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South Fence Road – Phase I Field Operations Summary

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SOUTH FENCE ROAD - PHASE I FIELD OPERATIONS SUMMARY

Site-Wide Hydrogeologic Characterization Project

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ABSTRACT

This report is a basic data report from the first phase of field operations associated with the drilling, logging, completion, and development of South Fence Road Wells SFR-1D and SFR-1S, SFR-2, SFR-3D and SFR-3S, and SFR-4. These test/monitoring wells were installed as part of Sandia National Laboratories, New Mexico, Environmental Restoration Project.

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SOUTH FENCE ROAD - PHASE I FIELD OPERATIONS SUMMARY

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1.0 EXECUTIVE SUMMARY

The South Fence Road (SFR) project is part of the Sandia National Laboratories, New Mexico (SNL/NM) Site-Wide Hydrogeologic Characterization (SWHC) task. The SWHC task is a component of the SNL/NM Environmental Restoration Project and has as its objective the reduction of uncertainty about the rate and direction of groundwater flow in the SNL/NM/Kirtland Air Force Base (KAFB) area.

The SFR project area is located along the southern boundary of SNL/KAFB. This project area was selected to provide site-specific information related to geology and groundwater hydrology within the Hubbell Spring/Tijeras/Sandia fault complex. Specific objectives included determining the depth to the Santa Fe Group/bedrock contact, the depth to the water table, and the hydrogeologic complexities related to faulting.

To attain the SFR project objectives, four boreholes were drilled along an east-west line in Sections 4 and 5, Township 8 North, Range 4 East. Borehole depths ranged from 510 feet for SFR-1 (the westernmost borehole) to 168 feet for SFR-4 (the easternmost borehole). Following drilling, SFR-1, SFR-2 and SFR-3 were completed as monitoring wells. SFR-4 was temporarily abandoned. Drilling and completion operations are summarized in Section 4.

To support the geologic objectives of the SFR project, each borehole was continuously cored over its entire length. The one exception to this is that only drill cuttings were obtained between 317 feet and 510 feet in the SFR-1 borehole. Core/cuttings lithology were described in detail and all core has been retained for future reference. Because the bedrock was consistently deeper than was initially estimated from a supplementary gravity data interpretation, only the SFR-4 borehole encountered bedrock (i.e., SFR-1, SFR-2 and SFR-3 were drilled entirely in Santa Fe Group sediments). The preliminary interpretation of the SFR-4 lithologic description suggests that this bedrock unit is weathered Permian Abo or Yeso Formation. Because the Santa Fe Group/bedrock contact was not penetrated in the other boreholes, no structural interpretation of faulting is possible. Information related to borehole geology is summarized in Section 5.

Information related to the local groundwater hydrology was obtained from water level measurements acquired during drilling, from core moisture observations, and from measurements in the installed monitoring wells. The information acquired during drilling and from core descriptions suggests the presence of perched aquifer layers in SFR-1, SFR-2 and SFR-3. SFR-1 was completed as a nested monitoring well with the deep monitoring interval (SFR-1D) from 304 to 418 feet and the shallow monitoring interval (SFR-1S) from 76 to 250 feet. Water level measurements from the shallow interval (depth to water = 90 feet; water level elevation = 5,304 ft., mean sea level [msl]) are approximately 50 feet higher than measurements from the lower interval (depth to water = 140 feet; water level elevation = 5,257 ft., msl). In addition, the water level from the lower interval rises approximately 144 feet above its upper seal suggesting the presence of a confined water-bearing unit in this interval. SFR-2 was completed from 74 to 162 feet as an unconfined water level monitoring well. The depth to water in this interval is approximately 101 feet (water level elevation = 5,327 ft.,

msl). SFR-3 was completed as a nested monitoring well with the deep monitoring interval (SFR-3D) from 277 to 406 feet (depth to water = 161 feet; water level elevation = 5,332 ft., msl) and the shallow monitoring interval (SFR-3S) from 155 to 230 feet (depth to water = 161 feet; water level elevation = 5,332 ft., msl). The measured water levels from both intervals are approximately equal. This suggests that there may be a connection in the borehole. Alternatively, it is possible that both intervals are connected in the formation. SFR-4 did not encounter the formation saturation to its total depth of 168 feet. This borehole was not completed and has been temporarily abandoned. Information related to borehole hydrology is summarized in Section 6.

Geophysical logging suites including density, gamma, and neutron logs were obtained from each borehole. This geophysical logging data supplements the lithologic and hydrologic information obtained from the other sources. Information related to borehole geophysics is summarized in Section 7.

Lateral comparison of hydrogeologic information is difficult in the SFR project area due to the highly heterogeneous nature of the Santa Fe Group sediments and the potential for structural complexity. A detailed evaluation of the SFR hydrogeologic data and comparison of this evaluation to other hydrogeologic data in the area will be accomplished in a future data synthesis study.

2.0 INTRODUCTION

2.1 Background

The Environmental Restoration (ER) Project of Sandia National Laboratories (SNL/NM) in Albuquerque, New Mexico is leading a program to evaluate potentially contaminated sites on Kirtland Air Force Base (KAFB), and if appropriate, manage necessary site remediation. Within the ER Project, the Site-Wide Hydrogeologic Characterization (SWHC) task is responsible for defining the regional hydrogeology to provide a consistent framework for this evaluation. The purpose of this task is to reduce the existing uncertainties about the rate and direction of groundwater flow in the SNL/KAFB area. The South Fence Road (SFR) program described herein is part of this effort.

2.2 Objective

The field investigation plan (FIP) for the SFR drilling program called for six wells to be drilled at three different locations along the southern boundary of KAFB (SNL/NM, 1992), as shown in Figure 1. The well locations were selected based on an interpretation of data from a surface gravity survey (IT Corporation, 1991). This interpretation provided an estimation of the depth to bedrock below the Santa Fe Group. At each location, the FIP called for one well to be drilled into and completed in the bedrock and one well to be completed as an uppermost aquifer monitoring well (i.e., screened across the water table) within the Santa Fe Group.

The objectives of the SFR drilling program included:

- To verify the interpretation of the surface gravity survey data;
- To identify the potential for vertical gradients between the Santa Fe Group and the underlying bedrock;
- To construct three monitoring wells in the uppermost aquifer and three monitoring wells in the bedrock for use in the non-ER monitoring well network; and
- To assess the aquifer characteristics of both the uppermost aquifer and the bedrock aquifer.

3.0 SITE GEOLOGY

3.1 Structure

The SFR boreholes lie on an east-west line along the southern boundary of KAFB. This line of boreholes is presumed to cross a fault complex near the intersection of the Tijeras Fault and the Hubbell Springs Fault (see Figure 1). Where this fault complex crosses South Fence Road, it is postulated to trend north-south and exhibit down-to-the-west displacement. It is possible that instead of a single fault, a series of north-south trending basin-bounding normal faults make up the fault complex in the SFR project area. Displacement across this fault complex was unknown at the beginning of this project.

3.1.1 Gravity Survey

To estimate displacement across the fault complex, a gravity survey was performed. The data from this survey were interpreted to estimate bedrock depth in the SFR project area (IT Corporation, 1991). This interpretation was then utilized to site the SFR boreholes and provide estimates of the depths to bedrock which were used in borehole planning. Figure 2 shows the gravity survey transects. The SFR boreholes were located near selected survey points on the southernmost transect. Figure 3 is a cross section showing the bedrock depths estimated from the gravity data.

One of the objectives of the SFR drilling program was to evaluate the interpretation of the gravity survey data. Preliminary results from drilling have indicated that depths to bedrock are greater than estimated in the initial interpretation (IT Corporation, 1991). Based on the results from drilling, the gravity data was reinterpreted (IT Corporation, 1992). Table 1 summarizes the total depths of the SFR boreholes as of November 1992, the initial bedrock-depth interpretation at these locations, and the most recent reinterpretation of this parameter. It is anticipated that future drilling in the SFR project area will attempt to define the variation in bedrock depth across the fault complex. This information in turn will help "tune" the gravity data interpretation.

Table 1 - Summary of SFR borehole depths and gravity data interpretations

BOREHOLE	TOTAL DEPTH [ft bgs] (NOV. 1992)	BEDROCK DEPTH ESTIMATE FROM GRAVITY DATA (ft bgs)	
		INITIAL (1991)	REVISED (1992)
SFR-1	510 ¹	280	667
SFR-2	365 ¹	190	455
SFR-3	408 ¹	158	408
SFR-4	168 ²	23	229

¹ Bedrock not penetrated. ² Weathered shales and mudstone (Abo or Yeso Fm.) penetrated at a depth of 35 ft.

Figure 2. Surface gravity transects in the southern portion of KAFB (IT Corporation, 1991)

Figure 3. Estimated depths to bedrock from the surface gravity survey report (IT Corporation, 1991)

3.2 Stratigraphy

In the project area, the surficial and subsurface stratigraphy includes piedmont-slope alluvium, Santa Fe Group basin-fill sequences, and Paleozoic and/or Precambrian bedrock lithologies. In general, the primary stratigraphic unit penetrated by the SFR boreholes is composed of lenticular, unconsolidated, unsaturated alluvial and eolian units of the upper Santa Fe Group. The thickness of this sequence is highly variable due to the expected normal faulting in this area. Based on the gravity data interpretation, the expected thickness of the piedmont-slope alluvium and the Santa Fe Group ranges from 670 feet at SFR-1, the westernmost SFR borehole, to 230 feet at SFR-4, the easternmost SFR borehole. The approximate distance between these two boreholes is 1.5 miles (2.4 km).

The bedrock stratigraphy underlying the Santa Fe Group is currently unknown. It is anticipated that the bedrock formations include Precambrian igneous and metamorphic rocks, and/or Paleozoic sedimentary rocks (i.e., the Pennsylvanian Madera and Sandia Formations, and the Permian Abo, Yeso, Glorieta Sandstone, and San Andreas Formations). Detailed descriptions of these stratigraphic units are included in Kelley (1977), Anderholm (1988), and Hawley and Haase (1992).

3.3 Hydrogeology

Hydrogeologic information in the project area was limited prior to the initiation of the drilling operations. It was anticipated that the regional water level would show a significant change across the fault complex. In other areas on SNL/NM property, the depth to saturated groundwater varies from 50-100 feet below ground surface (bgs) east of the fault complex to approximately 380-500 feet bgs west of the fault complex (SNL, 1992). Available information suggests that the direction of groundwater flow is to the northwest on the west side of the fault complex, and to the west on the east side of the fault complex. No site-specific information exists on aquifer parameters for the alluvial and bedrock aquifers. Additionally, there is no data on the groundwater flow conditions within the basin-bounding fault complex which bisects the SFR project area.

Hydrogeologic information intended to be obtained from the SFR wells included:

- The characterization of the variation in the water table elevation across the fault complex;
- Identification and characterization of possible perched water zones in the Santa Fe Group;
- The characterization of the vertical hydraulic gradient between the uppermost Santa Fe Group aquifer and the underlying bedrock aquifer;
- The characterization of aquifer parameters in the alluvial and bedrock aquifers underlying the SFR project area; and
- The characterization of the types of boundary conditions that exist in the vicinity of the fault complex.

4.0 BOREHOLE/WELL CONSTRUCTION INFORMATION

Field operations associated with the implementation of the SFR Project Phase I Field Investigation Plan (FIP) [SNL, 1992] were carried out between May and November, 1992. The drilling objectives for each borehole identified in this work plan included:

- Obtaining a complete lithologic description of the alluvial/bedrock material encountered in each borehole;
- Identifying perched water-bearing intervals within the Santa Fe Group;
- Identifying the unconfined water-table elevation; and
- Identifying the bedrock contact.

The last of these objectives was not attained during this phase of drilling due to differences in projected target depths (i.e., depth to bedrock was consistently deeper in each borehole) and drill rig scheduling conflicts.

This section provides a summary of all field operations which were accomplished during SFR Phase I on a borehole-by-borehole basis.

4.1 Drilling Method and General Drilling Approach

Drilling of the SFR Phase I boreholes was performed using the sonic resonance drilling technique. Sonic drilling was chosen in part to aid in the development of innovative technology and also to gain site-specific experience prior to using the method at SNL/NM ER hazardous waste sites.

Sonic drilling is unique in that it does not necessitate the use of drilling fluids (i.e., air, water, etc.) for progression of the bit. The sonic head houses an oscillator containing two (2) fifteen-pound weights that are out of sync by 180 degrees. When these weights are in the horizontal position the sound waves effectively cancel each other out, thereby reducing any lateral movement of the drill pipe. However, when in alignment in the vertical position, these weights (spinning at 10,000 revolutions per minute [rpm]) exceed resonance for the material which is being drilled. Resonance of the geologic material allows the core pipe to be advanced with limited stratigraphic disturbance.

The lack of drilling fluids contributes to the problem of borehole instability. Sloughing of the hole is particularly prevalent in the dry, heterogeneous, unconsolidated vadose zone and in areas of highly permeable saturated sands. As such, it is necessary to advance casing in the borehole for stabilization purposes.

Two drill rigs were used during the SFR Phase I drilling operations. The XT-70E rig was equipped with multiple drilling capabilities, including sonic, air rotary, percussion, cable tool, and mud rotary.

The Barber Rig was outfitted exclusively with sonic capabilities. In the case of the XT-70E rig, 10-3/4-inch (O.D.) casing for the borehole was driven with a diesel-driven hammer, producing a 9-inch borehole. Cuttings were blown out with air, and occasionally water was introduced to facilitate borehole cleanout. The 6-inch (O.D.) casing used by the Barber Rig was installed utilizing the sonic head, producing a 5-inch borehole. When the Barber Rig is advancing casing, water is frequently employed to wash out the cuttings. With both rigs, the 4-1/2-inch (O.D.) drill pipe is advanced ahead of the casing. In general, casing was driven after coring/drilling 10-20 feet.

Sonic coring generally resulted in 100-percent core recovery. However, core runs exceeding 100-percent were experienced due to clay expansion and flowing sands, and instances of lost core were observed. Calculations on percent recovery obtained for each borehole are shown in Appendix A. These calculations were based on the lithologic logs and the geologist's estimation of recovery.

Air rotary drilling provided by the XT-70E rig was used on the final 203 feet of the SFR-1 borehole. The primary reason for switching the drilling technology was to speed up the penetration rate.

4.2 SFR-1 Field Operations

The field operations at SFR-1 began on May 27, 1992. Drilling continued at this site until July 26, 1992. Completion of two wells in the borehole at SFR-1 proceeded until August 9, 1992.

4.2.1 SFR-1 Location

The SFR-1 site is the westernmost location in the SFR project area. The approximate geographic location of the site is NW 1/4 SE 1/4 Section 5 T8N R4E (Figure 4). A land survey of this area indicates that the ground elevation at this site is 5,394 ft above mean sea level (amsl). State plane coordinates for this well are; $x = 413524.06$ and $y = 1436237.64$.

4.2.2 SFR-1 Well Installation Plan

The well installation plan (SNL, 1992) required to meet the objectives at the SFR-1 site included the drilling and completion of one deep monitoring well (SFR-1D) and one shallow monitoring well (SFR-1S). The well installation plan for SFR-1D, projected to be completed as a bedrock monitoring well, included the following:

- Depth to bedrock estimated to be 280 feet;
- Depth to top of screen projected to be 330 feet (50 feet below Santa Fe Group/bedrock contact);
- Screen length specified to be 20 feet; and
- Total borehole depth to be 380 feet (100 feet below Santa Fe Group/bedrock contact).

The well installation plan for SFR-1S, projected to be completed as a water-table monitoring well, included the following:

- Depth to water-table estimated to be 179 feet;
- Depth to top of screen projected to be 174 feet;
- Screen length specified to be 20 feet; and
- Total borehole depth projected to be 196 feet.

4.2.3 SFR-1 Drilling Operations Summary

Drilling began on SFR-1 using the XT-70E rig on May 27, 1992. This borehole proved difficult to drill due to multiple intervals of flowing sands (see Section 6.1). The drilling technique was changed to air rotary at a depth of approximately 323 feet in anticipation of encountering bedrock (based on gravity data). The sonic technique was not intended to be used once bedrock was encountered.

The drive casing could not be advanced past 317 feet because a highly indurated interval was encountered. However, flowing sands were encountered below this depth, which required that the drive casing be advanced to continue drilling. In order to advance the drive casing, personnel from SNL's Explosives Application Laboratory (Division 9330) detonated twelve pounds of C-4 explosive in the borehole at approximately 323 feet. This operation was successful, and the drive casing was advanced to a total depth of 420 feet. Drilling was terminated in the Santa Fe Group at 510 feet on July 26, 1992. Figure 5 summarizes drilling operations for borehole SFR-1.

4.2.4 SFR-1 Well Completion

Because of the deeper than estimated depth to bedrock at the SFR-1 location, only one of the two planned boreholes was drilled. The multiple saturated zones and large water inflow encountered in the SFR-1 borehole were unanticipated. To maximize what could be learned about the subsurface hydrology at this location, the decision was made to install two wells in this borehole. The general strategy for this well installation was to complete one well below the indurated interval encountered at 317 feet, and one well in a saturated zone above this indurated interval.

The reason for this nested completion was an attempt to distinguish between two of the multiple water-bearing zones encountered in the Santa Fe Group. The screened interval for the deep monitoring well (SFR-1D) was set at 348-368 feet. This screened interval was identified during drilling to be the most significant saturated zone encountered in the borehole. The shallow monitoring well (SFR-1S) was completed at a screened interval of 152-172 feet. This interval was selected because it was the first major saturated interval encountered in the borehole. The following sections detail the final well completions accomplished in the SFR-1 borehole.

Figure 5. Drilling chronology of Borehole SFR-1

4.2.4.1 SFR-1D Well Completion

The borehole at SFR-1 was backfilled with a bentonite slurry from a total depth of 510 feet bgs to a depth of 418 feet. A four-inch diameter, Schedule 80 PVC well was then installed to a depth of 378 feet, with the 20-slot screen set at 348-368 feet. A 10-foot PVC sump was added below the screen. This well, SFR-1D, was backfilled with #3-8 mesh sand from 418 feet up to 304 feet, with a bentonite plug added from 304 feet up to 250 feet bgs. The well completion schematic for SFR-1D is included in Appendix B.

