Doc No. RDS-ED-0007

Southern Nevada Water Authority

Geologic Data Analysis Report for Monitor Well 181W909M in Dry Lake Valley

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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
HA	hydrographic area
RGU	regional geologic unit
SNWA	Southern Nevada Water Authority
TD	total depth
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
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
µs	microsecond
mi	mile
min	minute
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 181W909M is located in southeastern Dry Lake Valley in Section 7, T3S, R65E at an elevation of approximately 4,800 ft amsl (Figure 2). The site is approximately 28 mi west-northwest of Caliente, Nevada, and is reached by a power line service road (gravel) that runs northeastward from its intersection with U.S. Highway 93 approximately 29 mi west of Caliente. The site is west of the Burnt Springs Range, east of the Dry Lake Playa, and about 3/4 mi southeast of two wells drilled as part of the MX missile-siting program.

1.1 PURPOSE AND SCOPE

The purpose of this report is to describe the geologic, geophysical, and hydrologic data collected for Monitor Well 181W909M. 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.

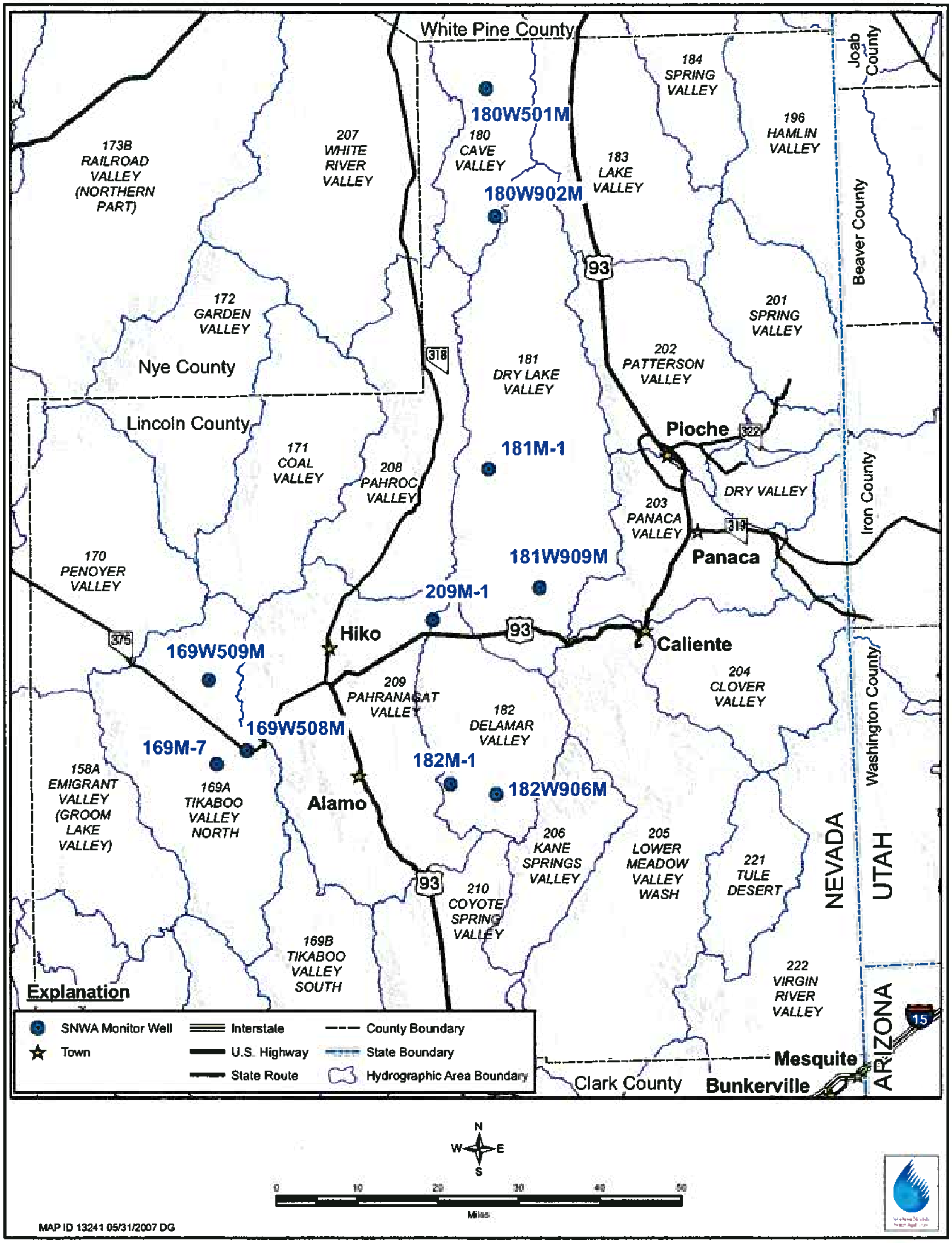
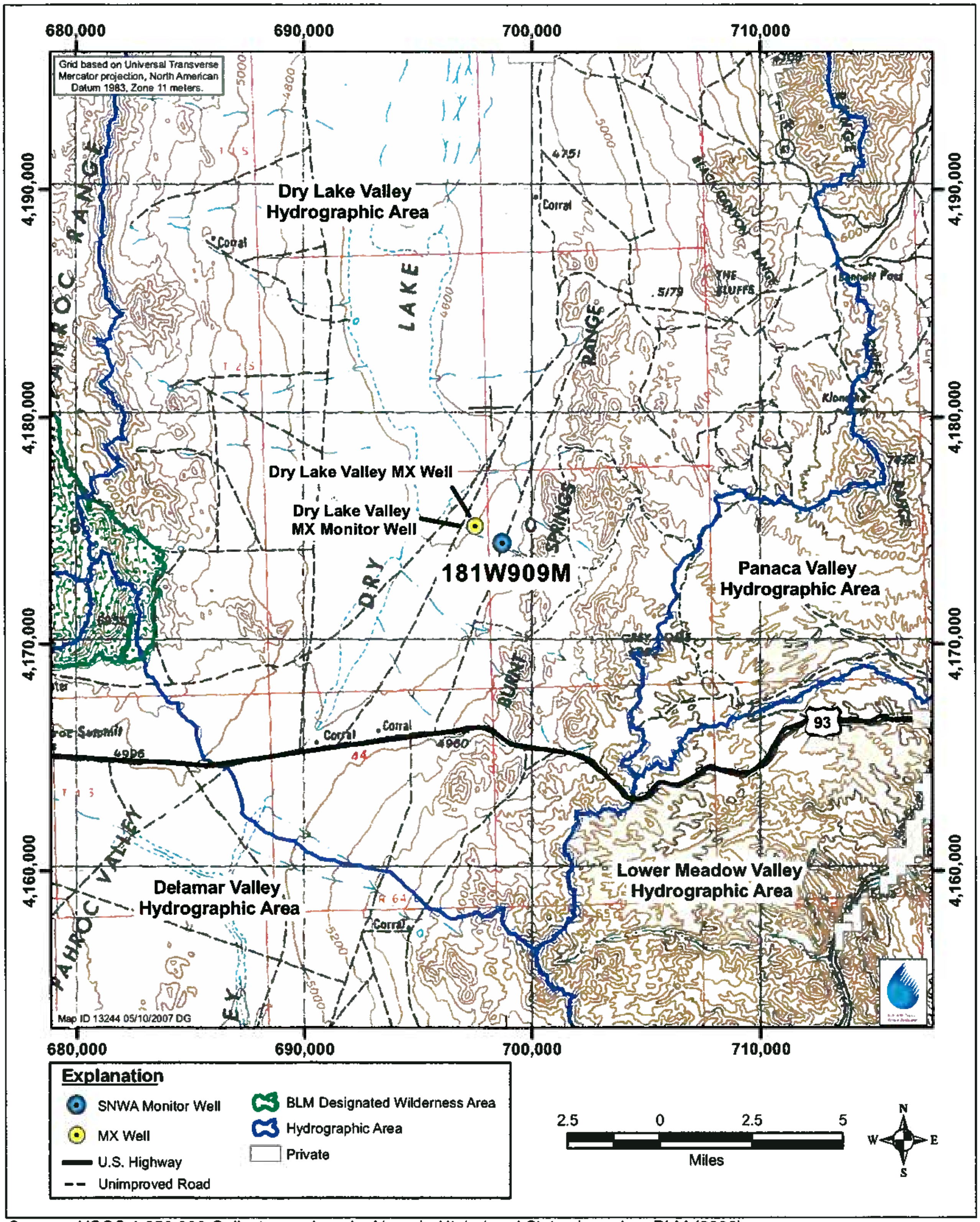


Figure 1
SNWA Monitor Well Locations, Lincoln County, Nevada



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

FIGURE 2
LOCATION OF MONITOR WELL 181W909M, LINCOLN COUNTY, NEVADA

1.3 SUMMARY OF WELL CONSTRUCTION

Monitor Well 181W909M was completed in two stages. An initial (pilot) hole was completed on April 29, 2005, to a depth of 1,320 ft bgs as a 5.875-in. borehole inside 9.75-in. O.D. surface casing. The monitor well was drilled and completed from September 16 to October 16, 2005, to a depth of 1,285 ft bgs. The monitor well was completed with 24-in. O.D. conductor casing to 171 ft bgs and a 12-in. I.D. well casing with a slotted interval from 637.35 to 1,239.65 ft bgs. The completion borehole was drilled using direct and flooded reverse circulation drilling techniques with a borehole diameter of 17.5 in.

