is present between 1,030 and 1,070 ft bgs with 30 to 45 percent plagioclase, sanidine, and quartz phenocrysts. This tuff is similar to the vitrophyric member of the Hiko Tuff described in the Delamar Lake quadrangle to the west (Scott et al., 1993). Toward the base of this zone are abundant iron oxidation and calcite veinlets, indicating a fault or strong fracture zone.

Below the vitrophyric tuff is a moderately welded tuff with abundant quartz and feldspar phenocrysts, 35 to 50 percent, and abundant biotite, 5 to 7 percent. This zone is between 1,070 and 1,190 ft bgs. Below this interval is a moderately to densely welded ash-flow tuff with 20 to 35 percent phenocrysts of plagioclase, sanidine, and quartz. This tuff has a low percentage of mafics, often less than 1 percent, which corresponds to descriptions as indicated in Section 2.1.1. A clay-rich or fines-rich zone was noted between about 1,230 and 1,350 ft bgs, indicative of probable faulting within the unit, where alteration of the tuff occurred along the fault zone. This alteration was particularly noticeable in the first 50 ft. Hematite was often common in the cuttings in this interval either on fractures or in the groundmass. Moderately to densely welded tuff is present to about 1,430 ft bgs, with strong hematite and clay alteration between 1,410 and 1,430 ft bgs.

Below 1,430 ft bgs, the Hiko Tuff is a partly to moderately welded ash-flow tuff with 10 to 30 percent phenocrysts of quartz, sanidine, and plagioclase and 5 percent lithics. This tuff has less than 1 percent to a maximum of 2 percent mafics, lithic fragments, and abundant pumice fragments and lithophysae. The mafics are a mixture of biotite, hornblende, and iron oxides. Pyroxene may be present. The partly welded tuff is similar to the partly welded unit of Scott et al. (1993), the lowermost unit of the Hiko Tuff. Below about 1,500 ft bgs, there is a slight increase in mafics, in the range of 0.5 to 3 percent. Also, below this depth, green minerals were occasionally noted, probably epidote and chlorite, from alteration of plagioclase and mafic minerals.

At 1,700 ft bgs, a zone of water-bearing material was encountered. This material appears to represent a fault zone with fragments of volcanic tuff with plagioclase, sanidine, quartz phenocrysts, and lithic fragments. This assemblage is typical of the partly welded Hiko Tuff. Rare clasts of quartzite and limestone were also noted in the borehole cuttings. Because of problems with hole caving above the drill bit and difficult drilling, the cuttings obtained may have had contamination from overlying units during drilling.