4.2.4.2 SFR-1S Well Completion

SFR-1S is isolated from SFR-1D by a bentonite seal that extends from 304 to 250 feet bgs. Sand (#3-8 mesh) was added from 250 feet up to a depth of 182 feet. A two-inch diameter Schedule 80 PVC well was installed at 182 feet. The 20-slot screen was set at 152 to 172 feet. A 10-foot PVC sump was installed below the screen. This well was then backfilled with a mixture of native material and #3-8 mesh sand, up to a depth of approximately 76 feet. A bentonite slurry was added from this depth to the land surface. The well completion schematic for SFR-1S is included in Appendix B.

4.2.5 SFR-1 Well Development

Well development is performed to promote the removal of foreign material that may have been introduced into the well annulus or well screen during construction. Development improves the hydraulic communication between the screened formation and the monitoring well by freeing the fine-grained materials from the formation and allowing them to be drawn into the well (Driscoll, 1986). General development procedures and water quality specifications are identified in the ER Program Field Operations Procedure (FOP), "Monitor Well Development (PRO 92-08 [Wood, 1992]). This FOP calls for a minimum of five well bore volumes to be removed from the well during development, and specifies water quality criteria that indicates successful development. Well bore volumes for each well are summarized in Table 2 below.

Table 2. Calculated well-bore volumes for the SFR wells

WELL	WELL DIAMETER (Inches)	HEIGHT OF WATER COLUMN (ft)	UNIT VOLUME (gallons per ft)	CALCULATED WELL-BORE VOLUME (gallons)
SFR-1D	4	238	0.4930	117.3
SFR-1S	2	92	0.1251	11.5
SFR-2S	4	21	0.4930	10.4
SFR-3D	2	200	0.1251	25.1
SFR-3S	2	61	0.1251	7.6

4.2.5.1 SFR-1D Well Development

Development of SFR-1D began on August 31, 1992. The well bore volume was calculated to be 117.3 gallons. Approximately 1,800 gallons of water were bailed from this well over the course of five days. Development was accomplished by bailing and swabbing. Developed water using these techniques did not meet water quality criteria specified in PRO 92-08. The well was successfully developed by pumping in March of 1993. Development data for SFR-1D is included in Appendix C.

4.2.5.2 SFR-1S Well Development

Development of SFR-1S began on November 30, 1992. The well bore volume was calculated to be 11.5 gallons. Approximately 21.5 gallons of water were bailed from the well over a two day period. Development of this well was accomplished by the use of a 5-foot bailer. Development ceased once the electrical conductivity and pH were stable as measured on the YSI flow-through meter. Recovery data was measured for this well after bailing ceased. Water level and recovery data can be found in Appendix C.

4.3 SFR-2 Field Operations

The field operations at SFR-2 began on July 8, 1992, and ended on August 13, 1992. Drilling was accomplished using both the Barber Rig and the XT-70E rig. The total depth of SFR-2 was 365 feet bgs.

4.3.1 SFR-2 Location

The SFR-2 site is located about 0.40 miles east of SFR-1. The approximate geographic location of the site is NE 1/4 SE 1/4 Section 5 T8N R4E (see Figure 4). A land survey of this area indicates that the ground elevation at this site is 5,428 ft. msl. State plane coordinates for this well are; x = 415280.40 and y = 1436176.40.

4.3.2 SFR-2 Well Installation Plan

The well installation plan (SNL/NM, 1992) required to meet the objectives at the SFR-2 site included the drilling and completion of one deep monitoring well (SFR-2D) and one shallow monitoring well (SFR-2S). SFR-2D was projected to be completed as a bedrock monitoring well as follows:

- Depth to bedrock estimated to be 190 feet;
- Depth to top of screen projected to be 363 feet (screened elevation interval to correspond to the screened elevation interval in SFR-1D);
- Screen length specified to be 20 feet; and

- Total borehole depth projected to be 385 feet (195 feet below Santa Fe Group/bedrock contact).

SFR-2S was projected to be completed as a water table monitoring well as follows:

- Depth to water table estimated to be 122 feet;
- Depth to top of screen projected to be 117 feet;
- Screen length specified to be 20 feet; and
- Total borehole depth projected to be 139 feet.

4.3.3 SFR-2 Drilling Operations Summary

Drilling of this well began on July 8, 1992, using the Barber Rig. This rig advanced the borehole to a depth of 365 feet on July 15, 1992. Drilling was terminated at this depth due to equipment limitations. No bedrock was encountered to this depth. Since the Barber rig was only capable of drilling a 5-inch borehole, the larger XT-70E rig was required to complete the well. The XT-70E rig was moved to SFR-2 on August 9, 1992, to ream the borehole to 9 inches. Time constraints placed on the XT-70E rig by other projects forced the completion of this borehole as a shallow monitoring well. Figure 6 illustrates the drilling chronology of the borehole at SFR-2.

4.3.4 SFR-2S Well Completion

Because of the deeper than estimated depth to bedrock at the SFR-2 location, only one of the two planned boreholes was drilled. In an attempt to meet one of the original objectives proposed by the work plan, this borehole was completed as a water-table monitoring well.

The SFR-2 borehole was backfilled from the total depth of 365 feet bgs with #3-8 mesh sand up to a depth of 200 feet. A bentonite slurry seal was added from 200 feet up to a depth of 162 feet. Sand (#3-8 mesh) was added up to a depth of 122 feet. A four-inch diameter well was then installed at 122 feet. The 4-inch diameter well was completed with Schedule 10, No. 316 stainless steel and Schedule 80 PVC. The stainless section extended from 122 feet up to 82 feet, and included a 10-foot sump, 20-foot screen (10-slot), and a 10-foot blank above the screen. The screen was set at a depth of 97 feet to 117 feet. Schedule 80 PVC was used to complete the well above the blank. Clean, silica sand (#10-20 mesh) was added from 122 feet up to 77 feet to seat the well screen and sump. Three feet of #3-8 mesh sand was added from 77 feet up to 74 feet. A bentonite slurry seal was added from 74 feet up to the land surface. The well completion schematic for SFR-2S is included in Appendix B.

Figure 6. Drilling chronology of Borehole SFR-2

4.3.5 SFR-2S Well Development

Development of SFR-2S began on September 5, 1992 following the same criteria described in Section 3.2.5. The well bore volume was calculated to be 10.4 gallons. A total of 1,260 gallons was bailed, swabbed and pumped from this well over a three day period. Development of this well by pumping was completed in March of 1993. Development data is shown in Appendix C.

4.4 SFR-3 Field Operations

The field operations at SFR-3 began on July 21, 1992, with the Barber Rig. The Barber Rig originally drilled the borehole to a total depth of 265 feet bgs on July 27, 1992. Drilling was reinitiated in this borehole on October 17, 1992. Drilling was terminated at 408 feet on November 1, 1992. Completion of two wells in the borehole at SFR-3 proceeded until November 10, 1992.

4.4.1 SFR-3 Location

The SFR-3 site is located about 0.55 miles east of SFR-2. The approximate geographic location of the site is NE 1/4 SW 1/4 Section 4 T8N R4E (Figure 4). A land survey of this area indicates that the ground level elevation at this site is 5,494 ft. msl. State plane coordinates for this well are ; x = 418472.52 and y = 1436169.84.

4.4.2 SFR-3 Well Installation Plan

The well installation plan (SNL, 1992) required to meet the objectives at the SFR-3 site included the drilling and completion of one deep monitoring well (SFR-3D) and one shallow monitoring well (SFR-3S). SFR-3D was projected to be completed as a bedrock monitoring well as follows:

- Depth to bedrock estimated to be 158 feet;
- Depth to top of screen projected to be 428 feet (screened elevation interval to correspond to the screened elevation interval in SFR-1D);
- Screen length specified to be 20 feet; and
- Total borehole depth projected to be 450 feet (292 feet below Santa Fe Group/bedrock contact).

SFR-3S was projected to be completed as a water table monitoring well as follows:

- Depth to water table estimated to be 101 feet;

- Depth to top of screen projected to be 96 feet;
- Screen length specified to be 20 feet; and
- Total borehole depth projected to be 118 feet.

4.4.3 SFR-3 Drilling Operations Summary

The Barber rig began drilling at SFR-3 on July 21, 1992. This borehole was drilled to a depth of 265 feet bgs on July 27, 1992. Bedrock was not encountered to this depth. Drilling resumed in this borehole on October 19, 1992. The borehole was advanced to a total depth of 408 feet. Bedrock was not encountered down to this depth.

Although the drilling itself progressed smoothly, problems were experienced with installing the casing by the sonic method. Water is normally used to clean out the borehole when installing the casing with the sonic method. However, during the beginning of the new drilling phase in October, lost circulation of clean-out water was frequently a problem and slowed down drilling progress. The addition of an organic drilling polymer decreased these lost circulation problems. Figure 7 outlines the drilling chronology of SFR-3.

4.4.4 SFR-3 Well Completion

Because of the deeper than estimated depth to bedrock at the SFR-3 location, only one of the two planned boreholes was drilled. To maximize what could be learned about the subsurface hydrology at this location, the decision was made to complete this borehole as a nested monitor well. The general strategy for this well installation was to attempt to isolate two potentially different saturated intervals. These different intervals were identified by a combination of core description and geophysical log interpretation.

4.4.4.1 SFR-3D Well Completion

The borehole was backfilled from 408 feet to a depth of 361.5 feet. with #3-8 mesh sand. A 2-inch diameter, Schedule 80 PVC well was then installed at this depth. This well, designated SFR-3D, included a 10-foot sump and a 40-foot, 10-slot screen. The screen was set from 311.5 feet to 351.5 feet. Clean, silica sand (#10-20 mesh) was added from 361.5 feet to 290.5 feet, with an additional 13.5 feet of #3-8 mesh sand added on top of the silica sand up to a total depth of 277 feet. A bentonite slurry seal was added from 277 feet up to a depth of 230 feet. The well completion schematic for SFR-3D is included in Appendix B.

Figure 7. Drilling chronology of Borehole SFR-3

4.4.4.2 SFR-3S Well Completion

The total depth of the shallow well, designated SFR-3S, was defined by the top of the bentonite seal above SFR-3D. A #3-8 mesh sand pack was placed from 230 feet up to 222 feet. A 2-inch diameter, Schedule 80 PVC well was installed at this depth. This well included a 10-foot sump and a 20-foot, 10-slot screen. The screen was set from approximately 182 feet to 212 feet. Clean, silica sand (#10-20 mesh) was added from 222 feet up to 160 feet. Five additional feet of #3-8 mesh sand was added up to 155 feet, with a bentonite slurry added from this depth to the ground surface. The well completion schematic for SFR-3S is included in Appendix B.

4.4.5 SFR-3 Well Development

Well development for SFR-3D and SFR-3S followed the same criteria as that stated in Section 3.2.5. Water level and recovery data for development are included in Appendix C.

4.4.5.1 SFR-3D Well Development

Development of SFR-3D began on November 18, 1992. The well bore volume was calculated to be 25.1 gallons. A total of 77 gallons was bailed from the well. Development was accomplished by the use of a 10-foot, bailer. Development was terminated once the electrical conductivity and pH were stable as measured on the YSI flow-through meter.

4.4.5.2 SFR-3S Well Development

Development of SFR-3S began on November 19, 1992. The well bore volume was calculated to be 7.6 gallons. Approximately 52 gallons of water were bailed from this well over a two-day period. Development was accomplished via a 5-foot, bailer. Development ceased once the electrical conductivity and the pH stabilized on the YSI flow through meter.

4.5 SFR-4 Field Operations

The field operations at SFR-4 began on July 28, 1992, with the Barber Rig. The borehole was completed to a total depth of 168 feet on August 5, 1992. There was no water encountered in this borehole during drilling, hence, there was no well installed at SFR-4.

4.5.1 SFR-4 Location

The SFR-4 site is located about 0.45 miles east of SFR-3 and is the easternmost borehole in the SFR project area. The approximate geographic location of the site is NE 1/4 SE 1/4 Section 4 T8N R4E (see Figure 4). A land survey of this area indicates that the ground elevation at this site is 5,568 ft. msl. State plane coordinates for this well are; $x = 420577.95$, $y = 1436205.77$.

4.5.2 Borehole Installation Plan

The decision to drill the SFR-4 borehole was made because bedrock had not been encountered in any of the other boreholes. This borehole was sited further to the east at station 11 of transect 5 (IT Corporation, 1991), with the objective of finding a location where bedrock would be encountered at a relatively shallow depth. Based on the initial gravity interpretation (IT Corporation, 1991), the estimated depth to bedrock at SFR-4 was less than 50 feet bgs.

The borehole installation plan included drilling into bedrock and identifying the potentiometric surface of the uppermost water-bearing unit. A total depth of 300 feet was specified as the maximum depth that would be drilled to reach these objectives. Subsequent well completion after drilling was to include screening a selected interval within the saturated bedrock.

4.5.3 SFR-4 Drilling Operations Summary

Drilling began at SFR-4 with the Barber rig on July 28, 1992. Weathered shales and mudstones were encountered at a depth of 30 to 40 feet bgs. The borehole at SFR-4 was drilled to a depth of 168 feet on August 5, 1992. A drilling chronology of this borehole is shown in Figure 8.

4.5.4 SFR-4 Well Completion

Because no water-bearing interval was encountered in this borehole, no well was installed at the SFR-4 location. Current plans are to plug and abandon this borehole at a later date.

4.6 SFR Well Construction Correlation

Figure 9 is a schematic cross section illustrating the correlation between the completion intervals in the SFR wells.

Figure 8. Drilling chronology of Borehole SFR-4

Figure 9. Cross section of completion intervals for the SFR wells

5.0 BOREHOLE GEOLOGY

The geologic information summarized in this section consists of lithologic descriptions for the core and cuttings obtained from the SFR boreholes. The principal geologic unit encountered in these boreholes is the Santa Fe Group. This unit is highly heterogeneous with limited lateral stratigraphic continuity. These characteristics make lithologic correlations between the SFR boreholes problematic.

The difficulty in establishing lithologic correlations between boreholes limits the structural information which can be interpreted from this data. The following discussions are limited to identifying the general lithologic sequence in each borehole and specific lithologic features of interest.

To supplement the detailed lithologic descriptions recorded by the well-site geologist, all of the core was photographed. This photographic record from each borehole is maintained by the SNL/NM ER Program Records Center and is available for review through the database maintained by the Records Center.

5.1 SFR-1 Borehole Geology

The stratigraphy encountered by the SFR-1 borehole is comprised of surficial, alluvial deposits and Santa Fe Group sediments. The uppermost 6.5 feet comprises silty to clayey silty sand, with scattered pebbles, clay, and caliche. Underlying this surficial unit is a 300-foot Santa Fe Group sequence of interbedded gravelly/pebbly silty sand, silty sandy clay, and clayey sandy silt. The scattered pebbles are composed of limestone, quartz and altered metamorphic rocks. Within this sequence, the intervals from 56 to 186 feet, and 193 to 248 feet include a significantly higher clay content. The sandy-silty units range from loose to moderately compacted, while the clay units are moderately to well compacted.

At a depth of 305 feet, a moderately to strongly cemented conglomerate was encountered. This conglomerate extends to a depth of approximately 317 feet and was described by the well-site geologist to be a "fault breccia."

Coring was terminated at a depth of 317 feet. Samples obtained below this depth to the total depth of 510 feet were drill cuttings. The descriptions of these drill cuttings suggest that this interval is composed of interbedded gravel, sand, and silty sand with clay. In addition to the cuttings descriptions, drilling indicators identified several flowing sands within this interval.

Complete lithologic descriptions for core and cuttings obtained from the SFR-1 borehole are included in Appendix D.

5.2 SFR-2 Borehole Geology

The stratigraphy encountered by the SFR-2 borehole is comprised of surficial, alluvial deposits and

Santa Fe Group sediments. The uppermost 4 feet comprises sandy silt with caliche and scattered pebbles. Underlying this surficial unit is a 48-foot interval of gravely sandy silt, sand, silty sand with cobbles, pebbles and gravel, and caliche.

The interval from a depth of 52 feet to the total depth of the borehole at 365 feet contains significant clay. Lithologically, this interval includes clay, sandy clay, silty clay, sandy silty clay, and clayey silty sand. Interbeds of gravel, sand, and silt are locally present.

One observation made by the well-site geologist bears noting. This observation suggests a possible fault contact at a depth of approximately 233 feet. This interpretation is based on an abrupt contact at a 45° angle between two lithologic units, and the potential for the silt associated with this contact to be gouge material (rock flour).

Complete lithologic descriptions of core obtained from the SFR-2 borehole are included in Appendix D.

5.3 SFR-3 Borehole Geology

The stratigraphy encountered by the SFR-3 borehole is comprised of surficial, alluvial deposits and Santa Fe Group sediments. The uppermost 117 feet is comprised of sandy silt, silty sand, and gravel. Underlying this uppermost unit is a 38-foot interval (117 to 155 feet) of silty sand with clay and scattered gravel. Between the depths of 155 feet and 167 feet, a sandy silt unit with sandstone nodules and lenses and conglomeratic lenses was encountered. This unit graded into a well-indurated conglomerate which extends from 167 feet to 192 feet.

The interval from a depth of 192 feet to the total depth of the borehole at 408 feet contains significant clay. Lithologically, this interval includes gravely sandy clay, sandy clay, clayey sand, sandy gravel with clay and clayey sand with pebbles. Interbeds of silty sand, pebbles, and gravel are locally present.

Complete lithologic descriptions of core obtained from the SFR-3 borehole are included in Appendix D.

5.4 SFR-4 Borehole Geology

The uppermost 34 feet is comprised of gravely silty sand with clay, gravely sandy silt and sandy gravel. The gravel material in the upper 24 feet is composed predominantly of limestone clasts (> 95%) with minor granitic and metamorphic clasts. From a depth of 24 feet to 34 feet, the composition of the gravel changes to predominantly granitic clasts (> 90%) with minor limestone and sandstone clasts.