Figures 3 and 4 are photographs of the completed monitor well taken January 23, 2007. For additional information on the well construction, refer to Stoller (2006).

FIGURE 3
VIEW OF MONITOR WELL 181W909M SITE, LOOKING EAST TOWARD THE BURNT SPRINGS RANGE

FIGURE 4
VIEW OF MONITOR WELL 181W909M SITE, LOOKING WEST TOWARD DRY LAKE PLAYA

DATA ANALYSIS

This section analyzes the lithology, geophysical logs, and drilling statistics to evaluate the geology encountered in Monitor Well 181W909M.

2.1 GEOLOGIC SETTING

Dry Lake Valley is a fault-block basin within the Great Basin subprovince (Fenneman, 1931) formed during regional extension during the late Tertiary Period (Rowley and Dixon, 2001). The eastern and western margins of the valley are marked by north-trending normal faults that were formed by extension within the Great Basin region (Tschanz and Pampeyan, 1970; Dixon et al., 2007). Significant geomorphic, alluvial, and structural features in Dry Lake Valley are described by Swadley (1995).

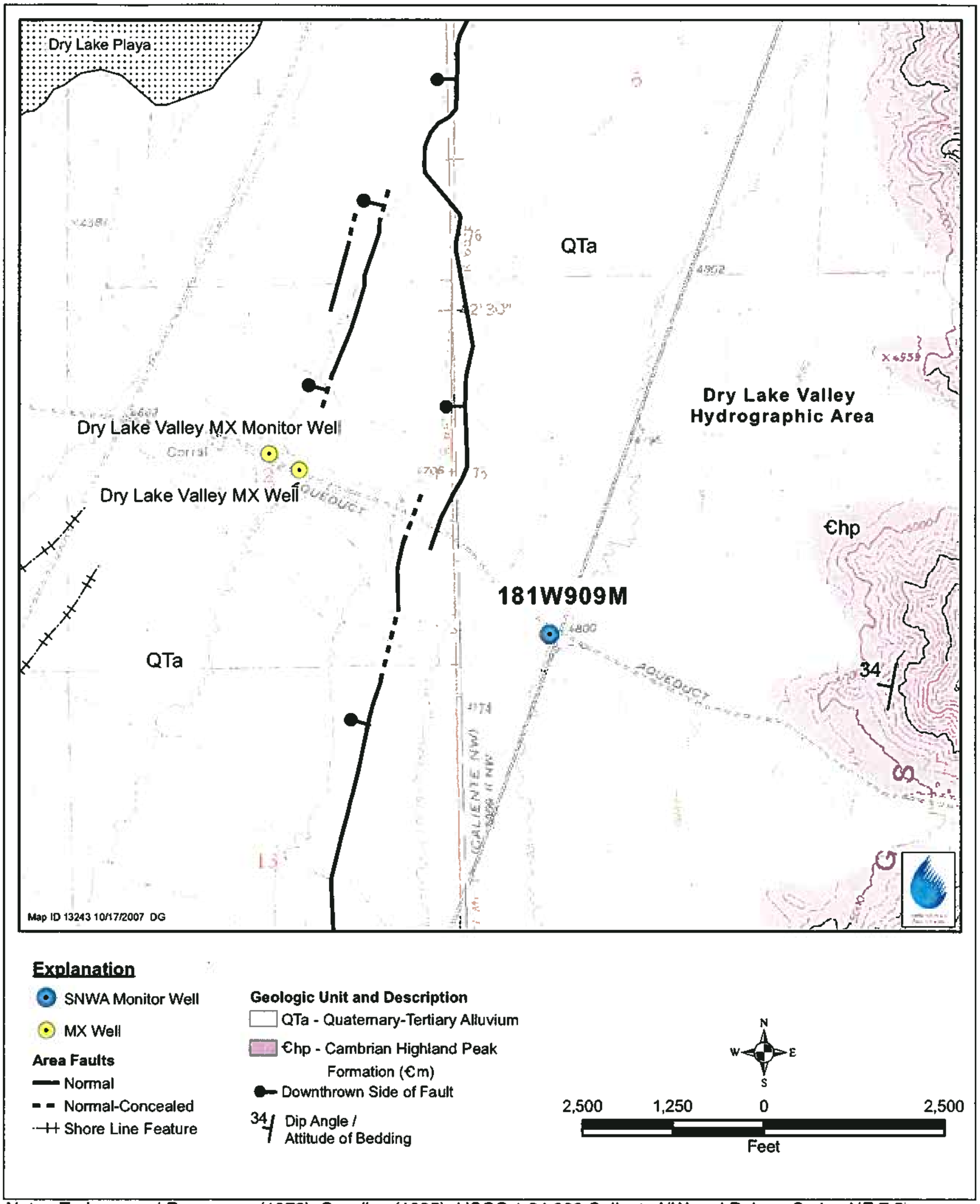
Monitor Well 181W909M is situated near the southeastern margin of Dry Lake Valley alluvial basin within the Dry Lake Valley Hydrographic Area. The monitor well is drilled in Quaternary-Tertiary alluvium near north-south trending faults related to the range-front fault adjacent to the Burnt Springs Range. The closest rock outcrops are limestone of the Cambrian Highland Peak Formation in the Burnt Spring Range (Tschanz and Pampeyan, 1970), about 1/2 mi to the east. The surface geology is shown on Figure 5.

2.1.1 GEOLOGIC UNITS ENCOUNTERED AT THE MONITOR WELL

The geologic unit encountered in Monitor Well 181W909M was exclusively Quaternary and Tertiary alluvium of the "surficial alluvium and basin fill" (QTa) regional geologic unit (RGU) (Dixon et al., 2007). This basin-fill alluvium consists of clasts of limestone, dolomite, chert and volcanic rocks, intermixed with silt and clay, derived primarily from the Burnt Springs Range east of the monitor well site where Tertiary volcanic rocks and Paleozoic rocks are exposed. The Paleozoic rocks include the Cambrian Dunderberg Shale of the upper Cambrian RGU (Ꞓu) and Highland Peak Formation of the middle Cambrian RGU (Ꞓm) (Figure 5) (Dixon et al., 2007). The Tertiary volcanics are Miocene and Oligocene ash flow tuffs of the Tt3 RGU (Dixon et al., 2007).