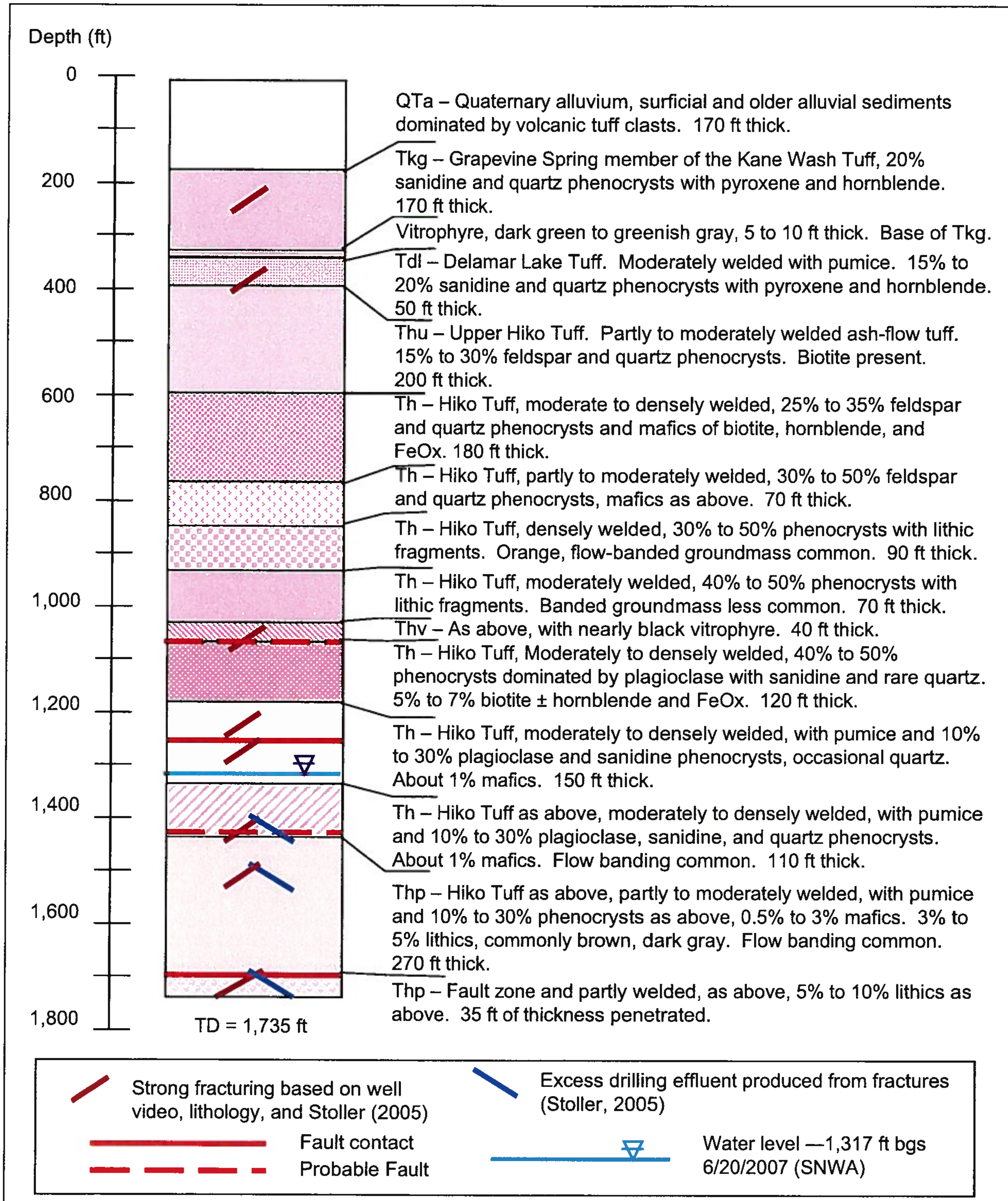
The number of zones of strong clay alteration and oxidation of iron in this well is most likely due to the proximity of the Coyote Spring Fault, an oblique-slip structure just west of the well (Figure 4). Its position to the west is indicated by the relatively shallow alluvium, which is less than 200 ft thick.

The well lithology is presented graphically on Figure 10.

2.2.2 BOREHOLE GEOPHYSICS

On completion of the borehole, caliper measurements and borehole videos were taken to maximum depths of 408 and 395 ft bgs, respectively (Stoller, 2005a). As a bridge of caved material was found at that depth, geophysical logging was not performed at that time.

On September 24, 2005, following completion of the cased hole, a final set of geophysical logs was taken through the well casing (Stoller, 2006). At this time, the water level in the well was at about



Correlation of geologic units with regional geologic units (RGUs) (Dixon et al., 2007):
The surficial and older alluvium are part of the QTa RGU.
The Kane Wash Tuff (Grapevine Spring Member, Tkg) and the Delamar Lake Tuff (Tdl) are part of the Tt4 RGU.
The Hiko Tuff and its members (Thu, Th, Thv, and Thp) are part of the Tt3 RGU.