From the depth of 34 feet to 90 feet, the lithology changes to a dark yellowish orange clay and

yellowish gray clayey silt. Reddish brown mottled zones and black iron staining are scattered throughout. The interval from 90 feet to the total depth of the borehole at 168 feet is comprised of an olive gray clay and claystone (or decomposed shale). Dusky yellow mottled zones, and black and yellow iron staining are common. The lithologies below a depth of 34 feet are distinctly different from those encountered in the other SFR boreholes and are interpreted to be weathered bedrock.

Complete lithologic descriptions of core obtained from the SFR-4 borehole are included in Appendix D.

6.0 BOREHOLE HYDROLOGY

One of the objectives of the SFR Project was to gather as much information as possible about the hydrology of the area. Specifically, information about the location and extent of perched water zones, water table elevations and the quantities of water available in the boreholes was determined to be essential hydrologic data to be gained from the drilling operation. Perched water zones were defined as saturated zones below which dry, unconsolidated material was found. When the borehole became continuously saturated, the water level associated with this saturated zone was defined as the water table.

Continuous core taken with a minimal use of drilling fluids allowed the saturated zones to be fairly readily identified. Degrees of moisture were observed and noted in the field notes by the site geologist. Illustrations of the relative core moisture are shown for each borehole. An additional indicator of saturation was the amount of water produced in the borehole during drilling and cleaning out the casing. Multiple saturated zones were also identified by means of water level measurements made during various stages of drilling and completion.

6.1 SFR-1 Borehole Hydrology

Based on water level measurements made during the drilling at SFR-1, several different water-bearing zones were encountered in this borehole, including one perched zone at a depth of approximately 75 feet. Various water levels encountered during drilling are shown in Table 3. These water levels correspond to varying depths of the borehole (also shown in Table 3) as casing advanced during drilling. In addition, this borehole encountered flowing sands at depths of approximately 75, 250, 273, and 330 feet during drilling. Water levels for both SFR-1D and SFR-1S after completion are available in Table 4.

Table 3. Water-level measurements encountered in SFR-1 during drilling.

DATE MEASURED	APPROXIMATE DEPTH TO WATER (ft bgs)	DEPTH OF BOREHOLE (ft bgs)
6/11/92	95	106
6/18/92	100	178
6/18/92	121	193
7/15/92	213	375
7/21/92	111	375
7/22/92	110	420
7/23/92	110	420
7/28/92	141	510

Table 4. Water-level measurements in SFR-1D and SFR-1S after completion.

DATE MEASURED	DEPTH TO WATER (ft) SFR-1D ^a	DEPTH TO WATER (ft) SFR-1S ^a
8/10/92	136.85	88.65
8/19/92	139.80	90.55
8/26/92	137.87	89.55
8/31/92	137.50	89.58
9/1/92 ^b	140.21	89.59
9/2/92 ^b	140.10	—
9/3/92 ^b	140.18	—
9/5/92 ^b	140.06	—
9/17/92 ^c	139.66	90.11
11/15/92 ^c	139.50	90.25
11/30/92 ^c	139.52	90.33
12/1/92 ^d	139.48	—

^a Depth to water was measured from the top of the steel riser.

^b These measurements were made after development of SFR-1D began.

^c These measurements were made from the top of the PVC casing inside the steel riser.

^d This measurement was made at the beginning of the second day of development of SFR-1S.

Table 4 indicates a consistent water level difference of approximately 50 feet between SFR-1D and SFR-1S. In addition, water levels measured in SFR-1S were stable during the development of SFR-1D, indicating that the two saturated zones are distinct. This data indicates the successful completion of two distinct water-bearing intervals in this borehole.

The depth to water measured in SFR-1S is approximately 90 feet. Review of drilling and completion records suggests that two water-bearing units with possibly different heads may be included in the completion interval. The identification of water level data from this well as either a perched aquifer or the water table aquifer is problematic. Therefore, this water level data should be viewed with caution. The depth to water measured in SFR-1D is approximately 140 feet. This water level rises approximately 125 feet above the upper seal of the completion interval. This indicates that the water-bearing interval monitored by SFR-1D is at least semi-confined.

A plot of relative core moisture versus depth during drilling is shown in Figure 10. This data is based on the qualitative geologic description by the well-site geologist. This figure suggests the potential for perched water-bearing intervals above a depth of 310 feet. However, the qualitative nature of this data precludes definitive conclusions.

Figure 10. Relative core moisture versus depth for SFR-1

6.2 SFR-2 Borehole Hydrology

During reaming of SFR-2, the potential for the existence of multiple saturated zones to the total depth of 365 feet was identified based on observations of water flowing into the borehole at different intervals. However, because of time constraints on rig availability, the identification of discrete saturated intervals could not be determined. Water levels in SFR-2S after completion are presented in Table 5.

Table 5. Water-level measurements in SFR-2S after completion.

DATE MEASURED	DEPTH TO WATER (ft) ^a
8/7/92	100.2
8/9/92	100.1
8/18/92	102.0
8/20/92	102.0
9/5/92	101.05
9/6/92	101.15
9/17/92 ^b	102.68
11/15/92 ^c	102.90

^a Depth to water was measured from the top of the PVC well casing.

^b This measurement was made from the top of the steel riser.

^c This measurement was made from the top of the PVC casing inside the steel riser.

A plot of relative core moisture versus depth during drilling is shown in Figure 11. This data is based on the qualitative geologic description by the well-site geologist and suggests the presence of more than one water-bearing zone in SFR-2. The presence of perched water is supported by the areas of relative dryness followed by zones of very moist or saturated core. Review of Figure 11 identifies the potential for a perched water-bearing interval above the depth of approximately 180 feet. However, the qualitative nature of this data precludes definitive conclusions.

6.3 SFR-3 Borehole Hydrology

During the initial drilling in July (from 0 to 265 feet), core descriptions by the well-site geologist did not identify an obvious saturated interval. However, once the borehole was filled with water for geophysical logging, the water level stabilized at approximately 160 feet, bgs during the two month drilling hiatus. These water level measurements are shown in Table 6.

Figure 11. Relative core moisture versus depth for SFR-2

Table 6. Water-level measurements in SFR-3 prior to completion.

DATE MEASURED	DEPTH TO WATER (ft bgs)*
8/7/92	161.0
8/9/92	160.8
8/19/92	161.0
9/17/92	160.75

- * Depth to water was measured from the land surface.
 Note: Borehole was open to approximately 177 ft.

After the borehole was completed to a total depth of 408 feet, geophysical logging indicated that two zones of saturation might exist. One zone was located at a depth of approximately 190 feet, while another zone was located at approximately 315-345 feet. Based on this interpretation of the geophysical logs, two wells were completed in this borehole, as previously detailed in Section 3.4.4. Water level data for these wells are shown in Table 7. Review of Table 7 shows that these water levels differ from less than 1.0 inch to approximately 2.5 inches. This small difference may indicate that the completion intervals are hydrologically connected.

Table 7. Water-level measurements in SFR-3S and 3D.

DATE MEASURED	DEPTH TO WATER-SFR-3D (ft bgs)	DEPTH TO WATER-SFR-3S (ft bgs)	ADJUSTED DEPTH TO WATER - SFR-3S ^c (ft bgs)
11/10/92 ^a	160.80	161.30	161.0
11/15/92 ^b	163.83	164.11	163.81
11/18/92 ^b	163.69	163.80	163.50
11/19/92 ^b	163.81	163.58	163.28
11/29/92 ^b	163.75	163.20	162.90

- a Water levels were measured from the ground surface.
 b Water levels were measured from the top of the PVC casing.
 c This water level is adjusted for the difference in casing elevation of 0.3 ft.

During development of these wells, the water level in each well fluctuated during development of the other. This information indicates that these completion intervals may be hydraulically connected either in the borehole itself or in the formation. Water levels measured periodically in SFR-3S during development of SFR-3D decreased 3.6 inches overall. In the initial development of SFR-3S, the

water level in SFR-3D declined by a total of 1.2 inches. However, on the second day of development of SFR-3S, the water level in SFR-3D *increased* 0.84 inches. The implications of these conflicting trends are not clear. Water level and recovery data recorded during development are included in Appendix C.

A plot of relative core moisture versus depth during drilling is shown in Figure 12. This data is based on the qualitative geologic description by the well-site geologist and suggests the potential presence of more than one water-bearing zone in SFR-3. The presence of perched water is supported by the areas of relative dryness followed by zones of very moist or saturated core. Review of Figure 12 identifies the potential for more than one perched water-bearing intervals above the depth of approximately 310 feet. However, the qualitative nature of this data precludes definitive conclusions.

As indicated in the above discussion, the data obtained at this location is inconsistent. Hence, conclusions about the hydrogeology at this site based on this data should be made with care.

6.4 SFR-4 Borehole Hydrology

During drilling of this borehole, no saturated zone was encountered. The relative core moisture versus drilling depth as shown in Figure 13. From this figure, one can see that the relative core moisture was in the range of dry to moist for the entire length of the borehole. After filling this borehole with water for geophysical logging, the water level began to slowly decline. At the last measurement on September 17, 1992, the water had dropped from an initial measurement of 21.6 feet, bgs to 45.55 feet, bgs (see Table 8). Further measurements were precluded because the borehole collapsed at 49.6 feet, bgs. Based on the declining water levels, no conclusion about the hydrology at this location can be inferred. The decline of the water levels is shown in Table 8.

Table 8. Water-level measurements in SFR-4D prior to completion.

DATE MEASURED	DEPTH TO WATER (ft, bgs) ^a
8/4/92	No water present
8/7/92 ^b	21.6
8/9/92	29.9
8/19/92	43.6
9/17/92	45.55

^a Depth to water was measured from the land surface.

^b This borehole was filled with water for geophysical logging purposes.

Note: This borehole caved in at 49.6 ft, bgs. The declining water level conforms with the observation that no saturation was encountered in this borehole.

Figure 12. Relative core moisture versus depth for SFR-3.

Figure 13. Relative core moisture versus depth for SFR-4

7.0 BOREHOLE GEOPHYSICS

The purpose of geophysical logging is to obtain more information from the borehole than can be obtained from drilling and sampling. The cost-benefit ratio of geophysical logging is usually quite favorable since the cost of logging is usually much less than costs associated with drilling the borehole (Keys, 1990).

Geophysical logs provide continuous digital data that can be interpreted to provide various physical properties of the media. This interpretation includes the lithology, thickness, and continuity of aquifers and confining beds; permeability, porosity, bulk density, resistivity, moisture content, and specific yield of aquifers and confining beds; and with some logs, the chemical and physical characteristics of ground water. With proper calibration, geophysical logs are quite repeatable, (even with different equipment), which over time can provide a basis for measuring changes in the aquifer matrix (i.e. porosity), or changes in water quality, such as salinity (Keys, 1990). Geophysical logs can also provide information on severe disturbances in the formation caused by drilling, i.e., large voids adjacent to the borehole caused by flowing sands or erosion from drilling operations.

Geophysical logs cannot completely replace study of cuttings and drill core, because such samples are frequently needed to calibrate geophysical log interpretations. In fact, the importance of core or cuttings can not be overemphasized. Individual logs do not have unique responses, and there are no unambiguous rules for log interpretation (Keys, 1990). As such, log interpretation is somewhat subjective and therefore, subject to the experience level of the interpreter. In addition, it is important to interpret logs as a suite, rather than individually, since this process renders more reliable interpretations. Successful log interpretation depends on trained personnel, both as analysts and as equipment operators. Calibration of the instruments is essential and can greatly affect the quality of the results.

Density, gamma and neutron geophysical logs were run in all four boreholes. The boreholes were flushed and filled with water prior to logging. A preliminary interpretation of each log is discussed in Appendix E. Appendix E also provides a brief discussion of the utility of the geophysical logs run in the SFR boreholes and includes copies of all logs.

7.1 SFR-1 Geophysical Logging

Geophysical logging was performed in SFR-1 on July 26, 1992. Three types of logs were run in this borehole, in addition to a caliper log (to determine borehole diameter). These logs included natural gamma, density, and neutron logs. Although this borehole was flushed and filled with water prior to logging, the borehole lost water to the formation until it reached a static level of approximately 140 feet, bgs. As such, when water was encountered by the logging tool, a scale change on the log trace was necessary to account for the change in fluid (i.e., air versus water). The logs were run through

the 10-3/4 inch casing to its entire depth of 410 feet. Logging continued in the open borehole to a depth of approximately 494 feet. Copies of the geophysical logs and preliminary log interpretations are included in Appendix E.

7.2 SFR-2 Geophysical Logging

Gamma and neutron logs were run on this borehole through both the 4-1/2 inch core barrel and the 6-inch casing on July 14, 1992. On the following day, neutron and density logs were run through the 6-inch casing only. The neutron logs correlate well to one another, although the log run through both pipes appears to be somewhat dampened, as expected. Logs were run to a depth of 360 feet with the borehole filled with water. Copies of the geophysical logs and preliminary log interpretations are included in Appendix E.

7.3 SFR-3 Geophysical Logging

Gamma, neutron, and density logs were run twice on the SFR-3 borehole after the initial total depth of 265 feet on July 27, 1992. Another suite of logs was run after the final total depth of 408 feet on November 3, 1992. The first set of logs (during the July logging) was run through both the 4-1/2 inch drill pipe and the 6-inch casing to a depth of 265 feet, while a second set of logs was run through the 6-inch casing to a depth of 210 feet. Although the two sets of logs from July appear to correlate well to one another (with the exception of a dampened effect from both sets of pipe), the gamma and density logs run through both sets of pipe show irregularities within the first 30 feet of the logs. It is not clear what caused these log fluctuations, thus, the reliability of the first set of logs is questionable. Subsequent logging in November was done through the 6-inch casing to the total depth of 408 ft. bgs. All logs were run with the borehole filled with water. Copies of both suites of geophysical logs and preliminary log interpretations of the November logging suite are included in Appendix E.

7.4 SFR-4 Geophysical Logging

Gamma, neutron, and density logs were run twice on the SFR-4 borehole. The first set of logs was run through both the 4-1/2 inch drill pipe and the 6-inch casing, while the second set of logs was run through the 6-inch casing only. The borehole was filled with water for both sets of logs. Unlike the previous logs, the two sets of logs do not correlate very well to each other. It appears that the logs are offset approximately 1-2 feet, i.e. a peak on the first gamma log is skewed approximately 1-2 feet from the corresponding peak on the second gamma log. It is possible that the depth recorder was skewed during the second log. However, given the trace fluctuations in SFR-3 when logs were run through both pipes, the interpretation was based on the logs run through the 6-inch casing, i.e. the second logs. Logs were run to a depth of 160 feet. Copies of the geophysical logs and preliminary log interpretations are included in Appendix E.

8.0 SUMMARY AND RECOMMENDATIONS

The following sections summarize the SFR-Phase I drilling activities and outline recommendations for future SFR activities.

8.1 Summary

The initial objectives of the South Fence Road project were:

- To verify results of the surface gravity survey.
- To examine the possible hydrologic vertical gradients in the fault-complex area.
- To provide a monitoring/test well network to aid in characterizing the groundwater characteristics for the Santa Fe Group and the underlying bedrock along South Fence Road.

An additional objective to provide a development field test for the sonic drilling technique was added prior to beginning drilling.

To reach these objectives, four boreholes were drilled along an east-west line at the southern boundary of KAFB. The depth to bedrock proved to be deeper than projected by the gravity data interpretation. Because of the depth limitations of the sonic drilling technique, several of the project objectives were not reached. Specifically, all objectives related to characterizing groundwater flow in the bedrock, and between the bedrock and the Santa Fe Group were not met.

What was accomplished by the field operations detailed in this report include:

- Establishing that the surface gravity data interpretation was not correct.
- Providing field testing and operational "shake-down" of the sonic drilling technique and equipment.
- Obtaining continuous core of Santa Fe Group sediments at three locations ranging in depths from approximately 310 feet at SFR-1, down to a maximum depth of 408 feet at SFR-3.
- Providing qualitative identification of multiple water-bearing intervals with different hydraulic heads within the Santa Fe Group.
- Providing qualitative identification of significant water-bearing intervals in the Santa Fe Group sediments.
- Installing two nested monitoring wells within the Santa Fe Group (SFR-1D/1S and SFR-

3D/3S).

- Installing one water-table monitoring well (SFR-2S) in the Santa Fe Group.

8.2 Recommendations

Since several important objectives were not accomplished during the field operations detailed in this report, a second phase of the South Fence Road project is recommended. This second phase should concentrate operations at SFR-3 and SFR-4 locations. The operations identified at each location are outlined in the following sections.

8.2.1 Proposed SFR-3 Operations

The nested monitoring well constructed at the SFR-3 location provides some site-specific information on the geology and hydrology within the Santa Fe Group. However, none of the objectives related to bedrock characterization that were specified in the well installation plan (SNL/NM, 1992) were met. To meet these remaining objectives, a follow-on project including the following elements is recommended:

1. Drill an offset borehole a minimum of 100 feet into the underlying bedrock. The most recent gravity data interpretation estimates that bedrock depth at this location is approximately 410 feet. Therefore, a minimum estimate of the total depth for this offset borehole, based on the gravity data interpretation is approximately 550 feet.
2. The offset borehole should be completed to facilitate aquifer testing in both the unconsolidated Santa Fe Group sediments below the water table and the underlying bedrock. This completion could be a combination open hole/cased hole with access to the selected test intervals. The well drilling plan should insure an adequate wellbore diameter relative to anticipated pump and test tool (i.e. packer(s)/transducer) assembly dimensions. After testing is completed, this well will be utilized as a monitoring well if appropriate.
3. A borehole casing program which supports the project objectives and contributes to borehole safety should be employed.
4. Drill cuttings should be logged to provide a supplementary lithologic record. In addition, selected intervals in the bedrock should be cored.

Prior to establishing a Phase II work plan, the appropriateness of all objectives will be reviewed and amended as necessary. Therefore, the preceding SFR-3 elements should not be construed as final program objectives. Rather, they identify potential objectives under consideration at this location.