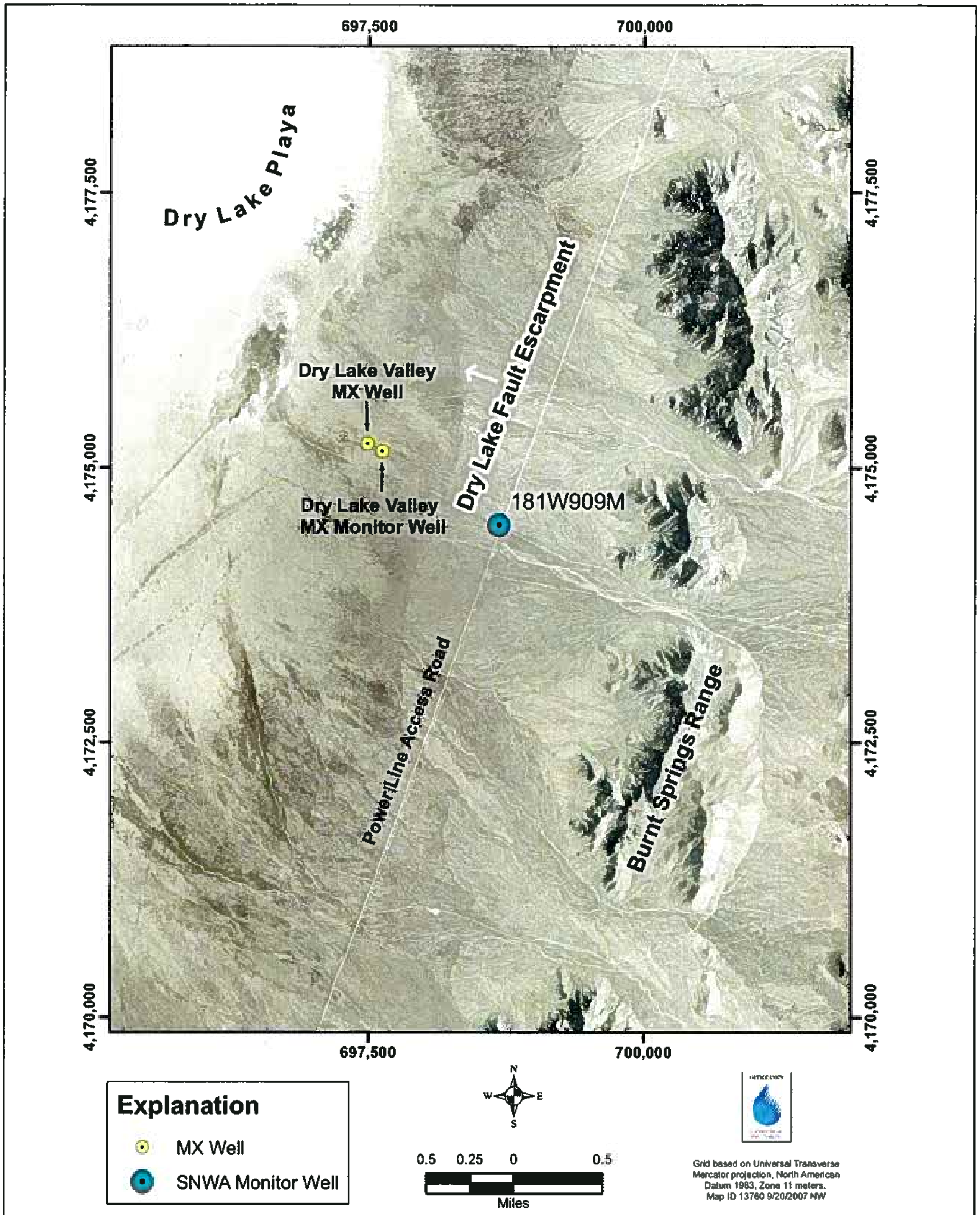
2.1.2 GEOLOGIC STRUCTURE AT THE MONITOR WELL SITE

The Dry Lake Fault forms a prominent escarpment west of and subparallel to the power line service road near the Monitor Well 181W909M site and can be observed on the aerial photograph (Figure 6). The photograph in Figure 7 shows a ground-level view of the Dry Lake Fault escarpment.



Note: Tschanz and Pampeyan (1970); Swadley (1995); USGS 1:24,000 Caliente NW and Pahroc Spring NE 7.5' Quadrangles. Unit designations in parentheses are the RGUs defined in Dixon et al. (2007).

FIGURE 5
GEOLOGIC MAP AROUND MONITOR WELL 181W909M, SOUTHEAST DRY LAKE VALLEY



Source: USDA, 2007; Scale 1:48,000.

FIGURE 6
AERIAL PHOTOGRAPH OF MONITOR WELL 181W909M SITE

Note: Photograph taken on January 23, 2007.

FIGURE 7
DRY LAKE FAULT ESCARPMENT AT GROUND LEVEL, LOOKING NORTHEAST

2.2 MONITOR WELL 181W909M

Monitor Well 181W909M was drilled in a single pass. An initial borehole was drilled near the completed monitor 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

Drill cuttings were collected for Monitor Well 181W909M at 10-ft intervals during the drilling process using SNWA internal procedures. These cuttings were described and the lithologic units encountered by drilling were identified based on descriptions by Tschanz and Pampeyan (1970). A summary of the lithologic log is included in Table 1.

The lithology of the monitor well was described using the Unified Soil Classification System (USCS) of ASTM D 2487-06.

The monitor well was drilled almost entirely within Quaternary and Tertiary alluvium consisting of diverse amounts of clay, silt, sand, and gravel. The coarser clasts are generally angular to subangular, sorting is generally poor, and the alluvium is generally well graded where not associated with abundant silt and clay. These clasts are of Tertiary volcanic tuff and Paleozoic sediments, including dolomite, limestone, chert, and quartzite, in various proportions. Clays and silts are generally calcareous, reacting vigorously with 10 percent hydrochloric acid.

TABLE 1
LITHOLOGY OF MONITOR WELL 181W909M
(Page 1 of 4)

Interval Top to Base (ft bgs)	Geologic Unit	General Lithology[a]	Description of Cuttings[b]
0 to 60	QTa	Alluvium (SM/GM)	Poorly sorted, lt brown silty sand and gravel. Sand is angular to subangular, occ subrounded, pink to red volcanic tuff with feldspar and quartz phenocrysts; gray to black carbonaceous limestone. Gravel is angular to subangular, gray to black limestone and white to pink volcanic tuff. Matrix is lt brown calcareous silt.
60 to 130	QTa	Alluvium (SW)	Well graded (poorly sorted), varicolored sand and gravel, and minor calcareous silt. Sand is angular to subangular, white to pink volcanic tuff, clear to white feldspar and quartz phenocrysts, and gray to black limestone. Gravel is angular to subangular, white to pink volcanic tuff, and gray to black limestone.
130 to 150	QTa	Alluvium (GW)	Mod to well graded (poorly sorted), varicolored gravel. Gravel is angular to subangular, white to pink volcanic tuff and gray to black limestone.
150 to 160	QTa	Alluvium (SW)	Well graded (poorly sorted), varicolored sand and minor calcareous silt. Sand is angular to subangular, white to pink volcanic tuff, clear to white feldspar and quartz phenocrysts, and lt gray to black, often blue-gray limestone.
160 to 200	QTa	Alluvium (SW/SM)	Mod to well graded (poorly sorted), varicolored sand and silt and some fine gravel. Sand is angular to subangular, clear to white feldspar and quartz phenocrysts and occ biotite; lt gray to black, often blue-gray limestone and pink, tan, and brown tuff. Silt is white to lt brown and calcareous.
200 to 250	QTa	Alluvium (SW)	Well graded (poorly sorted), varicolored sand and gravel. Sand and gravel are angular to subangular, white ash-fall tuff and pink to red volcanic tuff clasts with some minor biotite. Lt gray to dark gray limestone clasts.
250 to 360	QTa	Alluvium (SM/GM)	Poorly sorted, varicolored silty sand and gravel. Sand and gravel are angular to subangular lt to dark gray limestone, tan to red volcanic tuff, with minor white calcite. Silt is lt brown and calcareous.
360 to 400	QTa	Alluvium (GM)	Poorly sorted, varicolored silty gravel. Gravel is angular to subangular, lt to dark gray limestone, tan to red volcanic tuff, with minor biotite and hornblende. Silt is lt brown and calcareous.
400 to 500	QTa	Alluvium (GC)	Poorly sorted, varicolored clayey gravel. Gravel is angular to subangular, lt to dark gray limestone and tan to red volcanic tuff, with minor biotite and hornblende. Clay is lt brown and calcareous.
500 to 520	QTa	Alluvium (SC)	Poorly to mod sorted, lt brown clayey sand with varicolored fragments. Sand is angular to subangular, white to clear feldspar and quartz phenocrysts and lt pink to red volcanic tuff fragments with occ carbonate lithic fragment and minor biotite and hornblende. Clay is lt brown and calcareous.
520 to 540	QTa	Alluvium (SC/GC)	Poorly sorted, lt brown clayey sand and gravel. Sand is angular to subangular, pink to red volcanic tuff, gray to black limestone, and clear to white feldspar and quartz phenocrysts. Gravel is pink to reddish volcanics, white ash -fall tuff with occ gray to black limestone. Clay is lt brown and calcareous.
540 to 550	--	--	No samples collected due to lost circulation.