FIGURE 10
BOREHOLE STRATIGRAPHIC COLUMN OF MONITOR WELL 182W906M

1,300 ft bgs. In addition, a well video was taken to evaluate the cased well on September 24, 2005. The following geophysical logs were performed:

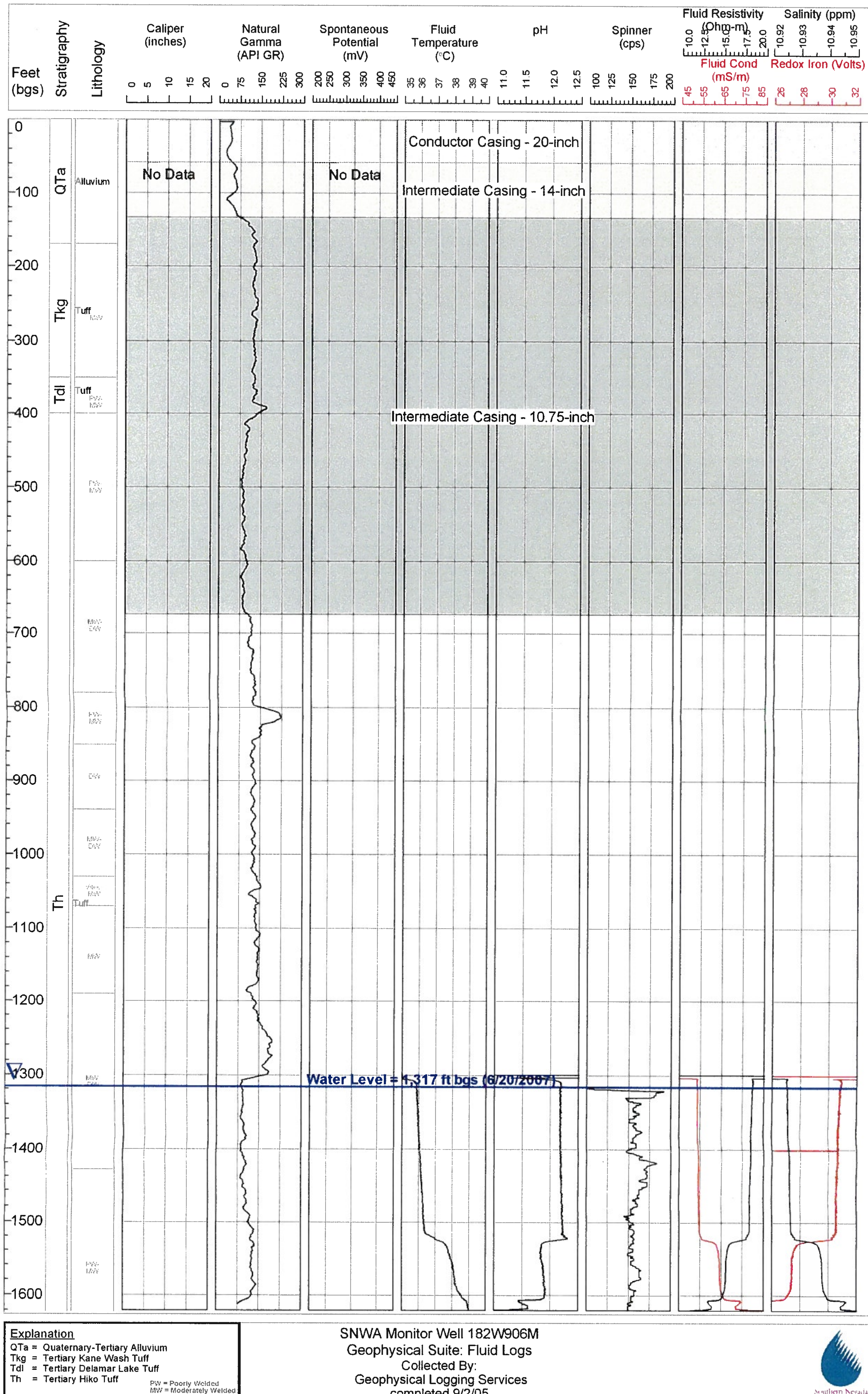
- Natural Gamma Ray
- Density
- Neutron
- Spectral Gamma – Potassium, Uranium, and Thorium (KUT)
- Total Spectral
- Temperature
- Differential Temperature
- Fluid Conductivity
- Fluid Resistivity
- Redox Iron Reduction Volts
- Salinity (NaCl)
- pH
- Spinner Log
- Deviation Log
- Pressure (psi).