8.2.2 Proposed SFR-4 Operations

The SFR-4 borehole was sited in order to encounter bedrock at a relatively shallow depth. This objective was accomplished when unsaturated weathered bedrock was encountered at a depth of approximately 35 feet. Drilling was terminated at a depth of 168 feet. At this depth, the borehole was still in an unsaturated weathered bedrock section which has tentatively been identified as belonging to the Abo or Yeso Formation.

While the primary objective for this borehole was met, a follow-on project to drill into saturated bedrock, and to test and sample the uppermost identified water-bearing interval is recommended. To meet these objectives, a follow-on project including the following elements is recommended:

1. Drill an offset borehole approximately 50 ft. into the underlying saturated bedrock. The most recent water level data from the SFR boreholes to the west suggests that the depth to water at the SFR-4 location is approximately 250 feet. Therefore, a minimum estimate of the total depth for this offset borehole is approximately 300 feet. In order to give some leeway to reaching this objective, a maximum total depth for drilling of 500 feet is recommended.
2. The offset borehole should be completed to facilitate aquifer testing in the saturated bedrock. This completion could be a combination open hole or cased hole with access to the selected interval. The well drilling plan should insure an adequate wellbore diameter relative to anticipated pump and test tool (i.e. packer(s)/transducer) assembly dimensions. After testing is completed, this well will be utilized as a monitoring well if appropriate.
3. A borehole casing program which supports the project objectives and contributes to borehole safety should be employed.
4. An air circulation drilling technique which facilitates the identification of water-bearing intervals during drilling should be employed throughout the unsaturated zone. Once fully saturated conditions are encountered (i.e. below the water table), a water-based circulation system should be employed.
5. Drill cuttings should be logged to provide a supplementary lithologic record. In addition, selected intervals in the bedrock should be cored.

Prior to establishing a Phase II work plan, the appropriateness of all objectives will be reviewed and amended as necessary. Therefore, the preceding SFR-4 elements should not be construed as final program objectives. Rather, they identify potential objectives under consideration at this location.

9.0 REFERENCES

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- Driscoll, F.G., 1986. *Groundwater and Wells, Second Edition*, Johnson Division, St. Paul, Minnesota, 1089 p.
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- IT Corporation, 1992, Draft Report on a surface gravity survey for fault delineation and hydrologic characterization.
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- Kelley, V.C., 1977, Geology of the Albuquerque Basin, New Mexico Bureau of Mines and Mineral Resources, Memoir 33.
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Appendix A: Core Recovery Data

RECOVERY OF CORE AT SFR-1

Depth (ft. bgs)	Amt. Cored	Recovered Amt.	% Recovered
2.5	2.5	1.8	72.0
3.2	0.7	1.6	228.6
5.2	2	2.4	120.0
8.6	3.4	2.7	79.4
11.1	2.5	3.1	124.0
15.4	4.3	4.3	100.0
18	2.6	2.7	103.8
22.3	4.3	4	93.0
24.4	2.1	3.3	157.1
26.6	2.2	2.2	100.0
29	2.4	3.5	145.8
31	2	2	100.0
33.5	2.5	3.8	152.0
35	1.5	2.65	176.7
36.7	1.7	1.5	88.2
39	2.3	2.3	100.0
42	3	4	133.3
46	4	5.6	140.0
48.6	2.6	2.7	103.8
50.7	2.1	3.5	166.7
52.8	2.1	2.3	109.5
55	2.2	2.4	109.1
56	1	1.1	110.0
61.6	5.6	5.6	100.0
76.6	15	15	100.0
87.1	10.5	13	123.8
107.1	20	20	100.0
116	8.9	9.9	111.2
125	9	14.5	161.1
132.5	7.5	7.8	104.0
140.5	8	7.8	97.5
164	23.5	24.3	103.4
171.6	7.6	8.1	106.6
178	6.4	7.9	123.4
187	9	9	100.0
188	1	0.9	90.0
193	5	5.9	118.0
197	4	4.2	105.0
204	7	7	100.0
214	10	12.1	121.0
226	12	12.1	100.8
238	12	12.4	103.3
246	8	10.7	133.8
251	5	5.5	110.0
265	14	14	100.0

RECOVERY OF CORE AT SFR-1

Depth (ft. bgs)	Amt. Cored	Recovered Amt.	% Recovered
269.7	4.7	4.7	100.0
273	3.3	3	90.9
289	16	16	100.0
293.7	4.7	5.7	121.3
305	11.3	10	88.5
307	2	2.4	120.0
312	5	3.3	66.0
317	5	2.1	42.0

RECOVERY OF CORE AT SFR-2

Depth (ft. bgs)	Amt. Cored	Recovered Amt.	% Recovered
2	2	2	100.0
4	2	3.6	180.0
7	3	3	100.0
10	3	2.8	93.3
12.5	2.5	2.3	92.0
14	1.5	2.4	160.0
18	4	4	100.0
23.5	5.5	3.6	65.5
27	3.5	3.9	111.4
30	3	4.7	156.7
33	3	3.2	106.7
38	5	7.5	150.0
42	4	5	125.0
46	4	3.5	87.5
49	3	3.2	106.7
52	3	3.6	120.0
57	5	5	100.0
63	6	5	83.3
66	3	3.2	106.7
70	4	3.7	92.5
75	5	5.8	116.0
80	5	5.5	110.0
83.5	3.5	4.1	117.1
87	3.5	4.7	134.3
90	3	3.3	110.0
93	3	3	100.0
96	3	3	100.0
99	3	3	100.0
102	3	3	100.0
104.5	2.5	2.5	100.0
106	1.5	2.3	153.3
108	2	2.3	115.0
110	2	2.2	110.0
118	8	8.4	105.0
123	5	5.4	108.0
127	4	3.9	97.5
138	11	11.3	102.7
147	9	8.8	97.8
154	7	6.4	91.4
163	9	10.2	113.3
178	15	13.7	91.3
183	5	5.3	106.0
191	8	8.3	103.8
217	26	27.7	106.5
228	11	10.7	97.3

RECOVERY OF CORE AT SFR-2

Depth (ft. bgs)	Amt. Cored	Recovered Amt.	% Recovered
263.5	35.5	48.5	136.6
291	27.5	32.8	119.3
315	24	25.6	106.7
318	3	3.5	116.7
344	26	26.1	100.4
365	21	21.4	101.9

RECOVERY OF CORE AT SFR-3

Depth (ft. bgs)	Amt. Cored	Recovered Amt.	% Recovered
16.5	16.5	11.1	67.3
24	7.5	8.5	113.3
28	4	5.4	135.0
32	4	3.2	80.0
36	4	4	100.0
38	2	2	100.0
45	7	4.3	61.4
52	7	7.3	104.3
60	8	6.2	77.5
65	5	5	100.0
76	11	11.2	101.8
87	11	10.8	98.2
97	10	10.1	101.0
104.5	7.5	8.1	108.0
107.5	3	3.8	126.7
112	4.5	4.8	106.7
115	3	3.2	106.7
117	2	2.7	135.0
126.5	9.5	9.5	100.0
130.5	4	4	100.0
134.5	4	4	100.0
140	5.5	5.5	100.0
148	8	4.8	60.0
157.5	9.5	10.2	107.4
167	9.5	9.7	102.1
177	10	4.5	45.0
195	18	7	38.9
208	13	12.7	97.7
222	14	14.6	104.3
238	16	20	125.0
242	4	4	100.0
250	8	9	112.5
259	9	7.8	86.7
265	6	6.2	103.3
271	6	6.3	105.0
279	8	7.6	95.0
283	4	4.6	115.0
296	13	14.4	110.8
301	5	5.6	112.0
312	11	10.8	98.2
317	5	6.2	124.0
325	8	6.4	80.0
334	9	9.5	105.6
336	2	1	50.0
345	9	7.7	85.6

RECOVERY OF CORE AT SFR-3

Depth (ft. bgs)	Amt. Cored	Recovered Amt.	% Recovered
354	9	13.7	152.2
361	7	0	0.0
372	11	10.1	91.8
380	8	7.6	95.0
394	14	16.2	115.7
408	14	14.1	100.7

RECOVERY OF CORE AT SFR-4

Depth (ft. bgs)	Amt. Cored	Recovered Amt.	% Recovered
4.5	4.5	4.5	100.0
7	2.5	3.2	128.0
14	7	3.8	54.3
18	4	4	100.0
24	6	5.2	86.7
27	3	3	100.0
30	3	3.3	110.0
31	1	1	100.0
41	10	8.6	86.0
48	7	7.1	101.4
51	3	3.3	110.0
66	15	15.5	103.3
71	5	5.4	108.0
77	6	10.4	173.3
90	13	20.2	155.4
100	10	13.4	134.0
106	6	10.6	176.7
110	4	5.8	145.0
114	4	7.6	190.0
120	6	10.3	171.7
125	5	11	220.0
129	4	6.7	167.5
137	8	10	125.0
142	5	10.1	202.0
146	4	8.4	210.0
148	2	2.8	140.0
151	3	6.3	210.0
168	17	6.7	39.4

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Appendix B: Monitoring Well Data Sheets and Survey Reports

SEP. 12-1992 12:43 FROM

TO

92963289 P. 82

1/14/93

SNL GROUND WATER MONITOR WELL DATA SHEET

WELL NUMBER: SFR-1D (4" MW)

LOCATION: KAFB - South Ferice Rd.

DATE INSTALLATION COMPLETED: 8/6/92

DATE OF DEVELOPMENT: 8/31 - 9/4/92

PLAN VIEW SURVEY POINTS

TOP OF
CONCRETE PAD

SURVEY POINTS

WELL NO.	<u>SFR-1D</u>
ELEV. 'A'	<u>5396.46</u>
ELEV. 'B'	<u>5394.29</u>
ELEV. 'C'	<u>5394.29</u>
ELEV. 'D'	<u>5394.30</u>
ELEV. 'E'	<u>5394.28</u>

ELEV. = FASL
SURVEY DATE: 1/14/93
REMARKS: _____

~ <u>5129</u>	<u>265</u>	
ELEV FASL	ELEV FBGS	TOP OF SEAL
~ <u>5090</u>	<u>304</u>	
ELEV FASL	ELEV FBGS	TOP OF SAND
~ <u>5046</u>	<u>348</u>	
ELEV FASL	ELEV FBGS	TOP OF SCREEN
~ <u>5026</u>	<u>368</u>	
ELEV FASL	ELEV FBGS	BOTTOM OF SCREEN
~ <u>5016</u>	<u>378</u>	
ELEV FASL	ELEV FBGS	BOTTOM OF SUMP
~ <u>4976</u>	<u>418</u>	
ELEV FASL	ELEV FBGS	BOTTOM OF HOLE

KEY:

GS = GROUND SURFACE
FBGS = FEET BELOW GROUND SURFACE
FASL = FEET ABOVE MEAN SEA LEVEL

PROTECTIVE COVER: Steel
ELEV. 5396.57 FAS

RISER ELEVATION
'A': 5396.46
(DATUM) FASL

CONCRETE PAD
RISER TYPE: SCH 80 PVC

DIAMETER: 4 IN(OD) _____ IN(ID)

LENGTH: 357 FT

BACKFILL:

SEAL: Volclay
SAND: #3-8 mesh & natural backfill

SCREEN DIA: 4 IN(OD) 3.78 IN(ID)

LENGTH: 20 FT

TYPE: SCH 80 PVC

SLOT SIZE: 0.020 IN

BOREHOLE DIA: ~ 9 IN

DRILL METHOD: Sonic & air rotary

SUMP LENGTH: 10'

STATE PLANER: X 413524.06 FT.

Y 1436237.64 FT.

GEOGRAPHIC:

LATITUDE

LONGITUDE

GENERAL COMMENTS: _____

SNL GROUND WATER MONITOR WELL DATA SHEET

WELL NUMBER: SFR-1S (2" MW)LOCATION: KAFE-South Fort. In.DATE INSTALLATION COMPLETED: 8/8/92DATE OF DEVELOPMENT: 11/30 - 12/1/92

PLAN VIEW SURVEY POINTS

OS NW CORNER
ELEV. "B"OS NE CORNER
ELEV. "C"OS SW CORNER
ELEV. "E"OS SE CORNER
ELEV. "D"TOP OF
CONCRETE PAD

SURVEY POINTS

WELL NO.	<u>SFR-1S</u>
ELEV. "A"	<u>5396.59</u>
ELEV. "B"	<u>5304.29</u>
ELEV. "C"	<u>5394.29</u>
ELEV. "D"	<u>5394.30</u>
ELEV. "E"	<u>5394.28</u>

ELEV. = FASL

SURVEY DATE: 1/14/93

REMARKS:

~ <u>5394</u>	<u>0</u>	
ELEV	ELEV	TOP OF
FASL	FBGS	SEAL
~ <u>5319</u>	<u>75</u>	
ELEV	ELEV	TOP OF
FASL	FBGS	SAND
~ <u>5242</u>	<u>152</u>	
ELEV	ELEV	TOP OF
FASL	FBGS	SCREEN
~ <u>5222</u>	<u>172</u>	
ELEV	ELEV	BOTTOM OF
FASL	FBGS	SCREEN
~ <u>5212</u>	<u>182</u>	
ELEV	ELEV	BOTTOM OF
FASL	FBGS	SUMP
~ <u>5129</u>	<u>265</u>	
ELEV	ELEV	BOTTOM OF
FASL	FBGS	HOLE

KEY:

GS = GROUND SURFACE
 FBGS = FEET BELOW GROUND SURFACE
 FASL = FEET ABOVE MEAN SEA LEVEL

PROTECTIVE COVER: Steel
ELEV 5396.59 FASLRISER ELEVATION
"A": 5396.49
(DATUM) FASL

CONCRETE PAD

RISER TYPE: SCH 80 PVCDIAMETER: 2 IN(OD) IN(ID)LENGTH: 154 FT

BACKFILL:

SEAL: VoklaySAND: # 3-8 meshSCREEN DIA: 2 IN(OD) IN(ID)LENGTH: 20 FTTYPE: SCH 80 PVCSLOT SIZE: 0.020 INBOREHOLE DIA: ~7 INDRILL METHOD: Sonic &
air rotarySUMP LENGTH: 10'STATE PLANER: X413524.016 FT.Y14316237.164 FT.

GEOGRAPHIC:

LATITUDE

LONGITUDE

GENERAL COMMENTS:

SEP-18-1992 12:43 FROM

TO

92953289 P.02

1/14/93

NE CORNER
ELEV. "B"

NG
SE CORNER
ELEV. "C"

SW CORNER
ELEV. "E"

NG
SW CORNER
ELEV. "D"

CONCRETE
BASE

PLAN
N.T.S.

WELL NO. 3FR-2	
ELEV. "A"	5430.10
ELEV. "B"	5427.86
ELEV. "C"	5427.85
ELEV. "D"	5427.84
ELEV. "E"	5427.82
ELEV. "F"	5430.26

Avg. Elev. = 5427.84
Ground

NG = NATURAL GROUND

FIGURE 3.
ELEVATION
N.T.S.

SFR-2S

PROJECT NO. SFR Well Project

SNL GROUND WATER MONITOR WELL DATA SHEET

WELL NUMBER: SFR-2S

LOCATION: SAFB - South Fork Rd.

DATE INSTALLATION COMPLETED: 8/20/92

DATE OF DEVELOPMENT: 9/5 - 3/7/92

PLAN VIEW SURVEY POINTS

SURVEY POINTS

WELL NO.	<u>SFR-2S</u>
ELEV. "A"	<u>5430.10</u>
ELEV. "B"	<u>5427.96</u>
ELEV. "C"	<u>5427.85</u>
ELEV. "D"	<u>5427.84</u>
ELEV. "E"	<u>5427.82</u>

ELEV. = FASL
SURVEY DATE: 1/14/93
REMARKS: _____

~5428	0	
ELEV FASL	ELEV FBGS	TOP OF SEAL
~5354	74	
ELEV FASL	ELEV FBGS	TOP OF SAND
~5331	97	
ELEV FASL	ELEV FBGS	TOP OF SCREEN
~5311	117	
ELEV FASL	ELEV FBGS	BOTTOM OF SCREEN
~5306	122	
ELEV FASL	ELEV FBGS	BOTTOM OF SUMP
~5266	162	
ELEV FASL	ELEV FBGS	BOTTOM OF HOLE

KEY: GS = GROUND SURFACE
FBGS = FEET BELOW GROUND SURFACE
FASL = FEET ABOVE MEAN SEA LEVEL

GEOGRAPHIC:
LATITUDE LONGITUDE

GENERAL COMMENTS: _____

SEP-23-1992 12:43 FROM NG SE CORNER ELEV. "C"

TO 92963289 P.02 1/14/93

WELL NO. SFR-3	
ELEV. "A"	W-2" PVC = 5495.27 SFR-3 E-2" PVC = 5495.57 SFR-3S
ELEV. "B"	5493.59
ELEV. "C"	5493.53
ELEV. "D"	5493.57
ELEV. "E"	5493.55
ELEV. "F"	5495.91

Avg. ~~NG~~ Elev. = 5493.56
Ground

NG = NATURAL GROUND

FIGURE 2.
ELEVATION
N.T.S.

SFR-3D (4' well)
SFR-3S (9' well)

PROJECT NO. SFR Well Project

SNL GROUND WATER MONITOR WELL DATA SHEET

WELL NUMBER: SFR-3D (2" West MW)

LOCATION: KAFB - South Fence Rd.

DATE INSTALLATION COMPLETED: 11/5/92

DATE OF DEVELOPMENT: 11/18/92

PLAN VIEW SURVEY POINTS

TOP OF
CONCRETE PAD

SURVEY POINTS

WELL NO. <u>SFR-3D</u>	
ELEV. 'A'	<u>5495.27</u>
ELEV. 'B'	<u>5495.39</u>
ELEV. 'C'	<u>5493.53</u>
ELEV. 'D'	<u>5493.57</u>
ELEV. 'E'	<u>5493.55</u>

ELEV. = FASL

SURVEY DATE: 1/14/93

REMARKS:

~5264	230	
ELEV FASL	ELEV FBGS	TOP OF SEAL
~5217	277	
ELEV FASL	ELEV FBGS	TOP OF SAND
~5182	311.5	
ELEV FASL	ELEV FBGS	TOP OF SCREEN
~5142	351.5	
ELEV FASL	ELEV FBGS	BOTTOM OF SCREEN
~5132	361.5	
ELEV FASL	ELEV FBGS	BOTTOM OF SUMP
~5086	408	
ELEV FASL	ELEV FBGS	BOTTOM OF HOLE

KEY: GS = GROUND SURFACE
FBGS = FEET BELOW GROUND SURFACE
FASL = FEET ABOVE MEAN SEA LEVEL

STATE PLANNER: X 418472.52 FT.
Y 1436169.84 FT.