Table 1
Lithology of Monitor Well 181W909M
(Page 2 of 4)

Interval Top to Base (ft bgs)	Geologic Unit	General Lithology[a]	Description of Cuttings[b]
550 to 560	QTa	Alluvium (SC/GC)	Poorly sorted, lt brown clayey sand and gravel. Sand is angular to subangular, white to clear feldspar and quartz phenocrysts, pink to red volcanic tuff, and black to gray limestone. Gravel is angular gray to black limestone and pink to red volcanic tuff. Clay is lt brown and calcareous.
560 to 570	QTa	Alluvium (GC/SC)	Poorly to mod sorted, lt brown clayey gravel and sand. Gravel is angular, black to gray limestone and pink to red volcanic tuff. Sand is angular to subangular gray to black limestone with minor biotite and hornblende. Clay is lt brown and calcareous.
570 to 610	QTa	Alluvium (CL)	Lt brown, calcareous clay with minor poor to mod sorted sand and gravel. Sand is angular to subangular, white to clear feldspar and quartz phenocrysts, Pink to red volcanic tuff. Gravel is gray to black limestone.
610 to 620	QTa	Alluvium (GW)	Well graded, poorly to mod sorted gravel with minor lt brown silt and clay. Gravel is subangular to angular and comprised almost entirely of tan to lt brown, pink, and cream-white tuff. Non-calcareous.
620 to 630	QTa	Alluvium (GC)	Poorly sorted clayey gravel. Gravel is angular to subangular, lt to dark gray limestone and red to pink tuff. Clay is brown and very calcareous.
630 to 640	QTa	Alluvium (SC)	Poorly sorted, red to dark gray clayey sand. Sand is angular to subangular, red to brown tuff and lt to dark gray limestone. Clay is reddish brown and calcareous.
640 to 660	QTa	Alluvium (CL)	Brown calcareous clay with minor poor to mod sorted sand and gravel. Gravel is lt to dark gray, angular limestone and angular to subangular lt gray to pink tuff. Sand is angular to subangular, clear to white quartz and feldspar with pink tuff and gray limestone.
660 to 670	QTa	Alluvium (GW)	Well graded (poorly sorted), tan to buff to dark gray gravel and sand. Gravel is subangular tan to buff to dark gray limestone and dark red tuff. Sand is subrounded to subangular, tan to buff to dark gray limestone and dark red tuff. Minor very calcareous silt and clay.
670 to 720	QTa	Alluvium (CL)	Brown to red calcareous clay, with some poorly sorted, angular sand. Sand is buff to dark gray limestone, red tuff, and clear to white quartz and feldspar.
720 to 730	QTa	Alluvium (SC)	Poorly sorted, varicolored clayey sand and minor gravel. Sand is angular to subangular, lt gray to gray to black limestone, tan, pink, and white volcanic tuff with clear to white feldspar and quartz phenocrysts. Clay is pinkish brown and calcareous.
730 to 800	QTa	Alluvium (SC/GC)	Poorly sorted, varicolored clayey sand and gravel. Sand is angular to subangular, gray to black limestone, pink to white volcanic tuff, and clear to white feldspar and quartz phenocrysts. Gravel is angular to subangular, gray to black limestone, and pink to white volcanic tuff. Clay is lt brown and calcareous. Cuttings contain lost circulation material.
800 to 810	QTa	Alluvium (CL)	Reddish brown calcareous clay, with lesser gravel. Gravel is poorly sorted, angular, with clasts of lt to dark gray limestone, red to brown tuff with minor biotite and hornblende. Limonite is common on surfaces.
810 to 820	QTa	Alluvium (GC)	Poorly sorted, varicolored clayey gravel and sand. Gravel is poorly sorted, angular, lt to dark gray limestone, red to orange tuff with minor welding, white to clear quartz and feldspar. Sand is clear to white to orange to red quartz and feldspar and tuff. Clay is reddish brown and calcareous.

TABLE 1
LITHOLOGY OF MONITOR WELL 181W909M
(Page 3 of 4)

Interval Top to Base (ft bgs)	Geologic Unit	General Lithology[a]	Description of Cuttings[b]
820 to 830	QTa	Alluvium (GW)	Mod to well graded (poorly to mod sorted), varicolored gravel and lesser sand and minor calcareous silt and clay. Gravel and sand are angular clasts of equal parts lt to dark gray and bluish gray limestone and tan and red to orange tuff with quartz and feldspar phenocrysts and minor biotite and hornblende.
830 to 850	QTa	Alluvium (GC)	Poorly sorted, varicolored clayey gravel and sand. Gravel is angular to subangular, with clasts of white to gray to dark gray often bluish gray limestone and lt gray, tan, red to orange tuff. Sand is angular to subangular, with clasts of red to orange volcanics with minor biotite and white to clear quartz and feldspar. Clay is lt brown to brown and calcareous.
850 to 860	QTa	Alluvium (CL)	Lt brown calcareous clay, and lesser poorly sorted gravel. Gravel is angular to subangular, with clasts of lt to dark gray limestone and red to orange mod welded tuff with some biotite and hornblende. Minor sand consisting of limestone, tuff, and quartz.
860 to 880	QTa	Alluvium (GW)	Well graded (poorly to mod sorted), varicolored gravel and sand. Gravel is angular to subangular, with clasts of lt to dark gray limestone, red-orange, pink, and tan tuff with minor biotite and hornblende. Sand is the same consistency of gravels plus white to clear quartz and feldspar. Minor lt brown clay and silt.
880 to 890	QTa	Alluvium (GC)	Poorly sorted, varicolored clayey gravel and sand. Gravel is angular to subangular, with clasts of red tuff with biotite and hornblende, lt gray to dark gray limestone. Sand is the same consistency as gravel plus white to clear quartz and feldspar. Clay is lt brown to pink and calcareous.
890 to 900	QTa	Alluvium (GW)	Well graded (poorly sorted), varicolored gravel and sand. Gravel is angular to subangular, with clasts of lt to dark gray limestone, gray to red tuff with biotite and hornblende. Sand is of lt to dark gray limestone, red tuff, and white to clear quartz and feldspar. Minor lt brown calcareous clay.
900 to 910	QTa	Alluvium (SC)	Poorly sorted, varicolored clayey sand and minor gravel. Sand is angular to subangular, gray to black limestone, pink to white volcanic tuff, and clear to white feldspar and quartz phenocrysts. Clay is lt brown and calcareous.
900 to 1,010	QTa	Alluvium (SC/GC)	Poorly sorted, varicolored clayey gravel and sand. Sand is angular to subangular, gray to black limestone, pink to white volcanic tuff, and clear to white feldspar and quartz phenocrysts. Gravel is angular to subangular, gray to black limestone, and pink to white volcanic tuff. Clay is lt brown and calcareous.
1,000 to 1,090	QTa	Alluvium (SC/GC)	Poorly sorted, varicolored clayey gravel and sand with less clay. Sand is angular to subangular, gray to black limestone, pink to white volcanic tuff, and clear to white feldspar and quartz phenocrysts. Gravel is angular to subangular, gray to black limestone, and pink to white volcanic tuff. Clay is lt brown and calcareous.
1,160 to 1,190	QTa	Alluvium (SC)	Tan to lt brown, poorly to mod sorted clayey sand. Sand is angular to subangular, pink to red volcanic tuff, white to clear feldspar and quartz phenocrysts, gray to black limestone, and minor biotite and hornblende. Clay is lt brown and calcareous.