These geophysical logs are presented on Figures 11 and 12.

Muller (2007a and b) evaluated the geophysical logs for Monitor Well 182W906M and indicated that the more reliable logs include Natural Gamma Ray (Gamma), Fluid Temperature, Fluid Conductivity, Fluid Resistivity, Salinity, pH, Deviation, and Pressure. For the Spectral (KUT) logs, Muller (2007b) considered the K (potassium) and U (uranium) logs to be questionable and the T (thorium) log as probably invalid.

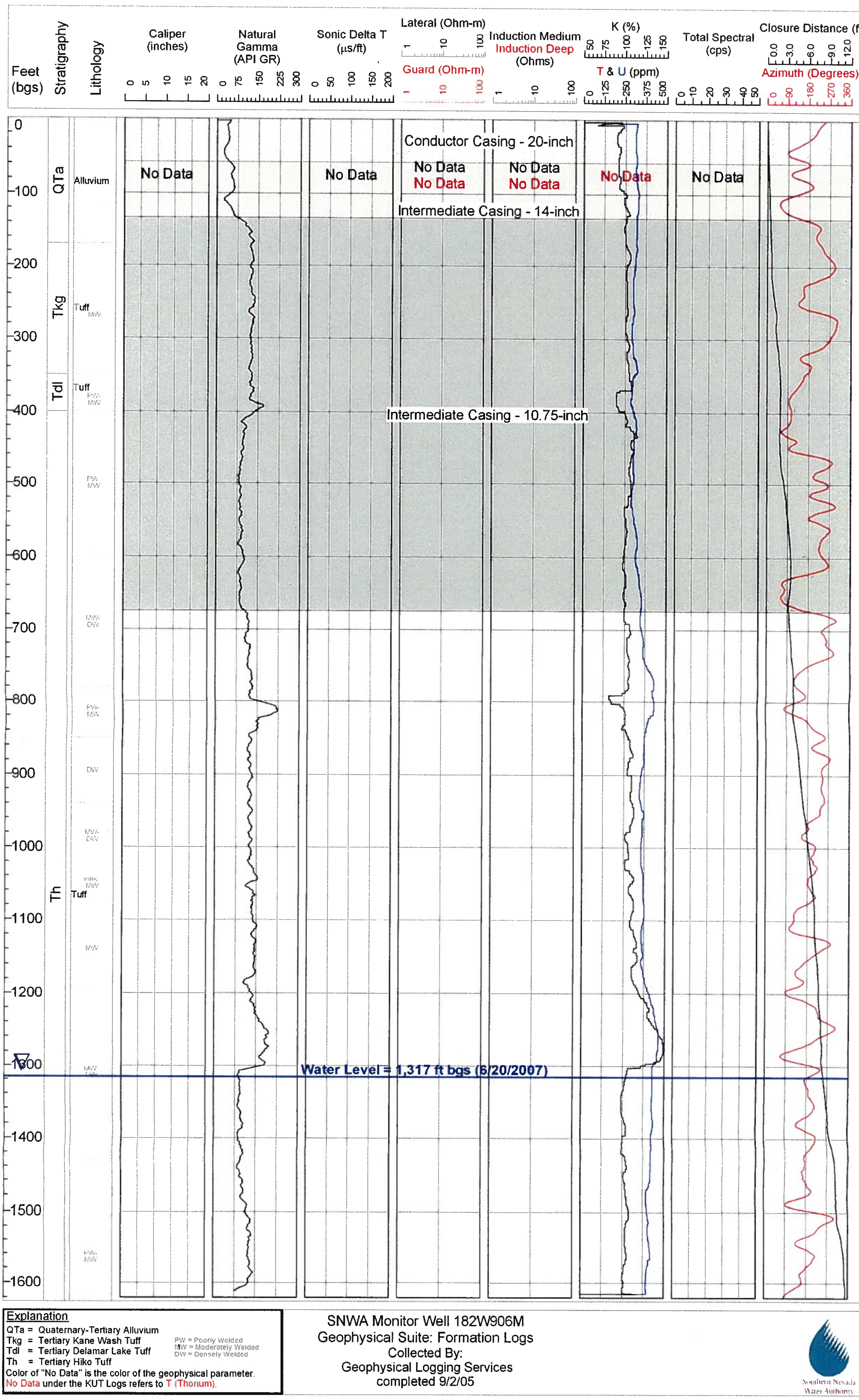
The Gamma log indicates activity of about 120 to 160 gru, with occasional spikes of 160 to 200 gru in the suballuvial volcanics down to the water level. An increase in the Gamma readings between 130 and 170 ft bgs indicates the base of the alluvium and the base of the outer intermediate casing (133 ft bgs). A spike in the Gamma log occurs at 390 ft bgs, the location of a zone that subsequently washed out during drilling of the completed well. This spike also is at the base of the Delamar Lake Tuff. Below this depth is the Hiko Tuff, wherein the Gamma count rate drops to about 100 gru. This count rate rises to about 120 gru at about 675 ft bgs, which most likely indicates the base of the second intermediate casing. More densely welded tuffs are also common below that depth. A spike in the Gamma log at 820 ft bgs is considered to represent the base of the upper Hiko Tuff, below which is a more phenocryst-rich tuff, commonly densely welded and often with an orangish-pink to orange-banded matrix.