GEOGRAPHIC:

LATITUDE

LONGITUDE

GENERAL COMMENTS:

SNL GROUND WATER MONITOR WELL DATA SHEET

WELL NUMBER: SFR-35 (2" East MW)

LOCATION: KAFB- South Fence Rd.

DATE INSTALLATION COMPLETED: 11/10/92

DATE OF DEVELOPMENT: 11/19/92; 11/29/92

PLAN VIEW SURVEY POINTS

TOP OF
CONCRETE PAD

SURVEY POINTS

WELL NO. <u>SFR-35</u>	
ELEV. 'A'	<u>5495.57</u>
ELEV. 'B'	<u>5493.59</u>
ELEV. 'C'	<u>5493.53</u>
ELEV. 'D'	<u>5493.57</u>
ELEV. 'E'	<u>5493.55</u>

ELEV. = FASL
SURVEY DATE: 1/14/93
REMARKS: _____

~5494	<u>0</u>	ELEV FASL	ELEV FBGS	TOP OF SEAL
~5339	<u>155</u>	ELEV FASL	ELEV FBGS	TOP OF SAND
~5312	<u>182</u>	ELEV FASL	ELEV FBGS	TOP OF SCREEN
~5282	<u>212</u>	ELEV FASL	ELEV FBGS	BOTTOM OF SCREEN
~5272	<u>222</u>	ELEV FASL	ELEV FBGS	BOTTOM OF SUMP
~5264	<u>230</u>	ELEV FASL	ELEV FBGS	BOTTOM OF HOLE

KEY:

GS = GROUND SURFACE
FBGS = FEET BELOW GROUND SURFACE
FASL = FEET ABOVE MEAN SEA LEVEL

PROTECTIVE COVER: Steel
ELEV 5495.91 FASL

RISER ELEVATION
'A': 5495.57
(DATUM) FASL

CONCRETE PAD

RISER TYPE: Sch. 80 PVC

DIAMETER: 2 IN(OD) IN(ID)

LENGTH: 183 FT

BACKFILL:

SEAL: Volclay

SAND: PRIMARY: 10-20 mesh 160'-222'
SECONDARY: 3-8 mesh 155'-160'

SCREEN DIA: 2 IN(OD) IN(ID)

LENGTH: 30 FT

TYPE: Sch 80 PVC

SLOT SIZE: 0.010 IN

BOREHOLE DIA: ~5 IN

DRILL METHOD: Sonic

SUMP LENGTH: 10'

STATE PLANNER: X418472.52 FT
Y1436169.84 FT.

GEOGRAPHIC:

LATITUDE

LONGITUDE

GENERAL COMMENTS: _____

SEP 13-1992 12:43 FROM

TO

92963289 P.02

1/14/93

BOREHOLE

WELL NO. SFR-4

ELEV. "A" HUB = 5567.72

ELEV. "B"

ELEV. "C"

ELEV. "D"

ELEV. "E"

ELEV. "F"

SE CORNER
ELEV. "B"

NG
SE CORNER
ELEV. "C"

SET
2" x 2"
HUB

SW CORNER
ELEV. "E"

CONCRETE
BASE

NG
SW CORNER
ELEV. "D"

PLAN
N.T.S.

NG = NATURAL GROUND

PUMP WELL CAP
(REMOVABLE)

WELL HEAD

PVC WELL CASING

STEEL RISER
ELEV. "F"

WELL HEAD
ELEV. "A"

CONCRETE
BASE

FIGURE 3.

ELEVATION

N.T.S.

SFR-25

PROJECT NO. SFR Well Project

Appendix C: Well Development Information

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 11.5 gallons

Date: 11/30/92

Page 1 of 1

Well Name: SFR-1S

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static} : 90.33

Ambient Air Temp. (°C): 6.6

Initial EC (Distilled Water): 5.50/5.71

Instruments Calibrated? pH y (7.00) EC

Total Gallons Bailed (Pumped): 5.5 gallons

[illegible]

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 11.5 gallons

Date: 12/1/92

Page 1 of 2

Well Name: SFR-1S

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static}: Bailer left in well - no static today

Ambient Air Temp. (°C): 14.3

Initial EC (Distilled Water): 0.876

Instruments Calibrated? pH y (10.00) EC

Total Gallons Bailed (Pumped):

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Deep Well	Gallons Bailed	Comments
1040	7.80	1.084	17.4		0.5	
1043	7.12	1.078	18.1		0.5	
1045	7.03	1.074	17.2	139.48	0.5	
1047	6.97	1.080	16.7		0.5	
1050	6.96	1.076	16.8		0.5	
1052	6.95	1.066	16.1		0.5	
1054	6.93	1.072	17.0		0.5	
1056	6.97	1.068	17.1		0.5	
1057	6.95	1.069	17.0		0.5	
1100	6.97	1.068	17.0		0.5	
1102	6.96	1.068	17.0		0.5	
1104	6.96	1.066	16.9		0.5	
1106	6.95	1.068	17.1		0.5	
1107	6.96	1.070	17.1		0.5	
1110	6.95	1.073	16.9		0.5	
1112	6.98	1.070	16.7	139.48	0.5	

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 11.5 gallons

Date: 12/1/92

Page 2 of 2

Well Name: SFR-1S

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static} : _____

Ambient Air Temp. (°C): 11.9

Initial EC (Distilled Water): _____

Instruments Calibrated? pH _____ EC _____

Total Gallons Bailed (Pumped): 16.0 gallons

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Deep Well	Gallons Bailed	Comments
1116	6.98	1.053	16.8		0.5	
1118	6.962	1.062	16.6		0.5	
1120	6.97	1.064	17.0		0.5	
1122	7.01	1.064	17.4		0.5	
1124	6.97	1.066	17.3		0.5	
1127	6.96	1.065	16.4		0.5	
1128	6.97	1.061	16.4		0.5	
1130	6.98	1.062	16.1		0.5	
1133	6.95	1.063	16.8	139.47	0.5	
1135	6.99	1.061	16.3		0.5	
1138	6.96	1.064	16.7		0.5	
1139	6.97	1.063	16.9		0.5	
1141	6.97	1.068	16.6	139.47	0.5	
1144	7.01	1.066	16.5		0.5	
1146	6.99	1.065	16.8		0.5	
1147	7.00	1.053	16.0		0.5	

WATER LEVEL RECOVERY WORKSHEET

Date: 12/1/92

Page 1 of 2

Well Name: SFR-1S

Well Diameter 2-inch

Type of Development: Bailing

Initial Depth to Water (ft. bgs), D_{static} : _____

Time Development Initiated: 1040 Time Development Terminated: 1147

Total Volume of Water Removed (gallons): 16

Note: $D_{initial}$ = Water level at the start of recovery; D_{time} = Water level during recovery; ΔD = Amt. Recovered.
 Note: The bailer was stuck in the borehole so the static water level could not be taken.

Time	Elapsed Time (min)	$D_{initial}$, (ft. bgs)	D_{time} , (ft. bgs)	ΔD , $D_t - D_i$
1147		93.05		
	0:33		92.70	
	1:51		92.45	
	3:41		92.39	
	4:58		92.38	
	6:24		92.35	
	7:32		92.34	
	8:57		92.32	
	10:29		92.29	
	12:07		92.27	
	13:51		92.24	
	15:31		92.22	
	16:42		92.21	
	17:52		92.19	
	20:04		92.17	
	22:48		92.14	
	25:14		92.12	

Recovery Worksheet (continued)

Page 2 of 2

Time	Elapsed Time (min)	D_{initial} , (bgs)	D_{time} , (bgs)	ΔD , $D_t - D_i$
	29:14		92.08	
	32:14		92.05	
	37:12		92.02	
	41:14		91.98	
	45:13		91.95	
	50:10		91.93	
	55:16		91.89	
	60:54		91.87	
	71:03		91.82	
	80:25		91.78	
	91:30		91.74	
	99:33		91.73	
	109:30		91.70	
	120:13		91.68	
	135:42		91.66	
	150:13		91.64	

Note: D_{initial} = Water level at the start of recovery; D_{time} = Water level during recovery; ΔD = Amt. Recovered.

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 117 gallons

Date: 3/30/93

Page 1 of 1

Well Name: SFR-1D

Well Diameter: 4 inch

Type of Development: Bailed/Pumped

Initial Depth to Water (ft. bgl), D_{static}: 139.25'

Ambient Air Temp. (°C): 16.4

Initial EC (Distilled Water):

Instruments Calibrated? pH 7.00 EC N Hach 3/29/93

Total Gallons Bailed (Pumped): 294

Pumping Rate (gpm): 8

Time	pH	EC (mmho)	Temp.	Turbidity (NTUs)	Gallons Bailed or Pumping Rate	Comments
1120				488	Bailed 5 gals.	Not much sand visible so we'll put pump in place
1123				> 2000	" "	
1455					8 gpm	Started pump; pump set @ 293.5' bgl
1510	6.15	0.251	19.7	212		
1516	6.52	0.275	19.8	443		Pumped dry; 168 gals.
1600						Started pump; pump set @ 356.5' bgl
1615	6.79	0.318	20.0	940	6 gpm	
1621						Pumped dry; 126 gals.

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 117 gallons

Date: 3/31/93

Page 1 of 2

Well Name: SFR-1D

Well Diameter: 4 inch

Type of Development: Pumped

Initial Depth to Water (ft. bgl), D_{static} : _____

Ambient Air Temp. (°C): 9.1

Initial EC (Distilled Water): _____

Instruments Calibrated? pH 7.00 EC N Hach 3/29/93

Total Gallons Bailed (Pumped): 2131

Pumping Rate (gpm): _____

Time	pH	EC (mmho)	Temp.	Turbidity (NTUs)	Gallons Bailed or Pumping Rate	Comments
0748					8.8 gpm	Started pump
0810	6.53	0.186	19.8	130		
0821	6.64	0.185	20.0	105		
0835	6.74	0.191	20.2	116		414 gals. so far
0842						Decrease in flow rate to ~ 1 gpm
0852						Stopped pump
1009					~ 5 gpm	Pump on
1015	6.77	0.211	19.5	184		Depth to water (DTW) ~ 143.7' bgl
1036	6.76	0.217	20.2	82.6		DTW ~ 159.35' bgl
1056	6.75	0.221	20.3	31.4		DTW ~ 220.2' bgl
1115	6.76	0.224	20.5	17.8		DTW ~ 321.3' bgl
1127						Pump off; 390 gals.
1302					7 gpm	Pump on
1311	6.78	0.228	19.8	90.2		
1330	6.76	0.214	20.3	26.0		
1345	6.80	0.222	20.3	17.0		

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 117 gallons

Date: 3/31/93

Page 2 of 2

Well Name: SFR-1D

Well Diameter: 4 inch

Type of Development: Pumped

[illegible]

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 117 gallons

Date: 4/1/93

Page 1 of 2

Well Name: SFR-1D

Well Diameter: 4 inch

Type of Development: Pumping

Initial Depth to Water (ft. bgl), D_{static} : _____

Ambient Air Temp. (°C): 7.1

Initial EC (Distilled Water): _____

Instruments Calibrated? pH 7.00 EC N Hach 3/29/93

Total Gallons Bailed (Pumped): 2788

Pumping Rate (gpm): _____

Time	pH	EC (mmho)	Temp.	Turbidity (NTUs)	Gallons Bailed or Pumping Rate	Comments
0731					8.5 gpm	Started pump
0744	6.86	0.183	19.6	59.0		
0806	6.72	0.186	20.1	19.3		
0820	6.75	0.183	20.2	14.0		
0832	6.74	0.185	20.2	10.1		
0849	6.73	0.200	20.3	10.4		
0854				9.05		Turbidity measurement from discharge pipe, not YSI meter
0904	6.74	0.210	20.4	8.08		
0906				7.71		Pipe discharge
0921	6.72	0.213	20.4	6.77		
0925				7.75		Pipe discharge
0936	6.73	0.218	20.4	9.41/8.37		YSI/Pipe discharge
0940				10.5		Pipe discharge
1000	6.73	0.230	20.4	12.8		
1010	6.73	0.227	20.4	13.2		
1013				13.2		Pipe discharge

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 117 gallons

Date: 4/1/93

Page 2 of 2

Well Name: SFR-1D

Well Diameter: 4 inch

Type of Development: Pumping

[illegible]

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 117 gallons

Date: 4/2/93Page 2 of 2

Well Name: SFR-1D

Well Diameter: 4 inch

Type of Development: Pumping

[illegible]

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 117 gallons

Date: 4/2/93

Page 1 of 2

Well Name: SFR-1D

Well Diameter: 4 inch

Type of Development: Pumping

Initial Depth to Water (ft. bgl), D_{static}: _____

Ambient Air Temp. (°C): 11.2

Initial EC (Distilled Water): 0.211

Instruments Calibrated? pH 7.00 EC N Hach 3/29/93

Total Gallons Bailed (Pumped): 2556 Pumping Rate (gpm): _____

Time	pH	EC (mmho)	Temp.	Turbidity (NTUs)	Gallons Bailed or Pumping Rate	Comments
0738					8.5 gpm	Started pump
0745	6.97	0.184	19.2	27.5		
0757	6.73	0.195	19.9	9.69		
0825	6.69	0.204	20.2	4.85		
0840	6.69	0.211	20.3	4.08		
0845				3.76		Pipe discharge
0855	6.69	0.200	20.4	56.2		
0905	6.70	0.210	20.4	13.8		
0920	6.69	0.209	20.5	118		Pipe discharge
0936	6.69	0.211	20.5	13.7		
0953	6.68	0.213	20.5	13.0		
1010	6.68	0.215	20.6	16.5		
1027	6.69	0.223	20.7	15.6		
1044	6.71	0.225	20.7	16.7		
1101	6.72	0.221	20.8	22.3		Pipe discharge
1103				20.8		YSI
1106						Pump off; 1768 gals.

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 10 gallons

Date: 4/3/93

Page 1 of 2

Well Name: SFR-2S

Well Diameter: 4 inch

Type of Development: Pumping

Initial Depth to Water (ft. bgl), D_{static} : 102.65'

Ambient Air Temp. (°C): 14.2

Initial EC (Distilled Water): 0.331

Instruments Calibrated? pH 7.00 EC N Hach 3/29/93

Total Gallons Bailed (Pumped): 284

Pumping Rate (gpm):

Time	pH	EC (mmho)	Temp.	Turbidity (NTUs)	Gallons Bailed or Pumping Rate	Comments
1019					7 gpm	Started pump
1020	7.28	1.146	17.9			Flow rate decreased to ~ 1.25 gpm
1029	7.01	1.208	18.1	> 1000		
1041	6.96	1.264	19.6	196		
1109	6.89	1.294	21.1	9.53		Pump off; problems w/fuel pump on generator; 61.25 gals.
1252					~ 1.25 gpm	Pump on
1255	7.00	1.231	19.2	43.8		
1310	6.93	1.252	20.3	6.70		
1320	6.95	1.261	21.2	5.90		
1331	6.95	1.267	21.6	3.88		
1340	6.94	1.266	21.4	3.82		
1350	6.92	1.269	21.5	3.41		10 Well Bore Volumes Discharged
1400	6.92	1.275	21.7	2.46		
1410	6.91	1.287	21.7	2.90		
1420	6.92	1.280	21.1	1.21		

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 10 gallons

Date: 4/3/93Page 2 of 2

Well Name: SFR-2S

Well Diameter: 4 inch

Type of Development: Pumping

[illegible]

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 25 gallons

Date: 11/18/92

Page 1 of 5

Well Name: SFR-3D

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static} : 163.39

Ambient Air Temp. (°C): 7.9

Initial EC (Distilled Water): 0.657

Instruments Calibrated? pH yes EC no

Total Gallons Bailed (Pumped):

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Shallow Well	Gallons Bailed	Comments
0835	6.70	0.472	16.7		1	Clear Water
0840	6.85	0.485	17.1		1	" "
0843	6.89	0.490	17.5	163.74	1	" "
0845	6.93	0.489	17.5		1	" "
0847	6.94	0.491	17.3		1	" "
0851	6.93	0.489	17.0		1	" "
0857	6.96	0.489	17.3		1	" "
0900	6.92	0.490	17.4	163.70	1	" "
0902	6.93	0.494	17.4		1	Cloudy Water
0905	6.88	0.484	17.0		1	" "
0915	6.88	0.487	17.6		1	" "
0918	6.89	0.493	17.9	163.65	1	
0920	6.77	0.513	17.8		1	
0926	6.87	0.499	17.5		1	Noticeable drop in H ₂ O level per developer
0928	6.69	0.540	17.6		1	Cloudy Water
0931	6.71	0.544	18.0		1	" "

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 25 gallons

Date: 11/18/92

Page 2 of 5

Well Name: SFR-3D

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static} : _____

Ambient Air Temp. (°C): 12.4

Initial EC (Distilled Water): _____

Instruments Calibrated? pH _____ EC _____

Total Gallons Bailed (Pumped): _____

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Shallow Well	Gallons Bailed	Comments
0933	6.56	0.623	17.5	Shallow well	1	Very Turbid Water
0937	6.45	0.678	18.2	163.65	1	" "
0940	6.42	0.706	17.8		1	" "
0944	6.34	0.836	17.9		1	" "
0947	6.29	0.918	17.6		1	" "
0950	6.29	0.918	17.8		1	" "
0955	6.36	0.820	17.9		1	" "
0958	6.32	0.911	17.4	163.63	1	" "
1000					1	" "
1004	6.31	1.066	17.7		1	" "
1006	6.26	1.041	17.6	163.63	1	" "
1012	6.32	0.993	18.3		1	Roger says deep well is holding its own now after falling approx. 10 ft.
1015	6.29	1.016	17.8		1	
1017	6.25	1.079	17.9		1	
1021	6.28	1.040	17.4		1	
1027	6.27	0.950	17.6	163.60	1	