TABLE 1
LITHOLOGY OF MONITOR WELL 181W909M
(Page 4 of 4)

Interval Top to Base (ft bgs)	Geologic Unit	General Lithology[a]	Description of Cuttings[b]
1,190 to 1,200	QTa	Alluvium (GC)	Poorly sorted, lt brown clayey gravel. Gravel is angular to subangular pink to red volcanic tuff, gray limestone, clear to white feldspar and quartz phenocrysts. Clay is lt brown and calcareous.
1,200 to 1,210	QTa	Alluvium (SC)	Poorly sorted, lt brown clayey sand. Sand is angular to subangular, clear to white feldspar and quartz phenocrysts, pink to red volcanic tuff, some gray limestone, and minor biotite and hornblende. Clay is lt brown and calcareous.
1,210 to 1,220	QTa	Alluvium (GC)	Poorly sorted, lt brown clayey gravel. Gravel is angular to subangular pink to red volcanic tuff, gray limestone, clear to white feldspar and quartz phenocrysts. Clay is lt brown and calcareous.
1,220 to 1,230	QTa	Alluvium (SC)	Poorly to mod sorted, lt brown clayey sand. Sand is angular to subangular, clear to white feldspar and quartz phenocrysts, pink to red volcanic tuff, some gray limestone, and minor biotite and hornblende. Clay is lt brown and calcareous.
1,230 to 1,270	QTa	Alluvium (SM)	Poorly sorted, lt brown silty sand. Sand is angular to subangular, pink to red volcanic tuff, gray limestone, clear to white feldspar and quartz phenocrysts, and some biotite and hornblende. Silt is lt brown and calcareous.
1,270 to 1,285	Tv	Tuff	White to lt gray volcanic tuff, mainly aphanitic matrix with minor feldspar and quartz phenocrysts; mafics include black biotite and pyroxene. Some clay alteration of the tuff.

[a]G, S, M, C-CL, W, P - Gravel, sand, silt, clay, well graded, poorly graded. Symbology is from the USCS of ASTM D 2487-06.
[b]Type of material listed in order of abundance in the cuttings.

Common abbreviations for the above table:
lt - light
med - medium
mod - moderate, moderately
occ - occasional, occasionally

Unit Correlation (Dixon et al., 2007):
QTa RGU - Quaternary-Tertiary alluvium.
Tv RGU - undifferentiated Tertiary volanics.

Silty sand and gravel were dominant within the first 60 ft of the borehole followed by a zone of relatively clean sand with occasional gravel between 60 and 160 ft bgs. Below 160 ft bgs, the alluvium is of silty sands and gravels to a depth of 400 ft bgs. The alluvium is of clayey sands and gravels to 570 ft bgs below which is a clay-rich zone from 570 to 720 ft bgs. Between 720 and 860 ft bgs, the alluvium is of clayey sands and gravels with variable amounts of clay. A cleaner sand and gravel is present between 860 and 900 ft bgs. The alluvium is of clayey sands and gravels from 900 to 1,230 ft bgs, with slightly more gravel between 900 and 1,160 ft bgs. Silty sand is present between 1,230 and 1,270 ft bgs. In the completed monitor well, the borehole penetrated 15 ft of partially clay-altered Tertiary volcanic tuff at the base of the hole. This tuff was not noted in the cuttings from the initial borehole.

The well lithology is presented graphically on Figure 8.