An increase in the Gamma counts below 1,240 ft bgs is within a fault zone. Below the water level at 1,300 ft bgs, the count rate drops to a range of 90 to 110 gru. The Gamma reading increases to 120 to 130 gru below 1,480 ft bgs, which is associated with the partly welded, lithic Hiko Tuff. The higher gamma counts may be due to a higher percentage of potassium-rich minerals, particularly sanidine and biotite. The cuttings do support this higher potassium content with an increase in biotite below 1,470 ft bgs and an increase in the amount of sanidine below about 1,550 ft bgs. Note that for all of these changes, the count rates were attenuated by the well casing.



Note: Correlation with Regional Geologic Units (Dixon et al., 2007): The Kane Wash and Delamar Lake tuffs are part of the Tt4 ash-flow tuffs, and the Hiko Tuff is part of the Tt3 ash-flow tuffs. Logs plotted by SNWA.

FIGURE 11
MONITOR WELL 182W906M GEOPHYSICAL FLUID LOGS



Note: Correlation with Regional Geologic Units (Dixon et al., 2007): The Kane Wash and Delamar Lake tuffs are part of the Tt4 ash-flow tuffs, and the Hiko Tuff is part of the Tt3 ash-flow tuffs. Logs plotted by SNWA.

FIGURE 12
MONITOR WELL 182W906M GEOPHYSICAL FORMATION LOGS

Generally, the Spectral logs are expected to be similar to the Gamma log overall. Dissimilarities were noted between the two logs. For instance, the surface casing and intermediate casing had no effect on K and U logs, but a noticeable effect on Gamma log. Small peaks in the Gamma log were either not reflected in the K and U logs or were seen as reductions in the potassium. The only similarities between the logs were a rise in counts below 1,200 ft bgs and a drop in counts below the water table, particularly for potassium. Because of the dissimilarities, Muller's (2007b) uncertainty with the Spectral logs for K and U is well founded and no further discussion of these logs is presented.

The Fluid Temperature was nearly constant at approximately 36°C to 1,520 ft bgs, and increased to 38°C at the base of the log, suggesting the influence of warm groundwater (about 40°C) deep in the well (Acheampong et al., 2007).

The Spinner log was fairly flat with little indication of vertical flow in the well. The readings increased slightly at about 1,410 to 1,450 ft bgs, indicating possible downward flow. This interval corresponds to a zone of strong hematite and clay alteration.