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 25 gallons

Date: 11/18/92

Page 3 of 5

Well Name: SFR-3D

Well Diameter: 2 inch

Type of Development: Bailing

Initial Depth to Water (ft. bgl), D_{static} : _____

Ambient Air Temp. ($^{\circ}C$): 10.9

Initial EC (Distilled Water): _____

Instruments Calibrated? pH _____ EC _____

Total Gallons Bailed (Pumped): _____

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Shallow Well	Gallons Bailed	Comments
1030	6.23	1.032	19.7	Shallow Water	1	Very Turbid Water
1034	6.24	1.029	17.8		1	"
1042	6.28	1.057	18.5	163.57	1	"
1046	6.24	0.987	18.2		1	"
1050	6.29	0.898	18.1		1	"
1054	6.23	1.044	18.1		1	"
1059	6.26	1.015	18.4		1	"
1102	6.23	1.026	19.3		1	"
1105	6.21	1.041	18.3		1	"
1111	6.19	1.036	18.7	163.57	1	"
1115	6.20	1.036	19.3		1	"
1119	6.20	1.043	19.0		1	"
1123	6.20	1.080	19.3		1	"
1129	6.16	1.141	19.4		1	"
1134	6.19	1.102	19.4		1	"
1140	6.17	1.150	19.8		1	"
1145	6.21	1.066	20.5	163.57 Shallow Well	1	"
1150	6.20	1.097	18.0		1	"

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 25 gallons

Date: 11/18/92

Page 4 of 5

Well Name: SFR-3D

Well Diameter: 2 inch

Type of Development: Bailing

Initial Depth to Water (ft. bgl), D_{static} : _____

Ambient Air Temp. (°C): 13.6/18.6(after lunch)

Initial EC (Distilled Water): _____

Instruments Calibrated? pH _____ EC _____

Total Gallons Bailed (Pumped): _____

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Shallow Well	Gallons Bailed	Comments
1156	6.20	1.063	18.1	164.34 (Deep well)	1	Very Turbid Water
1158	6.40	0.857	17.8		1	"
1311	6.31	1.190	18.9	163.61	1	"
1315	6.17	1.130	18.6		1	"
1317	6.15	1.114	18.8		1	"
1323	6.14	1.134	18.9		1	"
1327	6.20	1.099	18.8		1	"
1330	6.19	1.127	18.3	163.58	1	"
1333	6.25	0.997	18.4		1	"
1335	6.22	1.000	18.4		1	"
1341	6.15	1.101	18.3		1	"
1345	6.12	1.183	18.8		1	"
1350	6.17	1.161	18.6	Shallow Water	1	"
1356	6.13	1.177	18.3	163.58	1	"
1401	6.14	1.167	18.3		1	"
1404	6.16	1.144	18.5		1	"
1410	6.18	1.124	18.1		1	"

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 25 gallons

Date: 11/18/92

Page 5 of 5

Well Name: SFR-3D

Well Diameter: 2 inch

Type of Development: BailedInitial Depth to Water (ft. bgl), D_{static} : _____Ambient Air Temp. (°C): 11.9

Initial EC (Distilled Water):_____

Instruments Calibrated? pH _____ EC _____

Total Gallons Bailed (Pumped): 77

[illegible]

WATER LEVEL RECOVERY WORKSHEET

Date: 11/18/92

Page 1 of 1

Well Name: SFR-3D

Well Diameter 2-inch

Type of Development: Bailing

Initial Depth to Water (ft. bgs), D_{static} : 163.69

Time Development Initiated: 1311 Time Development Terminated: 1450

Total Volume of Water Removed (gallons): 25

Note: $D_{initial}$ = Water level at the start of recovery; D_{time} = Water level during recovery; ΔD = Amt. Recovered.

Note: The first reading was taken approximately 3-5 min. after bailing stopped.

Time	Elapsed Time	$D_{initial}$, (ft. bgs)	D_{time} , (ft. bgs)	ΔD , $D_t - D_i$
1455		164.22		
	1 min		164.21	
	2 min		164.21	
	3 min		164.20	
	4 min		164.20	
	5 min		164.20	
	10 min		164.20	
	15 min		164.19	
	20 min		164.19	
	30 min		164.18	
	42 min		164.17	
	50 min		164.16	
	60 min		164.16	
	75 min		164.14	
	90 min		164.13	

WATER LEVEL RECOVERY WORKSHEET

Date: 11/18/92

Page 1 of 1

Well Name: SFR-3D

Well Diameter 2-inch

Type of Development: Bailing

Initial Depth to Water (ft. bgs), D_{static} : 163.69

Time Development Initiated: 0835 Time Development Terminated: 1158

Total Volume of Water Removed (gallons): 52

Note: $D_{initial}$ = Water level at the start of recovery; D_{time} = Water level during recovery; ΔD = Amt. Recovered.

Time	Elapsed Time	$D_{initial}$, (ft. bgs)	D_{time} , (ft. bgs)	ΔD , $D_t - D_i$
11:58		164.34		
12:00	2 min		164.35	--
	3 min		164.35	
	4 min		164.35	
	5 min		164.35	
	10 min		164.32	
	15 min		164.32	
	20 min		164.30	
	25 min		164.29	
	30 min		164.28	
	40 min		164.26	
	50 min		164.24	
	60 min		164.23	

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 8 gallons

Date: 11/19/92

Page 1 of 3

Well Name: SFR-3S

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static} : 163.58

Ambient Air Temp. ($^{\circ}C$): 7.5

Initial EC (Distilled Water): 0.590

Instruments Calibrated? pH Y EC N

Total Gallons Bailed (Pumped):

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Deep Well	Gallons Bailed	Comments
1028	6.38	1.635	18.9		0.5	Sludge
1029	6.71	1.320	20.3	163.79	0.5	
1031	6.91	1.240	19.1		0.5	
1034	6.94	1.202	18.5		0.5	
1036	7.00	1.194	20.1		0.5	
1039	7.02	1.172	18.7	163.79	0.5	
1041	7.03	1.156	18.2		0.5	
1045	7.06	1.093	18.4		0.5	
1046	7.08	1.099	18.9		0.5	
1050	7.07	1.108	18.2		0.5	
1052	7.15	1.056	18.5		0.5	
1054	7.11	1.094	19.9	163.79	0.5	
1056	7.17	1.047	19.5		0.5	
1100	7.17	1.043	18.7		0.5	
1102	7.18	1.029	18.5		0.5	
1104	7.18	1.035	18.5		0.5	
1107	7.13	1.085	18.7	163.77	0.5	
1110	7.12	1.036	18.4		0.5	

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 8 gallons

Date: 11/19/92

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Well Name: SFR-3S

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static} : 163.58

Ambient Air Temp. ($^{\circ}C$): 13.7

Initial EC (Distilled Water):

Instruments Calibrated? pH EC

Total Gallons Bailed (Pumped):

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Deep Well	Gallons Bailed	Comments
1112	7.18	1.007	18.5		0.5	
1114	7.25	1.029	18.1		0.5	
1117	7.15	1.045	19.0		0.5	
1121	7.16	1.041	18.7	163.76	0.5	
1124	7.22	0.989	18.9		0.5	
1126	7.23	0.977	19.0		0.5	
1129	7.22	0.970	19.2	163.76	0.5	
1132	7.24	0.962	19.0		0.5	
1135	7.25	0.952	17.7		0.5	
1137	7.24	0.955	18.3		0.5	
1140	7.24	0.950	18.0	163.76	0.5	
1142	7.28	0.944	19.2		0.5	
1145	7.25	0.939	22.8		0.5	
1147	7.27	0.938	18.1		0.5	
1305	7.42	0.949	19.2	163.75	0.5	
1308	7.34	0.927	18.6		0.5	
1310	7.30	0.908	20.4		0.5	
1315	7.32	0.886	17.7	163.73	0.5	

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 8 gallons

Date: 11/19/92

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Well Name: SFR-3S

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static} : 163.58

Ambient Air Temp. (°C): 17.6

Initial EC (Distilled Water):_____

Instruments Calibrated? pH _____ EC _____

Total Gallons Bailed (Pumped): 21.0

[illegible]

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 8 gallons

Date: 11/29/92

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Well Name: SFR-3S

Well Diameter: 2 inch

Type of Development:

Initial Depth to Water (ft. bgl), D_{static} : 163.20

Ambient Air Temp. (°C): -1.1

Initial EC (Distilled Water): 0.702

Instruments Calibrated? pH Y EC N

Total Gallons Bailed (Pumped):

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Deep Well	Gallons Bailed	Comments
0829	7.11	0.772	9.1		0.5	Very Muddy
0834	7.21	0.847	13.9	163.78	0.5	
0839	7.26	0.844	13.1		0.5	
0844	7.24	0.832	13.3		0.5	
0848	7.24	0.843	14.3		0.5	
0852	7.27	0.853	14.6	163.77	0.5	
0854	7.25	0.866	16.0		0.5	
0855	7.26	0.863	15.5		0.5	
0858	7.28	0.863	15.3		0.5	
0901	7.30	0.879	14.5		0.5	
0906	7.37	0.903	15.3		0.5	
0909	7.30	0.861	16.5		0.5	
0913	7.45	0.937	15.9	163.77	0.5	
0917	7.44	0.920	15.5		0.5	
0920	7.33	0.856	15.9		0.5	
0923	7.31	0.852	16.4		0.5	
0929	7.32	0.842	16.4		0.5	
0932	7.31	0.838	16.1	163.78	0.5	

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 8 gallons

Date: 11/29/92

Page 2 of 4

Well Name: SFR-3S

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static} : 163.20

Ambient Air Temp. (°C): 2.1

Initial EC (Distilled Water):

Instruments Calibrated? pH EC

Total Gallons Bailed (Pumped):

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Deep Well	Gallons Bailed	Comments
0934	7.32	0.844	16.0		0.5	
0937	7.34	0.843	16.1		0.5	
0939	7.37	0.845	16.0		0.5	
0941	7.35	0.843	16.1		0.5	
0943	7.33	0.841	16.3		0.5	
0945	7.35	0.841	16.4		0.5	
0948	7.34	0.842	17.0	163.78	0.5	
0950	7.34	0.843	16.6		0.5	
0952	7.33	0.837	16.9		0.5	
0955	7.33	0.833	16.3		0.5	Swabbed 15 min
1105	7.28	0.826	16.9	163.80	0.5	Silty
1112	7.28	0.827	16.7		0.5	
1114	7.28	0.827	16.4		0.5	
1116	7.30	0.836	17.2		0.5	
1120	7.30	0.815	15.7		0.5	
1123	7.28	0.797	16.5		0.5	
26	7.29	0.821	16.1		0.5	
1129	7.31	0.826	16.5	163.80	0.5	

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 8 gallons

Date: 11/29/92

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Well Name: SFR-3S

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static} : 163.20

Ambient Air Temp. ($^{\circ}C$): 3.1/5.5 (after lunch)

Initial EC (Distilled Water):

Instruments Calibrated? pH EC

Total Gallons Bailed (Pumped):

Time	pH	EC (mmho)	Temp.	Depth to Water (ft) Deep Well	Gallons Bailed	Comments
1321	7.24	0.784	14.9		0.5	
1324	7.28	0.826	16.0		0.5	
1327	7.28	0.830	15.4		0.5	
1329	7.28	0.831	16.2		0.5	
1333	7.28	0.826	15.1	163.82	0.5	
1336	7.28	0.826	15.9		0.5	
1338	7.30	0.827	15.2		0.5	
1340	7.28	0.826	15.6		0.5	
1343	7.28	0.826	15.5		0.5	
1345	7.28	0.830	16.1		0.5	
1349	7.27	0.827	14.5		0.5	
1350	7.31	0.833	14.9		0.5	
1353	7.29	0.828	15.1	163.82	0.5	
1355	7.32	0.821	15.9		0.5	
1358	7.30	0.821	15.5		0.5	
1400	7.30	0.826	15.9		0.5	
1402	7.32	0.830	16.2		0.5	
1405	7.31	0.820	14.7		0.5	

WELL DEVELOPMENT WORKSHEET - SWHC PROJECT

Well Bore Volume: 8 gallons

Date: 11/29/92

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Well Name: SFR-3S

Well Diameter: 2 inch

Type of Development: Bailed

Initial Depth to Water (ft. bgl), D_{static} : 163.20

Ambient Air Temp. (°C): 2.3

Initial EC (Distilled Water):_____

Instruments Calibrated? pH _____ EC _____

Total Gallons Bailed (Pumped): 31.0

[illegible]

WATER LEVEL RECOVERY WORKSHEET

Date: 11/19/92

Page 1 of 1

Well Name: SFR-3S

Well Diameter 2-inch

Type of Development: Bailing

Initial Depth to Water (ft. bgs), D_{static} : 163.58

Time Development Initiated: 1305 Time Development Terminated: 1334

Total Volume of Water Removed (gallons): 10

Note: $D_{initial}$ = Water level at the start of recovery; D_{time} = Water level during recovery; ΔD = Amt. Recovered.
 Note: Approx. 45 minutes elapsed before recovery data could be taken due to rig malfunctions.

Time	Elapsed Time (min)	$D_{initial}$, (ft. bgs)	D_{time} , (ft. bgs)	ΔD , $D_t - D_i$
1418		164.08		
	12:50		164.03	
	18:12		164.00	
	23:30		163.98	
	32:11		163.96	
	44:54		163.92	
	52:30		163.90	
	67:04		163.87	
	78:07		163.85	
	92:25		163.83	
	104:30		163.81	
	116:58		163.78	

WATER LEVEL RECOVERY WORKSHEET

Date: 11/19/92

Page 1 of 2

Well Name: SFR-3S

Well Diameter 2-inch

Type of Development: Bailing

Initial Depth to Water (ft. bgs), D_{static} : 163.58

Time Development Initiated: 1028 Time Development Terminated: 1146

Total Volume of Water Removed (gallons): 16

Note: $D_{initial}$ = Water level at the start of recovery; D_{time} = Water level during recovery; ΔD = Amt. Recovered.

Time	Elapsed Time (min)	$D_{initial}$, (ft. bgs)	D_{time} , (ft. bgs)	ΔD , $D_t - D_i$
1151	4:20	165.12		
	5:25		165.09	
	6:26		165.03	
	7:22		164.99	
	8:13		164.97	
	9:27		164.94	
	10:38		164.88	
	11:40		164.86	
	12:40		164.84	
	13:56		164.80	
	15:56		164.76	
	17:10		164.73	
	18:36		164.71	
	20:14		164.68	
	23:31		164.64	
	25:51		164.59	
	27:29		164.57	

Recovery Worksheet (continued)

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Note: D_{initial} =Water level at the start of recovery; D_{time} =Water level during recovery; ΔD = Amt. Recovered.

Appendix D: Lithologic Logs

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG

South Fence Road - 1 Deep (SFR-1D)

Ground Elevation: 5394 feet Drilling Method/Fluids: Sonic/Dry
Logged by: U.S. Geological Survey (Abeyta, Szalona, Dam, Thorn)
Drilling began: 27MAY92 Drilling completed: 26JUL92 Total depth: 510 feet
Color Chart: Goddard, E.N., and others, 1984, Rock color chart: Geological Society of America, Boulder, Colo.

0'-2.5' (1.8' recovered) Upper 0.7' - Silty sand with pebbles and caliche; sand - very fine to medium grained, sand - subangular to subrounded, gravel - subangular to subrounded, poorly sorted, pebbles < 5% and $\leq$ 38 mm, minor caliche; sand - arkose, gravel - limestone; Moderate Yellowish Brown 10YR5/4; loosely compacted, reacts with HCl; wet; gradational basal contact. Middle 0.5' - Silty sand; sand - very fine to fine grained, well sorted; sand - arkose; Moderate Brown 5YR4/4; numerous root casts with roots in place; slightly compacted; moist; abrupt basal contact. Lower 0.6' - Silty sand with clay and caliche; sand - very fine to fine grained, minor clay and caliche; sand - arkose; Moderate Brown 5YR4/4; minor roots casts; dry.

2.5'-3.2' (1.6' recovered) Upper 0.8' - Clayey silty sand; sand - very fine to fine grained, well sorted; sand - arkose; Moderate Brown 5YR4/4; numerous roots; loose, unconsolidated, very minor reaction with HCl; very slightly moist; abrupt basal contact. Middle 0.6' - Silty sand with clay and caliche; sand - very fine to fine grained; Light Brown 5YR5/6 with bands of Very Pale Orange 10YR8/2; minor 0.1' laminations; strongly compacted, reacts with HCl; dry; abrupt basal contact. Lower 0.2' - Silty sand with pebbles and caliche nodules; sand - very fine to fine grained, minor pebbles < 1% and $\leq$ 4 mm, poorly sorted, subangular; pebbles - limestone and feldspar; Moderate Yellowish Brown 10YR5/4; nodules and pebbles in loose matrix, reacts with HCl; dry.

3.2'-5.2' (2.4' recovered) Silty sand with caliche; sand - very fine to fine grained; upper 0.2' - Pale Yellowish Brown 10YR6/2, grades to Light Brown 5YR6/4 and to Very Pale Orange 10YR8/2 towards bottom due to increase in caliche content; caliche occurs in matrix and as nodules, nodules in loose matrix, reaction with HCl increases towards bottom; very slightly moist.

5.2'-8.6' (2.7' recovered) Upper 1.3' - Silty sand with caliche; sand - very fine to fine grained; Very Pale Orange 10YR8/2; caliche abundant in matrix and as nodules $\leq$ 30 mm, nodules in loose matrix, reacts with HCl; very slightly moist; abrupt basal contact. Middle 0.5' - Pebbly silty sand; sand - very fine to very coarse grained, pebbles $\leq$ 15% and $\leq$ 60 mm, subrounded to subangular, very poorly sorted; sand - arkose, pebbles - limestone and granite; Moderate Orange Pink 5YR8/4; loose, reacts with HCl; very slightly moist; gradational basal contact. Lower 0.9' - Silty sand; sand - very fine to fine grained with minor, < 1%, very coarse sand, well sorted with minor caliche; Light Brown 5YR6/4; loose with minor compacting as nodules, reacts with HCl; dry.