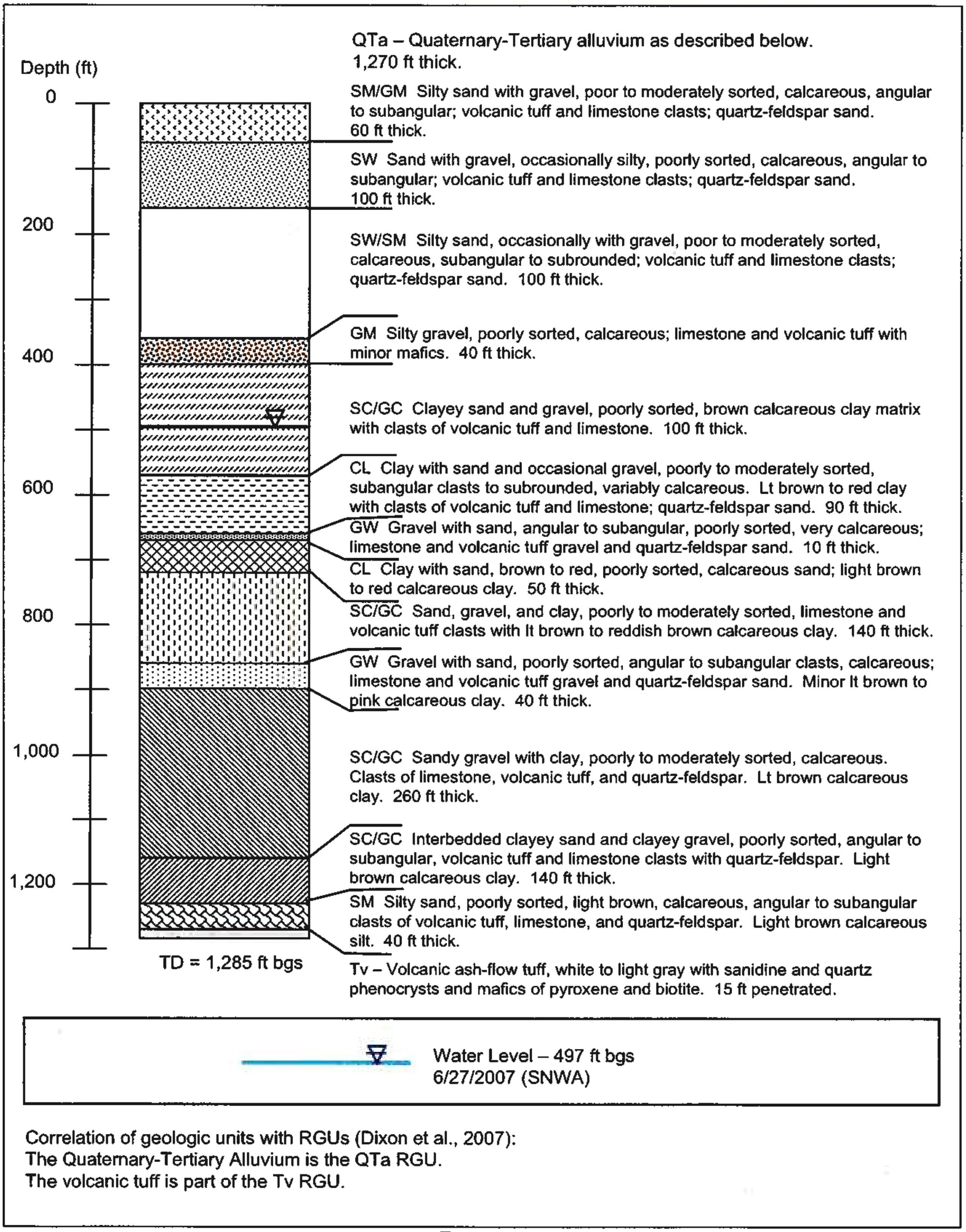


Figure 8
Borehole Stratigraphic Column of Monitor Well 181W909M

2.2.2 BOREHOLE GEOPHYSICS

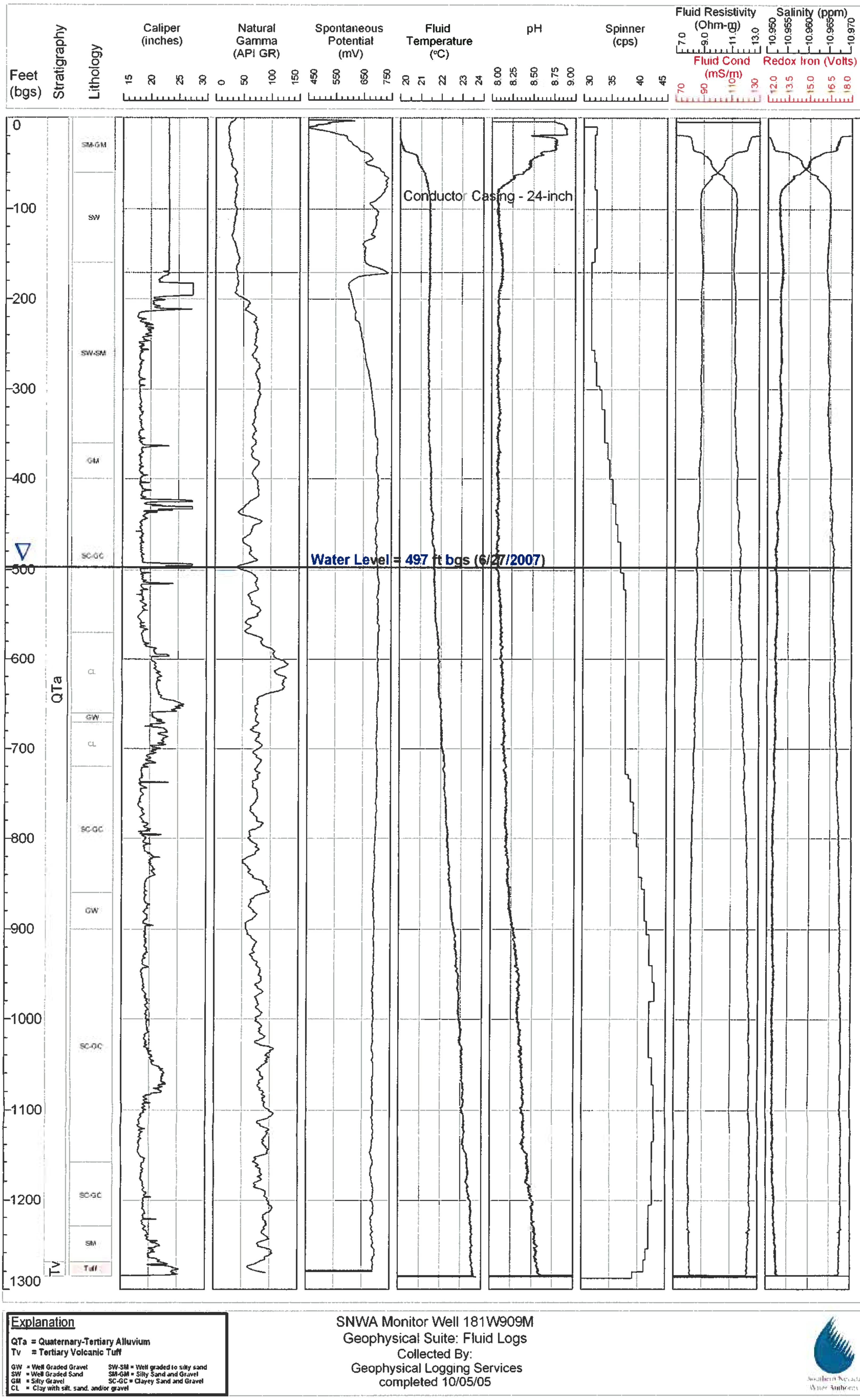
On October 5, 2005, following the completion of drilling, geophysical logging was performed to the full depth of the borehole (Stoller, 2005). No video log was conducted due to the high mud content of the drilling fluid. The following geophysical logs were performed:

- Natural Gamma Ray
- Deep Induction (Resistivity)
- Medium Induction (Resistivity)
- Long Guard
- Lateral Resistivity
- Spontaneous Potential
- Spectral Gamma – Potassium, Uranium, and Thorium (KUT)
- Total Spectral
- Neutron
- Density
- Sonic Delta T and Full Wave Sonic
- Fluid Temperature
- Differential Temperature
- Fluid Conductivity
- Fluid Resistivity
- Redox Iron Reduction Volts
- Salinity (NaCl)
- pH
- Spinner Log
- Caliper Log
- Deviation Log
- Pressure (psi)

These geophysical logs are presented on Figures 9 and 10.

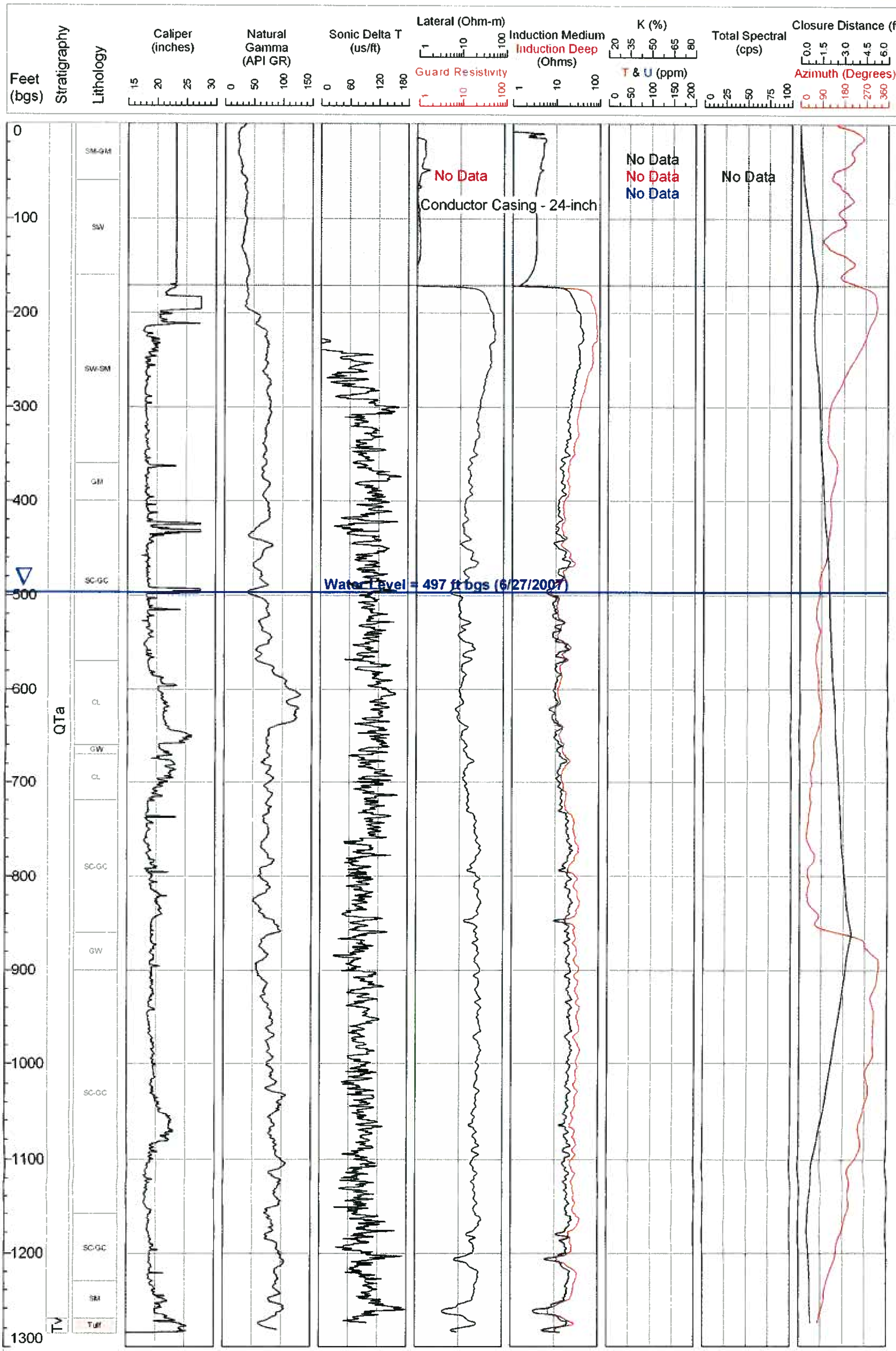
Muller (2007a and b) evaluated the geophysical logs for Monitor Well 181W909M. The more reliable logs for this well include Natural Gamma Ray (Gamma), resistivity logs (Deep Induction, Medium Induction, and Lateral Resistivity), Spontaneous Potential, Fluid Temperature, Fluid Conductivity, Fluid Resistivity, Salinity, pH, Deviation, and Pressure. Muller (2007c) indicated that the validity of the Spinner log seems uncertain, and the Guard, KUT, and Spectral logs are unreliable. At the time of geophysical logging the geophysical logs indicated a fluid level of 75 ft bgs (Muller, 2007d), approximately 420 ft higher than the water level of approximately 495 ft bgs (Stoller, 2006) taken about three months after well completion.

The Deep Induction, Medium Induction, and Lateral Resistivity logs are generally conformable and are discussed in this and subsequent paragraphs as Electric logs. The Electric log values increase steadily above the static water level of 495 ft bgs, with the highest values between the bottom of the surface casing and 240 ft bgs. This increase is a direct result of decreasing penetration of the alluvium by the borehole fluid. Inside the surface casing the Electric logs are meaningless. The Electric log values below about 400 ft bgs are meaningful, representing the maximum penetration of the alluvium by the borehole fluid above the regional water level.