Logs of pH, Fluid Resistivity, Fluid Conductivity, Salinity, and Redox Iron were all derived from an Idronaut Water Quality Probe. The strong similarity of the logs indicate that they were all derived from one sensor (Muller, 2007b), so only the Fluid Conductivity log will be considered.

The Fluid Conductivity was fairly constant at 55 mS/m to 1,530 ft bgs and then increased to 65 mS/m, most likely due to mixing of the drilling fluid with groundwater. The fluid conductivity increased again to 74 mS/m at 1,605 ft bgs where the groundwater influence is greatest. These logs indicate that most of the groundwater entering the well is from near and below the depth of the geophysical logging interval, i.e., at or below about 1,530 ft bgs.

Caliper logs and borehole videos indicated washed out or caved zones at 109 ft bgs, 255 to 260 ft bgs, and 390 to 395 ft bgs, at which depth the borehole video encountered a blockage. Additional caved intervals occurred at about 670 ft bgs and at 803 ft bgs, and additional caving was indicating by the number of bridges that had to be penetrated while installing the well casing and screen (Stoller, 2005a).

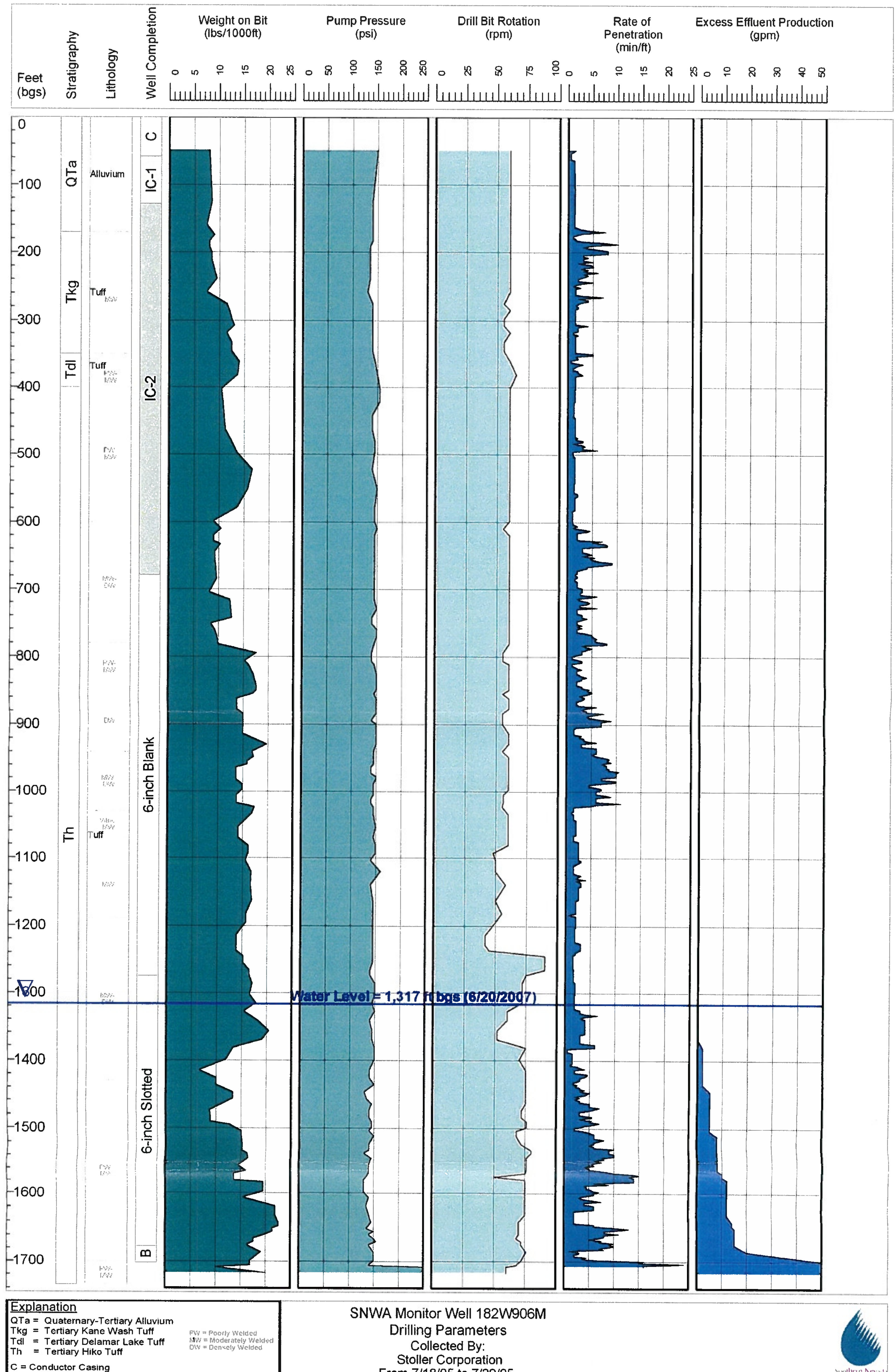
The Deviation (Closure Distance) log is reasonable overall. However the variations in the azimuth are questionable. It is as if the instrument was wobbling inside the 6-in. I.D. casing and was not taking accurate azimuth readings. If, overall, the readings are approximately correct, then the position of the hole at 1,620 ft bgs is approximately 11.6 ft S20W of the surface position.