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

8.6'-11.1' (3.1' recovered) Upper 0.8' - Pebbly silty sand; sand - very fine to very coarse grained, pebbles $\leq 15\%$ and ≤ 50 mm, subrounded to subangular, very poorly sorted; sand - arkose, pebbles - limestone and granite; Moderate Orange Pink 5YR8/4; loose, reacts with HCl; very slightly moist. Middle 1.1' - Silty sand with pebbles; sand - very fine to fine grained, pebbles $\leq 3\%$ and ≤ 7 mm, subrounded to subangular; Light Brown 5YR6/4; loose, reacts with HCl; very slightly moist; gradational basal contact. Lower 1.2' - Pebbly silty sand; sand - very fine to fine grained, pebbles approximately 15% and ≤ 30 mm, very poorly sorted; sand - arkose, pebbles - limestone; Light Brown 5YR6/4; very slightly moist.

11.1'-15.4' (4.3' plus recovered) Upper 1.6' - Pebbly silty sand; sand - very fine to fine grained, pebbles approximately 15% at top increasing to approximately 20% at lower end, ≤ 60 mm, subrounded, poorly sorted; pebbles - limestone and crystalline limestone; Light Brown 5YR6/4; dry; gradational basal contact. Lower 2.7' - Silty sand; sand - very fine to fine grained, well sorted; sand - arkose; Light Brown 5YR5/6; slightly compacted, reacts with HCl; very slightly moist.

15.4'-18.0' (2.7' plus recovered) Upper 1.4' - Silty sand; sand - very fine to fine grained, well sorted; sand - arkose; Light Brown 5YR5/6; slightly compacted, reacts with HCl; very slightly moist. Lower 1.3' - Pebbly sand with cobble; sand - fine to very coarse grained, pebbles ≤ 4 mm, cobble 2.5", subrounded to subangular, very poorly sorted; sand - arkose, pebbles - limestone, cobble - limestone; limestone cobble on top of section; reacts with HCl; very slightly moist.

18.0'-22.3' (4.0' recovered) Upper 2.2' - Sand with pebbles; sand - fine grained, poorly sorted, minor pebbles; sand - arkose with abundant quartz, pebbles - limestone and feldspar; Light Brown 5YR6/4; loose, reacts with HCl; slightly moist; abrupt basal contact. Lower 1.8' - Sand; medium to coarse grained, poorly sorted; Pinkish Gray 5YR8/1; loose, reacts with HCl; dry; gradational basal contact.

22.3'-24.4' (2.1' plus recovered) Sand with pebbles; sand - very fine to very coarse grained, poorly sorted; Pinkish Gray 5YR8/1; numerous color laminations, 0.6' from top of core - 0.05' thick band of silty clay, Grayish Yellow 5Y8/4; loose, strong reaction with HCl, gradational contact; in same layer a 25 mm pebble, rounded, Pale Yellowish Orange 10YR8/6 to Grayish Yellow 5Y8/4, no reaction with HCl, at 0.7' from top of core - a diffuse band of hard lithic fragments (probably pebble fractured by rig) possibly chert or metagranite or other silicious material, very hard, Medium Dark Gray N4, no reaction with HCl, gradational contact, at bottom 0.3' - variably colored weathered lithic fragments, Moderate Yellow 5YR7/6, Grayish Green 10GY5/2, and Moderate Red 5R5/4, probably volcanic ash and obsidian 5 mm, black, subrounded, sphericity 0.5, roundness 0.5, pitted slightly; loose, minor to no reaction with HCl; dry.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

24.4'-26.6' (2.2' plus recovered) Upper 1.2' - Sand with minor pebbles; sand - very fine to very coarse grained, poorly sorted; Moderate Orange Pink 5YR8/4; loose, reacts with HCl, reaction increases with depth; very dry; gradational basal contact. Lower 1.0' - Sand; very fine to fine grained with abundant coarse to very coarse grains and minor pebbles, poorly sorted; pebbles - quartz; Pinkish Gray 5YR8/1; cemented sand nodules in sand matrix, strong reaction with HCl; dry.

26.6'-29.0' (1.8' plus recovered) Sand with minor pebbles; sand - medium to very coarse grained, poorly sorted; slightly micaceous; Pinkish Gray 5YR8/1 to Yellowish Gray 5Y8/1; 20 mm clay nodule 0.6' from top of core - Light Olive Green 5Y5/2; loose, reacts with HCl; slightly moist.

29.0'-31.0' (1.7' plus recovered) Sand; medium to coarse grained, well sorted, very minor to no pebbles, subangular to subrounded; quartz, feldspar and minor mafic minerals; Pinkish Gray 5YR8/1; hard and compact, no to minor reaction with HCl; slightly moist.

31.0'-33.5' (3.8' recovered) Upper 0.5' - Sandy silt; sand - very fine to fine grained, minor medium to coarse grains, well sorted; Pale Yellowish Brown 10YR6/2; loose, powdery, minor reaction with HCl; dry; gradational basal contact. Lower 3.3' - Silty sand with caliche; sand - very fine to very coarse grained, very poorly sorted; arkosic/quartz sand; matrix - Pale Pink 5RP8/2; medium grained sand lenses about 0.25" thick, clay nodules 0.5" diameter; caliche cemented, reacts with HCl; dry.

33.5'-35.0' (2.65' recovered) Upper 1.6' - Silty sand grading to sandy silt; sand - very fine to fine grained with minor medium to very coarse sand in upper 0.6', well sorted; upper 0.4' - Pale Yellowish Brown 10YR6/2, middle upper 0.3' - Light Brownish Gray 5YR6/1, middle lower 0.4' - Pale Yellowish Brown 10YR6/2, lower 0.5' - Light Gray N7; minor reaction with HCl; dry; very clear gradational change to silt. Middle 0.5' - Silty sand; sand - very fine to fine grained, minor very coarse grains, fine pebbles and 1 pebble 45 mm, subangular to subrounded, very poorly sorted; Light Brown 5YR6/4; loose, clay nodules ≤ 8 mm; slightly moist; abrupt basal contact. Lower 0.55' - Clay with caliche cap; caliche cap - Pinkish Gray 5YR8/1, clay - Pale Yellowish Brown 10YR6/2; minor black organic filled root casts; tight and compacted, clay is shiny, mottled, slight reaction with HCl, caliche has strong reaction with HCl; slightly moist.

35.0'-36.7' (1.5' plus recovered) Upper 0.7' - Silty sandy clay; sand - very fine to fine grained; Light Brown 5YR6/4; tight and compacted, sand held tight in clay matrix, reacts with HCl; dry. Lower 0.8' - Clay; Moderate Yellowish Brown 10YR5/4; abundant organic veins; very tight and compacted, shiny, mottled, slight reaction with HCl; dry.

36.7'-39.0' (2.4' plus recovered) Upper 0.8' - Sandy silt (possible ash welded); sand - very fine to fine grained; Pinkish Gray 5YR8/1; friable in some areas with very hard and compacted lenses ≤ 1.5 " thick, moderate reaction with HCl; dry; gradational basal contact. Middle 0.6' - Sandy silt; sand - very fine to fine grained; Light Brown 5YR6/4; moderately compacted, friable, breaks into fine soft powder, no reaction with HCl; moist; abrupt basal contact. Lower 1.0' - Sand; medium grained, subrounded to subangular, very well sorted; arkose; loose, no reaction with HCl; moist.

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ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

39.0'-42.0' (4.0' recovered) Sand; medium grained, subangular to subrounded, very well sorted; arkose; loose to slightly compacted, no reaction with HCl; slightly moist.

42.0'-46.0' (5.6' recovered) Sand; medium grained, subangular to subrounded, very well sorted; arkose; loose to slightly compacted, no reaction with HCl; slightly moist.

46.0'-48.6' (2.7' plus recovered) Upper 0.6' - Sand; medium grained, subangular to subrounded, very well sorted; arkose; loose to slightly compacted, no reaction with HCl; slightly moist; abrupt basal contact. Upper middle 0.3' - Silty sand; sand - very fine to medium grained, subrounded, well sorted; Pale Yellowish Brown 10YR6/2; loose, slight reaction with HCl; dry; abrupt basal contact. Lower middle 0.7' - Silty sand with caliche; sand - medium to very coarse grained, with abundant sand nodules ≤ 1 " diameter, also in lenses ≤ 1 " thick; arkose; matrix - Pinkish Gray 5YR8/1; loose sand in caliche matrix, CaCO_3 cemented arkosic sand nodules and caliche lenses, strong reaction with HCl; dry; gradational basal contact. Lower 1.1' - Sand with caliche and nodules (significantly less caliche than previous section); sand - medium to very coarse grained, subangular to subrounded, well sorted, nodules - 1" diameter and 80 mm x 60 mm x 15 mm (flat); arkosic sand with caliche cemented sand nodules; sand is loose with nodules intermixed, CaCO_3 content increases towards bottom of section, nodules are very hard, sand has mild reaction with HCl, nodules have strong reaction with HCl; dry.

48.6'-50.7' (3.5' recovered) Sand; fine to medium grained, subangular, well sorted; arkose; loose with abundant caliche cemented sand nodules ≤ 30 mm in lower 0.8', 100 mm sand nodule with minor clay at 1.2' from top of recovery, sand has no reaction with HCl, nodules react with HCl; slightly moist.

50.7'-52.8' (2.3' plus recovered) Sand; fine to medium grained, subangular, well sorted, rounded caliche cemented nodules ≤ 30 mm in lower 0.8'; arkose, quartz; loose, sand has no reaction with HCl, sand nodules react with HCl; slightly moist, moisture increases towards lower end.

52.8'-55.0' (2.4' recovered) Sand; fine to medium grained, subangular, well sorted with very minor rounded caliche cemented nodules ≤ 15 mm; arkose, quartz; loose, sand does not react with HCl, nodules react with HCl; slightly moist.

55.0'-56.0' (1.1' plus recovered) Sand; fine to medium grained, subrounded to subangular, well sorted; arkose, quartz; loose, no reaction with HCl; slightly moist.

56.0'-61.6' (5' plus recovered) Upper 0.6' - Clayey sand; sand - fine to medium grained, subangular to subrounded, poorly sorted; sand - arkose, quartz; clay - Moderate Brown 5YR3/4; friable, nodular, no reaction with HCl; slightly moist; abrupt basal contact. Middle 4.1' - Sand; fine to medium grained with minor coarse to very coarse grains, subangular to subrounded,

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ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

56.0'-61.6' continued -- well sorted; arkose, quartz; greenish tinge to sand from 0.6' to 2.1' within section; loose, no reaction with HCl; moist; gradational basal contact. Lower 0.9' - Clayey sand; sand - fine to very coarse grained, subangular to subrounded, very poorly sorted; arkose, quartz; clay - Dark Yellowish Brown 10YR4/2; one good clay lens about 4 mm thick near bottom of section; compacted, no reaction with HCl; moist.

61.6'-76.6' (13' recovered) Upper 0.9' - Clayey sand; sand - fine to medium grained, subangular to subrounded, poorly sorted; sand - arkose, quartz; clay - Dark Yellowish Brown 10YR4/2; compacted, friable, no reaction with HCl; moist; gradational basal contact. Middle 8.4' - Silty sand with minor clay; sand - very fine to very coarse grained, subangular to subrounded, very poorly sorted; sand - arkose, quartz; clay - Dark Yellowish Brown 10YR4/2; compacted, friable, no reaction with HCl in upper 6.2' of section, middle 0.8' has visible CaCO_3 veins and strong reaction with HCl, lower 1.4' has no reaction with HCl; slightly moist; gradational basal contact. Lower 3.7' - Clayey sand; sand - fine to medium grained, subangular, very poorly sorted; sand - arkose; clay - Dark Yellowish Brown 10YR4/2; clay content increases significantly in lower 2' and sand size increases to medium to very coarse with pebbles ≤ 6 mm; no reaction with HCl; very moist.

76.6'-87.1' (15.4' recovered, retrieved 2' from previous run) Upper 13.2' - Clayey sand; sand - fine to medium grained, subangular to subrounded, very poorly sorted; sand - arkose, quartz; clay - Grayish Brown 5YR3/2; very compacted, some due to moisture, no reaction with HCl; upper 0.7' - very moist, upper middle 0.9' - wet, lower middle 5.6' - very moist, lower 6.0' - moist to very moist; gradational basal contact. Lower 2.2' - Sandy clay; sand - very fine to medium grained, subangular, very poorly sorted; sand - arkose, quartz; clay - Moderate Brown 5YR4/4; tight and compacted, some sand veins cemented with CaCO_3 , reacts with HCl; moist. *NOTE: 75.3' to 76.2' (approximate) saturated zone - probable perched water.*

87.1'-107.1' (20' plus recovered) Sandy clay; sand - very fine to medium grained, fairly well sorted; Moderate Brown 5YR4/4; sand grain size becomes more fine towards bottom of interval with little or no medium sand; tight and compacted, caliche more abundant towards bottom in matrix and as nodules; moist.

107.0'-116.0' (8.9' plus recovered, 6' slough) Sandy clay with caliche and pebbles; sand - very fine to fine grained, pebbles $< 1\%$ and ≤ 15 mm, sand - subrounded, pebbles - rounded, fairly well sorted; sand - arkose, pebbles - limestone; Moderate Brown 5YR4/4; pebbles scattered towards bottom of interval; very tight and compacted, caliche more abundant towards bottom, reacts with HCl; slightly moist.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

116.0'-125.0' (14.5' recovered) Sandy clay with caliche; sand - very fine to fine grained, sand nodules < 1% and $\leq$ 25 mm, nodules - subrounded, fairly well sorted; sand - arkose; Moderate Brown 5YR4/4; moderately compacted to compacted, friable in some zones, caliche abundant in various zones, sand nodules are CaCO_3 cemented, reacts with HCl; moist.

125.0'-132.5' (7.8' plus recovered) Upper 2.7' - Sandy clay with caliche; sand - very fine to fine grained; fairly well sorted; sand - arkose; matrix - Moderate Brown 5YR4/4; compact, friable, reacts with HCl; moist. Middle 1.2' - Clayey sand with pebbles and caliche; sand - fine to medium grained with < 5% pebbles and nodules $\leq$ 60 mm, sand - subrounded, pebbles - subrounded to rounded, very poorly sorted; sand - arkose; Very Pale Orange 10YR8/2; compact, friable, caliche abundant in matrix and as nodules, strong reaction with HCl; moist. Lower 3.9' - Sandy clay with caliche and pebbles; sand - very fine to fine grained, pebbles < 1% and $\leq$ 4 mm, subrounded, fairly well sorted; sand - arkose; matrix - Moderate Brown 5YR4/4; pebble content increases towards bottom of core; compact, friable, some CaCO_3 cemented sand, reacts with HCl; moist.

132.5'-140.5' (7.8' plus recovered) Upper 4.3' - Sandy clay; sand - fine to coarse grained, moderately well sorted, subrounded to rounded; Light Brown 5YR5/6; one 50 mm sandstone pebble, medium grained, rounded, sand grains rounded to subrounded at 2.9' from top of core (135.4'); moderately compacted, moderate reaction with HCl; moist; abrupt basal contact. Middle 1.0' - Clayey sand with pebbles; sand - medium grained, pebbles < 5% and $\leq$ 4 mm, sand - rounded to subrounded, pebbles - subrounded; sand - arkose and quartz, pebbles - quartz; Very Pale Orange 10YR8/2; friable, moderate reaction with HCl; dry; abrupt basal contact. Lower 2.5' - Sandy clay with pebbles; sand - fine to medium grained, pebbles $\leq$ 4 mm, sand and pebbles subrounded, moderately sorted; sand and pebbles - arkose and quartz; Light Brown 5YR5/6; moderately compacted, moderate reaction with HCl; moist.

140.5'-164.0' (24.3' recovered) Upper 14.0' - Sandy clay; sand - fine to medium grained, rounded, well sorted; sand - quartz with minor feldspar; Light Brown 5YR5/6; compacted, moderate reaction with HCl; moist. Lower 10.3' - Sandy clay to clayey sand; sand - fine to coarse grained, scattered rounded to subrounded pebbles, well to poorly sorted; sand - quartz, feldspar and biotite, pebbles - limestone, sandstone and altered metamorphic rocks; Pale Yellowish Brown 10YR6/2; friable, coarser grained toward bottom of section, scattered FeO_2 staining; poorly cemented, no to very slight reaction with HCl; slightly moist.

164.0'-171.6' (8.1' plus recovered) Clayey sand; sand - fine to medium grained, sparsely scattered pebbles, pebbles - rounded to subrounded, moderately to poorly sorted; sand - quartz, feldspar, pebbles - quartz, feldspar; clay content increases towards bottom; poorly cemented, lower 3' is more strongly cemented and contains caliche, upper section has no reaction with HCl, lower portion has slight reaction with HCl; moist.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

171.6'-178' (7.9' plus recovered) Clayey sand with pebbles; sand - fine to very coarse, pebbles < 5% and ≤ 20 mm, sand - subangular to subrounded, pebbles - rounded to angular, poorly sorted; pebbles - quartzite, dolomitic limestone, greenstone; Pale Yellowish Brown 10YR6/2; pebble content increases towards bottom, sand grain size increases towards bottom; moderately compacted, strongly compacted in lower 1', upper 2/3 of core has no reaction with HCl, lower 1/3 has moderate reaction with HCl; very moist.