Note: Correlation with regional geologic units (Dixon et al., 2007): The Tertiary volcanic tuff is part of the Tv RGU. Plotted by SNWA.

FIGURE 9
MONITOR WELL 181W909M GEOPHYSICAL FLUID LOGS



Explanation

QTa = Quaternary-Tertiary Alluvium
Tv = Tertiary Volcanic Tuff

GW = Well Graded Gravel
SW = Well Graded Sand
GM = Silty Gravel
CL = Clay with silt, sand, and/or gravel
SW-SM = Well graded to silty sand
SM-GM = Silty Sand and Gravel
SC-GC = Clayey Sand and Gravel

SNWA Monitor Well 181W909M
Geophysical Suite: Formation Logs
Collected By:
Geophysical Logging Services
completed 10/5/05

Note: Correlation with regional geologic units (Dixon et al., 2007): The Tertiary volcanic tuff is part of the Tv RGU. Plotted by SNWA.

FIGURE 10
MONITOR WELL 181W909M GEOPHYSICAL FORMATION LOGS

In general, the variability of the Electric logs is minor, which confirms a minimal variation in lithology. The Electric logs generally indicate lower resistivity between approximately 400 and 730 ft bgs compared to the interval below. These logs suggest a coarser-grained and possibly more permeable zone below about 730 ft bgs, which does not correlate with the monitor well lithology, which indicates an increase in clay with depth. Short drops in resistivity are noted in the Electric logs at several specific depths, including at 790, 850, 1,205, and 1,260 ft bgs. The drop at 850 ft bgs corresponds with a clay layer, and the drop at 1,260 ft bgs corresponds with the base of the alluvial material. However, no significant increase in clay was noted at 790 and 1,205 ft bgs, and other clayey zones did not correspond to drops in resistivity.

The Sonic Delta T (Sonic) log value drops between 420 and 440 ft bgs approximately at a drop in Gamma counts at 440 ft bgs. Though there is no change in lithology at this depth, there is a caved interval noticeable on the Caliper log at 430 to 440 ft bgs, which can by itself result in a decreased Gamma reading. A slight but distinct decrease in the Sonic log suggests a slight decrease in the porosity below about 780 ft bgs, which would be typical of coarser-grained sediments. Sharp rises in the Sonic log correspond well to the drops in resistivity noted at 1,205 and 1,260 ft bgs.

The Gamma log shows a slight increase in counts from 40 gru to between 60 and 70 gru at 200 ft bgs. This increase is a combination of a higher count rate below the bottom of the casing at 171 ft bgs and below a caved interval from 180 to 200 ft bgs. A reduced Gamma rate occurs at 495 to 505 ft bgs similar to the reduced Gamma discussed in the previous paragraph at 440 ft bgs and most likely for the same reason, a caved interval. Another caved interval at 650 to 665 ft bgs does not show a corresponding reduction in Gamma counts. The position of the instrument in the hole also has a bearing on the Gamma reading.

Gamma counts increase from about 55 to 70 gru to about 80 to 125 gru between 570 and 640 ft bgs. Though there is an increase in clay from 570 to 620 ft bgs within this interval, there is also abundant clay between 640 and 660 ft bgs and between 670 and 720 ft bgs. In these intervals, the Gamma counts are similar to Gamma counts in relatively clean sands and gravels. Therefore, it is more likely that the variation in volcanic tuff clasts in the alluvial material is an important reason for the variation in the Gamma count rate over much of the borehole.

Another Gamma peak occurs between 840 and 860 ft bgs at 90 to 100 gru. This interval does correspond to a clay-rich interval suggesting that here clay is a cause of increased Gamma counts. This interval also corresponds with a slight dip in the Electric logs over about 5 ft at the middle of this interval, again an indication of clay. There is a steady increase in the Gamma counts below about 910 ft bgs, indicative of an increase in clay content of the alluvium and correlative with a section of clayey to silty gravels.

The Fluid Temperature log indicates increasing temperature with depth to a maximum of about 23.5°C near the bottom of the borehole. This temperature is trending toward the 25.6°C groundwater temperature obtained on June 5, 2006 (Acheampong et al., 2007). No noticeable inflections are evident on the Fluid Temperature log. The increasing temperature with depth is indicative of groundwater interacting with the borehole fluids, probably at numerous intervals within the alluvium.

The Spinner log indicates a higher downward flow rate lower in the borehole, particularly below about 720 ft bgs. A downward flow is expected as the borehole fluid extends to an artificially high level and is moving downward and outward into the alluvium.

Logs of pH, Fluid Resistivity, Fluid Conductivity, Salinity, and Redox Iron were 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 log indicates a steady increase downhole from about 110 mS/m within the conductor casing to about 125 mS/m at 1,000 to 1,250 ft bgs. The electrical conductance value obtained during pumping on June 5, 2006, was 61.7 mS/m (Acheampong et al., 2007), a value that more nearly represents the groundwater value. The rise in fluid conductance toward the bottom of the hole indicates that the borehole fluid became less similar to the groundwater conductance, which indicates the influence of the conductance of the groundwater was very limited. Variations in the fluid conductance were primarily due to variations in the drilling fluid mixture, which overwhelmed any contribution by the groundwater.

Intervals of caving indicated by the Caliper log were discussed previously in this section. Additional caved zones indicated a general zone of increased hole diameter between 590 and 720 ft bgs and a shorter zone of increased hole diameter between 1,055 and 1,080 ft bgs. This latter zone is associated with a zone of slightly reduced Gamma. There is also caving at the bottom of the borehole, at 1,250 to 1,285 ft, which is also associated with a reduced Gamma count.

The Deviation (Closure Distance) log indicates that the borehole deviates approximately 0.8 ft S73E. The maximum deviation was 3.5 ft to the east at about 860 ft bgs.

2.2.3 DRILLING PARAMETERS

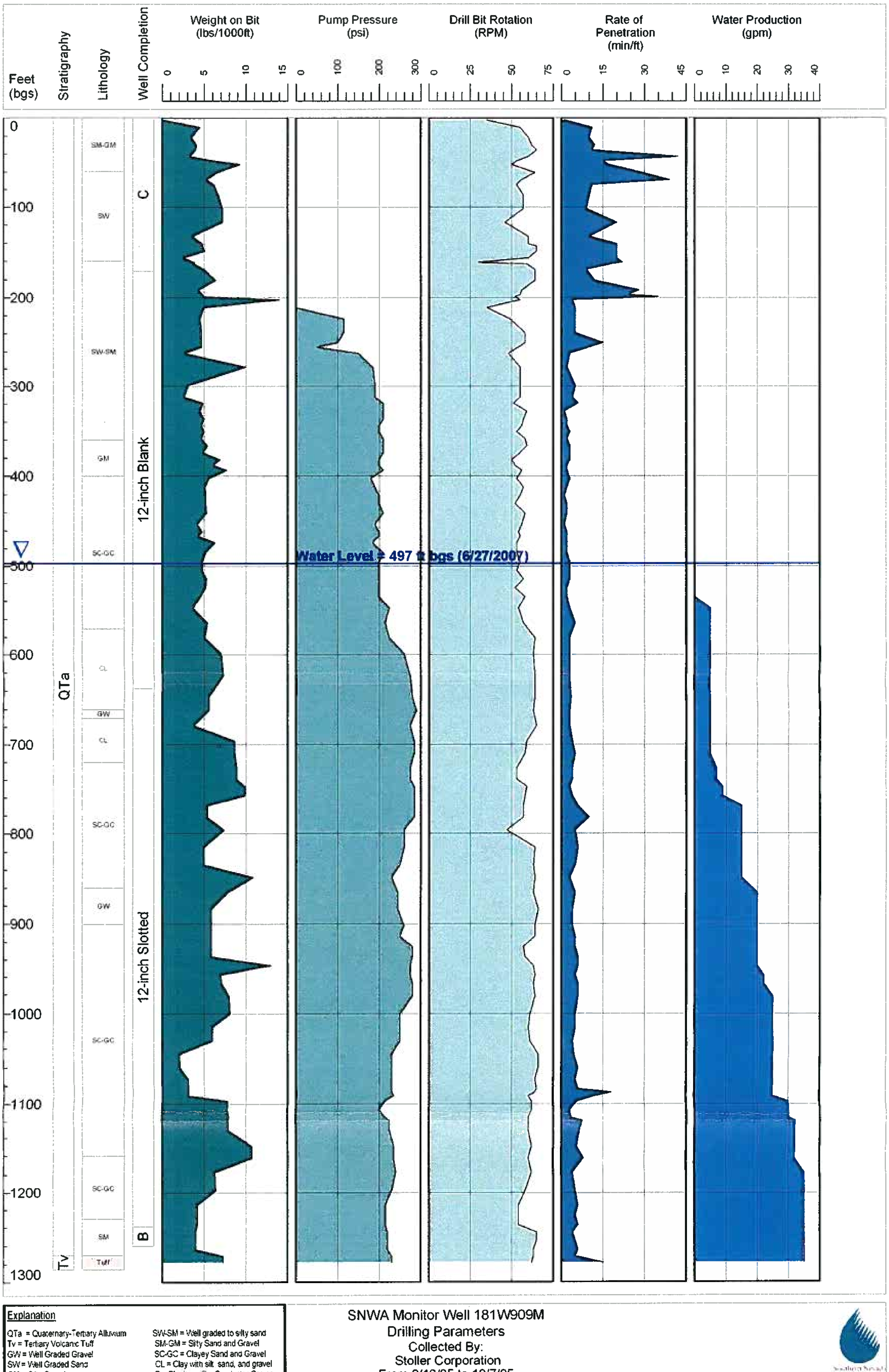
Stoller (2006) provided data on the drilling parameters as follows:

- Weight on bit
- Pump pressure
- Drill bit rotation
- Rate of Penetration
- Water Production

These drilling parameters are presented on Figure 11.

The rate of penetration was generally low but variable for the first 200 ft of drilling. During this interval, the drilling method was conventional mud, and variations in the weight on the bit appear to have been used to improve the penetration rate, particularly at 50 and 200 ft bgs. After drilling to 197.5 ft bgs, casing was set and the drilling method was switched to conventional air-foam. Except for the short interval from 250 to 260 ft bgs, from 200 to about 775 ft bgs the penetration was relatively fast at 1 to 4 min/ft. At 543 ft bgs the drilling method switched to flooded reverse circulation, though this had little, if any, effect on the penetration rate. Again, the weight on the bit appeared to have been varied to assist with the penetration rate. At 590 ft bgs, the pump pressure increased, probably due to clay, which is relatively abundant in the cuttings below this depth.

At 775 to 790 ft bgs, a short interval with a lower penetration rate was encountered, apparently associated with a clay layer within the alluvium. Drill bit rotation reduced as the weight on the bit was increased at just below this depth, which can happen with clay. At 1,090 ft bgs, another sharp reduction in penetration rate occurred.



Note: Correlation with regional geologic units (Dixon et al., 2007): The Tertiary volcanic tuff is part of the Tv RGU. Plotted by SNWA.

FIGURE 11
MONITOR WELL 181W909M DRILLING PARAMETERS

A spike (decrease) in the rate of penetration was accompanied by a decrease in the drill bit rotation and pump pressure at approximately 775 and 1,075 ft bgs. An increase in the Water Production log also occurs just below these interval. These data may indicate clay zones within the clayey sands and gravels within the alluvium penetrated by the borehole. The decrease in the penetration rate at the bottom of the borehole is coincident with the penetration of the Tertiary volcanics beneath the alluvium.

2.3 HYDROGEOLOGY

Monitor Well 181W909M is completed (screened) within the Quaternary-Tertiary alluvium on the east margin of Dry Lake Valley. During drilling operations, excess drilling effluent was first observed at a depth of about 518 ft bgs (Stoller, 2005). Excess effluent production increased to approximately 5 gpm by 543 ft bgs, after which, due to sloughing of the alluvial sediments into the hole, the decision was made to convert from air-foam drilling to flooded reverse circulation.

Excess effluent increased to about 15 gpm at 760 ft bgs, 20 gpm at 860 ft bgs, 25 gpm at 980 ft bgs, 30 gpm at 1,095 ft bgs, and 33 gpm at 1,165 ft bgs. At the total depth of the hole, excess drilling effluent was flowing at a rate of 35 gpm. These zones of increasing effluent production relate to zones of groundwater interaction with the monitor well. The increase at 760 ft bgs is below a clay-dominant zone in the alluvium. The increase at 860 ft is at the top of a much less clayey gravel. Other increases may also reflect intervals of less clayey material within the alluvium that were too thin to show in the cuttings. Since the well is undeveloped, drilling mud influenced these flow rates, and some productive zones may have been blocked by this mud infiltrating into the formation during the drilling procedure.

A depth-to-water level of 494.93 ft bgs was taken at 11:25 on January 9, 2006, by SNWA (Stoller, 2006). The surface elevation at the well is approximately 4,800 ft amsl, which gives a groundwater elevation of approximately 4,305 ft amsl. This site has not been professionally surveyed. Eight additional water level readings have been taken since June 2006, ranging from 497.02 to 497.40 ft bgs and averaging 497.17 ft bgs, or approximately 4,303 ft amsl. These readings are all within 0.4 ft of each other and less than 2.5 ft lower than the reading taken in January 2006. Table 2 summarizes the water-level measurement collected at the monitor well.

The South Dry Lake MX well and an associated observation well (the MX wells) are located approximately 4,800 ft (1,460 m) N53W of Monitor Well 181W909M at an elevation of about 4,640 ft amsl, about 160 ft lower than the monitor well. Though the screened intervals of the MX wells are different from those of Monitor Well 181W909M, the difference in water levels provides an approximation of the water level difference between the two wells. On June 20, 2007, the water level at the MX observation well was 381.71 ft bgs (USGS, 2007), a groundwater elevation of 4,258 ft amsl. On the same day the water level in Monitor Well 181W909M was 497.02 ft bgs, a groundwater elevation of 4,303 ft amsl. The water level elevation in the MX observation well was about 45 ft lower than that of the monitor well.

2.4 SUMMARY

Monitor Well 181W909M was drilled in September and October 2005 for the purpose of collecting geologic, hydrologic, and geochemical data. This monitor well is located in southeastern Dry Lake

Table 2
Water Level Measurements for Monitor Well 181W909M

Date	Time	Depth (ft bgs)	Water Elevation (ft amsl)	Data Collected By
4/29/2005	9:45	525	4,275	GLS, initial hole from geophysical logs (Stoller, 2006)
1/9/2006	11:25	494.93	4,305	Stoller (2006), completed monitor well
6/5/2006	10:00	494.7	4,305	SNWA (2006)
10/24/2006	14:25	497.3	4,303	SNWA
12/8/2006	12:15	497.1	4,303	SNWA
1/22/2007	15:53	497.4	4,303	SNWA
2/26/2007	12:35	497.3	4,303	SNWA
4/3/2007	13:35	497.1	4,303	SNWA
5/15/2007	14:44	497.0	4,303	SNWA
6/20/2007	11:25	497.0	4,303	SNWA
6/27/2007	18:00	497.11	4,303	SNWA

Note: GLS = Geophysical Logging Services (Prescott, AZ).
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.

Valley and was drilled to a total depth of 1,285 ft bgs with a slotted interval from 637.35 to 1,239.65 ft bgs. This monitor well was drilled approximately 4,800 ft (1,460 m) southeast of the South Dry Lake MX well.

The monitor well was drilled almost entirely within Quaternary and Tertiary alluvial sediments, an agglomeration of sands, gravels, silts, and clays. The cuttings indicate a variation in content of these components, generally sandier with gravel in the upper 400 ft of the alluvium and with more clay in the interval from 400 to 1,230 ft bgs. Particularly clayey zones were noted at 570 to 660 ft bgs and 670 to 720 ft bgs, with a sandy gravel between these intervals. Below 1,230 ft bgs, the alluvium is of silty sand to 1,270 ft bgs. At that depth, 15 ft of Tertiary volcanic ash flow tuff was encountered to the total depth of the borehole.

Geophysical logs and drilling parameters provided additional data for analysis. These logs assisted in defining differences between sandy and clayey material and defining intervals where Tertiary volcanic fragments or Paleozoic carbonate fragments were more abundant.

Water level measurements indicate a water-level elevation of about 4,303 ft amsl. Groundwater interaction with the well probably occurs at several intervals within the alluvium, beginning at 540 ft bgs in clayey sands and gravels above a clay-dominant interval.

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