2.2.3 DRILLING PARAMETERS

Stoller (2006) provided data on the drilling parameters as follows:

- Weight on Bit
- Pump Pressure
- Drill Bit Rotation
- Rate of Penetration
- Water Production.

These drilling parameters are presented on Figure 13.



Note: Correlation with Regional Geologic Units (Dixon et al., 2007): The Kane Wash and Delamar Lake tuffs are part of the Tt4 ash-flow tuffs, and the Hiko Tuff is part of the Tt3 ash-flow tuffs. Logs plotted by SNWA.

FIGURE 13
MONITOR WELL 182W906M DRILLING PARAMETERS

The rate of penetration declined in the upper part of the Grapevine Springs member of the Kane Wash Tuff. In the upper part of the Hiko Tuff, penetration rates were variable. Mixed moderately and densely welded tuff are present in a zone of variable penetration rate between 600 and 780 ft bgs. Partly welded tuff is present in a zone of low penetration rate between 780 and 800 ft bgs. Between 850 and 1,040 ft bgs, the penetration rate was low in moderately to densely welded tuff. The penetration rate increased markedly below 1,040 ft bgs, where fault zones and fracturing within the tuff where the tuff were encountered.

Below the water table, penetration rates became more variable. Clay and silt-sized cuttings are particularly noticeable between 1,280 and 1,420 ft bgs, and the rate of penetration decreased in this zone. Penetration rates in the lower part of the hole were further reduced, particularly within the partly welded tuff between 1,430 and 1,700 ft bgs. The weight on the bit increased below 1,500 ft bgs, indicative of an attempt by the contractor to increase the penetration rate. Increases in the weight on bit at 1,580 and 1,620 ft bgs resulted in increases in the low penetration rate. However, these increases in penetration rate were short-lived due to the softer portions of the partly welded Hiko Tuff. In addition, the drill bit had been in use for over 100 hours (Stoller, 2005a). A fault zone and softer partly welded tuff probably explain the very low penetration rate and high pump pressure at and below 1,700 ft bgs.

2.3 HYDROGEOLOGY

Monitor Well 182W906M was completed within the Hiko Tuff. During drilling operations, little water was encountered until approximately 1,700 to 1,735 ft bgs, where drilling returns increased to approximately 50 gpm (Stoller, 2005a, July 29, 2005). This zone appeared to be that of fractured tuff within a partly to moderately welded rhyolitic tuff that appears similar to the partly welded member of the Hiko Tuff of Scott et al. (1993). Note that much of the borehole below the groundwater elevation is in partly welded tuff, which may hinder groundwater flow due to its softer nature.

The lower fractured tuff zone was not screened due to difficulty with keeping the borehole open between 1,710 and 1,735 ft bgs, and the casing advance system used to install the casing and screen was not capable of advancing the casing to this depth.

A depth-to-water level of 1,300.11 ft bgs was taken at 12:00 on January 9, 2006, by SNWA (Stoller, 2006). The surface elevation at the well is approximately 4,802 ft amsl, which gives a groundwater elevation of approximately 3,502 ft amsl. This site has not been professionally surveyed. Eight additional water level readings have been taken since June 2006 ranging from 1,317.26 to 1,319.76 ft bgs and averaging 1,318.81 ft bgs or approximately 3,483 ft amsl. All of these readings are more than 15 ft lower than the reading taken in January 2006. A complete set of water level measurements is provided in Table 2.

2.4 SUMMARY

Monitor Well 182W906M was drilled in July 2005 and cased and screened in August and September 2005 for the purpose of collecting geologic, hydrologic, and geochemical data. This monitor well is located in southeastern Delamar Valley and was drilled to a total depth of 1,735 ft bgs with a slotted interval from 1,275.4 to 1,677.6 ft bgs.

TABLE 2
WATER LEVEL MEASUREMENTS FOR MONITOR WELL 182W906M

Date	Time	Depth (ft bgs)	Elevation (ft amsl)	Data Collected By
7/26/05	8:45	1,280	3,522	Stoller, on completion of drilling
9/24/2005	NP	1,302	3,500	Geophysical Logging Services (Prescott, AZ)
1/09/2006	12:00	1,300.11	3,502	SNWA
6/16/2006	10:55	1,298.4	3,504	Layne Christensen Co. (Yermo, CA) (SNWA, 2006)
10/24/2006	16:45	1,319.76	3,482	SNWA
12/11/2006	13:15	1,319.70	3,482	SNWA
1/22/2007	10:44	1,319.49	3,483	SNWA
2/26/2007	9:43	1,318.10	3,484	SNWA
4/02/2007	10:09	1,317.34	3,485	SNWA
4/25/2007	15:30	1,319.60	3,482	SNWA
5/14/2007	10:40	1,319.25	3,483	SNWA
6/20/2007	9:55	1,317.26	3,485	SNWA

Note: Groundwater elevations are rounded to the nearest foot to reflect the uncertainty in the surface elevation of the well and the variability of the water level measurement procedures.
NP = Not provided.

The monitor well encountered 170 ft of alluvium and 1,565 ft of volcanic tuff. The volcanic tuffs include three units. The first is the Grapevine Spring member of the Kane Wash Tuff, an ash-flow tuff with phenocrysts of sanidine, quartz, and iron-rich hornblende, pyroxene, and olivine, to a depth of about 350 ft bgs. The next is the Delamar Lake Tuff, an ash-flow tuff about 50 ft thick, to 400 ft bgs. The third unit is the Hiko Tuff, which is 1,335 ft thick in the borehole. This tuff is an ash-flow tuff with phenocrysts of plagioclase and sanidine feldspars along with quartz, hornblende, and biotite. The Hiko Tuff was divided into the upper, lower, vitrophyric, and partly welded members based on the lithology and the geophysics.

Geophysical logs and drilling parameters provided additional data for analysis. The geophysical logs were performed within the well casing due to instability of the borehole. The Gamma log assisted in defining the Delamar Tuff-Hiko Tuff boundary and the boundary between upper and lower Hiko Tuff. Other geophysical logs primarily defined the properties of the drilling fluid, but these logs did indicate interaction of the drilling fluid with the groundwater toward the bottom of the casing. The borehole video showed the base of the alluvium and fracture zones in the first 395 ft of well depth. The drilling parameters indicated zones of difficult drilling, which reflected zones of soft or densely welded volcanic tuff.

Water level measurements consistently gave a water level of approximately 1,300 ft bgs or 3,500 ft amsl. Subsequent water level measurements, October 2006 to June 2007, indicated a water level of 1,317 to 1,320 ft bgs or approximately 3,485 ft amsl.

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