178'-187' (9' plus recovered) Upper 0.6' - Sandy clay with pebbles; sand - medium to very coarse grained, pebbles < 4% and ≤ 10 mm, angular to subangular, very poorly sorted; pebbles - limestone and minor quartz and feldspar; Pale Yellowish Brown 10YR6/2; strongly compacted with abundant CaCO_3 in matrix and in lenses, strong reaction with HCl; slightly moist. Upper middle 1.4' - Clayey sand with pebbles; sand - medium to very coarse grained, pebbles < 8% and ≤ 60 mm, sand is about 35%, angular to subangular, very poorly sorted; sand - arkose, pebbles - limestone and quartz; Dark Yellowish Brown 10YR4/2; compacted, moderate reaction with HCl, reaction decreasing towards bottom; moist; abrupt basal contact. Lower middle 6.4' - Clay with sand; sand - very fine to fine grained, < 1% sand and pebbles in upper 5.1', < 10% sand in lower 1.3', angular to subangular, poorly sorted; Moderate Brown 5YR4/4; strongly compacted, reacts with HCl; abrupt basal contact. Lower 0.6' - Silty sand with clay; sand - fine to very fine grained, interval capped with 2" layer of pebbles ≤ 25 mm, angular to subangular; Very Pale Orange 10YR8/2; strongly compacted, CaCO_3 cemented sand and pebbles, CaCO_3 very abundant, strong reaction with HCl; very slightly moist.

187'-188' (0.9' recovered) Silty sand with clay; sand - very fine to fine grained; Very Pale Orange 10YR8/2; strongly compacted, CaCO_3 very abundant, strong reaction with HCl; very slightly moist.

188'-193 (5.9' recovered) Upper 2.1' - Silty sand with caliche; sand - very fine to fine grained, < 2% very coarse sand to pebbles ≤ 4 mm, angular to subangular, poorly sorted; coarse sand and pebbles - limestone, quartz, feldspar; Grayish Orange 10YR7/4 to Light Brown 5YR6/4; strongly compacted, CaCO_3 very abundant especially in upper section, strong reaction with HCl; very slightly moist; gradational basal contact. Middle 1.3' - Sandy clay with pebbles; sand - very fine to fine grained, well sorted; Moderate Yellowish Brown 10YR5/4; moderately compacted, slight to moderate reaction with HCl; moist; gradational basal contact. Lower 2.5' - Sand with clay and caliche; sand - very fine to fine grained, < 4% very coarse grained sand and pebbles < 10 mm in lower 0.5', subangular to subrounded, fairly well sorted, poorly sorted in lower 0.5'; pebbles - limestone; Light Brown 5YR6/4; 60 mm fine grained CaCO_3 cemented sandstone nodule in upper 0.3' of section; strongly compacted, CaCO_3 abundant, strong reaction with HCl; slightly moist.

193'-197' (4.2' plus recovered) Upper 1.9' - Sandy clay with caliche; sand - very fine to fine grained, fairly well sorted, caliche abundant in matrix and as nodules; matrix - Moderate Brown 5YR4/4, caliche - Light Brown 5YR6/4; compacted, moderately cemented with caliche, strong reaction with HCl; very slightly moist; gradational basal contact. Middle 2.0' - Sandy clay with

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LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

pebbles and abundant caliche; sand - very fine to fine grained with pebbles < 3% and ≤ 5 mm, subangular to subrounded, caliche abundant in matrix and as rounded nodules; pebbles - limestone, quartz, and feldspar; Light Brown 5YR6/4; probable gouge; moderately compacted with strong caliche cementing, friable into fine powder in some areas, strong reaction with HCl; very slightly moist to dry; abrupt basal contact. Lower 0.3' - Sandy clay; sand - very fine to fine grained; Moderate Brown 5YR4/4; moderate to strongly compacted, moderate to strong reaction with HCl; very moist to moist.

197'-204' (7.3' recovered) Sandy clay with pebbles; sand - very fine to fine grained, pebbles < 1% and ≤ 5 mm, subangular; pebbles - limestone; Moderate Brown 5YR4/4; caliche very abundant in middle 3' in matrix and as nodules, compacted with moderate to strong CaCO_3 cementing, strong to moderate reaction with HCl; very slightly moist to dry.

204'-214' (12' plus recovered) Upper 3.8' - Pebbly clayey sand; sand - fine to very coarse grained, pebbles approximately 25% and ≤ 30 mm, very angular to subrounded, flat surfaces on many pebble pieces, very poorly sorted; sand and pebbles - quartz, limestone and feldspar; matrix - Moderate Brown 5YR4/4; probable fault breccia, many broken faces on pebbles; moderately to strongly compacted with some CaCO_3 cementing, moderate to strong reaction with HCl; moist; gradational basal contact. Lower 8.2' - Clayey silty sand with caliche; sand - very fine to fine grained; well mixed, caliche in matrix and as nodules increasing significantly towards bottom; Moderate Brown 5YR4/4 to Light Brown 5YR6/4 where caliche is abundant; strongly compacted, clay binding, moderate to strong reaction with HCl; moist.

214'-226' (12.1' plus recovered) Clayey sand; sand - very fine to fine grained, well sorted, caliche very abundant 3.6' to 4.6' below top of section and decreasing towards bottom; Moderate Brown 5YR4/4 to Light Brown 5YR6/4 where caliche is abundant; fine grained CaCO_3 cemented sandstone, sandstone broken up in clay matrix in barrel drill bit (probably fractured during drilling); moderately compacted, slight reaction with HCl above caliche zone, strong reaction with HCl where caliche is abundant, no reaction with HCl below caliche zone near bottom of interval; moist, sandstone dry.

226'-238' (12' plus recovered) Upper 8' - Silty clay with caliche; Light Brown 5YR5/6; strongly compacted, caliche in matrix and as veins, more abundant in some zones, strong reaction with HCl; moist; gradational basal contact. Lower 4' - Clayey silt with sand and pebbles; sand - very fine to fine grained, pebbles < 1% and ≤ 50 mm, sand is scattered; pebbles - quartz sandstone, fine grained, poorly to moderately cemented, angular to subrounded; Light Brown 5YR5/6; moderately compacted, moderate to weak reaction with HCl; moist.

238'-246' (10.7' plus recovered, note: upper 7.7' was stuck in barrel and was retrieved and described about 2.5 weeks later) Upper 3.7' - Clayey sand with pebbles; sand - very fine to coarse grained, subangular to subrounded, very poorly sorted, pebbles ≤ 60 mm, angular to subrounded; sand - arkose, pebbles - limestone and quartz, larger pebbles are scattered, almost angular and limestone; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, strong reaction with HCl. Upper middle 1.5' - Clayey sand with

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LITHOLOGIC LOG - Continued

South Fence Road - 1 Deep (SFR-1D)

pebbles and caliche; sand - very fine to coarse grained, subangular to subrounded, very poorly sorted, pebbles ≤ 60 mm, angular to subrounded; sand - arkose, pebbles - limestone; Moderate Yellowish Brown 10YR5/4; two blebs or lenses of CaCO_3 cemented medium to coarse sand and pebbles < 5 mm - poorly sorted - angular to subrounded - arkose and limestone; moderately to strongly compacted, strong reaction with HCl. Lower middle 2.5' - Clayey sand; sand - very fine to fine grained; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, strong reaction with HCl. Lower 3.0' - Clayey silt with sand and pebbles; sand - very fine to fine grained, pebbles $< 1\%$ and ≤ 50 mm, sand is intermixed; pebbles - quartz sandstone, fine grained, angular to subrounded; Light Brown 5YR5/6; moderately compacted, moderate to strong reaction with HCl; moist.

246'-251' (5.5' plus recovered) Upper 1.8' - Sandy clay; sand - very fine to medium grained, subangular to rounded, poorly sorted; sand - quartz; Light Brown 5YR5/6; sand is intermixed with clay and grades downward to sand lenses ≤ 4 mm thick, strongly compacted, very mild to no reaction with HCl; moist; very abrupt basal contact. Lower 3.7' - Silty sand with pebbles; sand - very fine to very coarse grained, pebbles approximately 5% and ≤ 30 mm, subangular to rounded, very poorly sorted; sand and pebbles - predominately quartz, feldspar; matrix - Dark Yellowish Brown 10YR4/2; medium grained sand grades to very poorly sorted silty sand with pebbles towards bottom; slightly compacted, no cementing, no reaction with HCl; wet.

251'-265' (14' plus recovered) Upper 2.2' - Silty sand with clay; sand - fine to very coarse grained, poorly sorted, subangular to rounded; sand - predominately quartz; Moderate Yellowish Brown 10YR5/4; moderately compacted, weak to moderate reaction with HCl; very moist; abrupt basal contact. Middle 4.1' - Silty clay with pebbles; pebbles $< 2\%$ and ≤ 20 mm, rounded to subrounded, poorly sorted; pebbles - quartzite; Grayish Orange 10YR7/4; moderately compacted, with a strongly compacted clay 1.5' to 2.5' from top of section, slight to moderate reaction with HCl; very moist; abrupt basal contact. Lower 7.7' - Silty sand with minor clay; sand - very fine to medium grained, rounded to subrounded, poorly sorted; sand - predominately quartz; matrix - Pale Yellowish Brown 10YR6/2; moderately compacted/cemented, CaCO_3 cementing, moderate reaction with HCl; very moist.

265'-269.7' (4.7' plus recovered) Silty sand with minor clay; sand - very fine to medium grained, $< 5\%$ clay, subangular to rounded, poorly sorted; sand - quartz; matrix - Pale Yellowish Brown 10YR6/2; two pebbles in lower section - 50 mm, one is crystalline limestone, one is sandstone, both rounded with secondary angular faces; well compacted, variable amounts of CaCO_3 towards bottom of section in matrix and as nodules, no reaction with HCl at top of section, moderate to strong reaction with HCl at bottom of section; very moist.

269.7'-273' (3.0' plus recovered) Silty sand with pebbles; sand - fine to medium grained, pebbly in upper 1' $\leq 3\%$ and ≤ 35 mm, sand - subangular to rounded, pebbles - rounded, well sorted; sand - quartz, pebbles - quartz and limestone; Pale Yellowish Brown 10YR6/2; slightly compacted, no reaction with HCl; wet.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

273'-289' (16' plus recovered) Upper 7' - Clayey pebbly sand and cobble; sand - very fine to fine grained, pebbles vary from 20% upwards to clayey pebbles in the center of the section, one cobble fractured into three < 30 to 40 mm pieces, pebbles - subangular to rounded, very poorly sorted; pebbles - quartzite with minor limestone and various igneous/metamorphics; matrix varies from Pale Yellowish Brown 10YR6/2 to Dark Yellowish Brown 10YR4/2; moderately compacted; no to very slight reaction with HCl; moist; gradational basal contact to pebbly sand with clay. Lower 9' - Silty sand with minor clay; sand - very fine to fine grained, subangular to subrounded; sand - arkose; Pale Yellowish Brown 10YR6/2; moderately compacted, no to slight reaction with HCl; very moist; lower portion of interval grades to clayey silty sand.

289'-293.7' (5.7' plus recovered) Upper 2.8' - Clayey silty sand; sand - very fine to fine grained, minor scattered pebbles ≤ 10 mm, sand - subangular to subrounded, poorly sorted; sand - arkose, mica flakes scattered throughout core; Dark Yellowish Brown 10YR4/2; central and basal portion iron stained yellow to brown yellow; moderately to strongly compacted, no to slight reaction with HCl; moist. Middle 1.4' - Silty sand with gravel and clay grading downward to clayey silty sand with minor gravel; sand - very fine to coarse grading downward to very fine to fine, sand and gravel - subangular to subrounded; sand - arkose, gravel - quartzite; Dark Yellowish Brown 10YR4/2; moderately to strongly compacted, no to slight reaction with HCl; moist. Lower 1.5' - Gravely clayey sand grading downward to clayey sandy gravel and last to silty sand with clay and gravel; sand - very fine to coarse grained grading downward to very fine to fine grained, gravel ≤ 20 mm, subangular to subrounded, poorly sorted; gravel - quartzite, igneous, and metamorphics, some weathered; Dark Yellowish Brown 10YR4/2; moderately to strongly compacted, some caliche-like zones (decomposed tuff?) with slight to medium reaction with HCl; moist.

293.7'-305' (10' plus recovered) Upper 6.0' - Silty sand with clay and pebbles; sand - fine to medium grained, pebbles generally ≤ 50 mm, predominately < 10 mm with sizes > 10 mm occurring in upper 2' of section, subangular to subrounded, pebbles poorly dispersed; sand - arkose; Moderate Brown 5YR4/4 to Moderate Brown 5YR3/4; moderately to strongly compacted, no to slight reaction with HCl; very moist. Middle 2.3' - Clayey silty sand with pebbles; sand - very fine to fine grained, pebbles generally < 10 mm, two pebbles < 60 mm with freshly broken surfaces; pebbles - limestone; moderate reaction with HCl; moist to very moist; abrupt basal contact. Lower 1.7' - Silty sandy caliche; mostly broken nodules with freshly broken limestone pieces approximately 10 mm; Very Pale Orange 10YR8/2; friable, moderately cemented with CaCO_3 , strong reaction with HCl; dry.

305'-307' (2.4' recovered) Gravel with sandy silty clay and cobbles; nodules containing pieces of cemented, angular sand and small gravel, 2 cobbles - largest cut to core size (3.75 inches), cobbles - subangular to subrounded, very poorly sorted; gravel - quartz, feldspar, limestone, red claystone, cobbles - limestone; fine matrix - Pale Yellowish Brown 10YR6/2; loosely compacted, strong reaction with HCl, clay matrix is powdery and dissolves in HCl; slightly moist.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

307'-312' (3.3' recovered) Upper 2.7' - Conglomerate; clasts - 2 to 40 mm in a silty sandy matrix cemented with CaCO_3 , clasts - angular to subangular; larger clasts are predominately limestone, smaller clasts are limestone, quartz, sandstone, shale, and greenstone; matrix - Moderate Reddish Brown 10R4/6; interval from 1.7' to 2.1' from top of section and basal portion have finer clasts with bedding dipping approximately 8 degrees; moderately cemented with some poorly cemented zones, moderate to strong reaction with HCl; moist; abrupt basal contact. Lower 0.6' - Silty sandstone; sand grains - very fine to medium grained with < 1.0 % coarse grains, subangular to subrounded; sandstone - arkose; fine matrix similar to upper 2.7'; upper contact is conformable, with bedding continuous from overlying material.

312'-317' (2.1' recovered) Upper 0.5' - Conglomerate; clasts - 2 to 40 mm in a silty sandy matrix cemented with CaCO_3 , clasts - angular to subangular; larger clasts are predominately limestone, smaller clasts are limestone, quartz, sandstone, shale, and greenstone; matrix - Moderate Reddish Brown 10R4/6; recovered as lenses and gravel sized pieces, moderately cemented with some poorly cemented zones, moderate to strong reaction with HCl; moist. Next 0.3' - Pebbles with sand; pebbles ≤ 30 mm, sand - very fine to coarse grained, poorly sorted, angular to subrounded; pebbles - mostly limestone, sand - arkose; Moderate Orange Pink 5YR8/4 to Light Brown 5YR6/4; chalky in some zones possibly weathered or affected by drilling; loose, strong to very strong reaction with HCl; wet; abrupt basal contact. Next 0.6' - Conglomerate; clasts - 2 to 50 mm, silty sandy matrix is minor, cemented with CaCO_3 , larger clasts predominate, clasts - angular to subangular, poorly sorted; larger clasts are predominately limestone, smaller clasts are limestone, quartz; sandstone, shale, and greenstone, total limestone composition is approximately 70%; matrix - Moderate Reddish Brown 10R4/6, limestone - Light Gray N7; well packed, strongly cemented with CaCO_3 , strong reaction with HCl; moist; abrupt basal contact. Lower 0.7' - Sandy pebbles with minor silt and clay; sand - very fine to coarse grained, pebbles ≤ 50 mm, angular to subangular, poorly sorted; sand - arkose, pebbles - mostly limestone; Moderate Brown 5YR4/4; 0.2' zone in middle of section is clayey silty pebbly sand, poorly sorted, pebbles $\leq$ to 7 mm with poorly defined concave downward bedding; loose, strong reaction with HCl, wet.

311'-330' (Recovered as rock bit cuttings) Pebbles and sand; pebbles - 65% and 4 to 15 mm, some clasts ≤ 20 mm, sand - 35% and very fine to coarse grained, predominately fine to medium grained, angular to subangular; pebbles - 90% limestone, 10% sandstone, sand - limestone with minor quartz; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

330'-335' (Recovered as rock bit cuttings) Sand and pebbles; sand - 50% and very fine to coarse grained, predominately fine to medium grained, pebbles 50% and 3-8 mm (natural faces), < 3% 5-20 mm (faces cut by drilling), sand - angular to subangular, pebbles - angular to subrounded; pebbles - limestone with minor schist, sandstone and quartz; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

335'-340' (Recovered as rock bit cuttings) Pebbly sand; sand - very fine to coarse grained, pebbles 20% and ≤ 5 mm, angular to subangular; sand and pebbles - limestone with minor quartz and arkose; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

340'-345' (Recovered as rock bit cuttings) Sand with pebbles, silt and clay; sand - very fine to coarse, predominately coarse, pebbles, silt and clay < 15%, pebbles ≤ 5 mm, angular to subangular; sand and pebbles - limestone with minor quartz and arkose; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

345'-350' (Recovered as rock bit cuttings) Sand with silt and pebbles; sand - very fine to coarse grained, pebbles 10% and ≤ 5 mm, sand - angular to subangular, pebbles - angular to subrounded; sand and pebbles - limestone, with minor quartz and arkose; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

350'-355' (Recovered as rock bit cuttings) Clayey silty pebbly sand; sand - very fine to coarse grained sand, pebbles < 12 mm (70% < 8 mm), sand - subangular to subrounded, pebbles - subangular, very poorly sorted; sand - limestone, quartz and arkose, pebbles - limestone with minor sandstone quartz; Light Brown 5YR5/6; strong reaction with HCl.

355'-360' (Recovered as rock bit cuttings) Sand and pebbles; sand - 50% and very fine to coarse grained, predominately medium to coarse grained, pebbles - 50% and ≤ 15 mm (90% < 5mm, 10% < 10 mm with few subrounded 10-15 mm), angular to subrounded, sand - limestone with minor quartz and arkose, pebbles - limestone with minor quartz and sandstone; clay occurs as few sandy clayballs approximately 15 mm; strong reaction with HCl.

360'-365' (Recovered as rock bit cuttings) Sand with silt; sand - very fine to coarse grained, predominately medium grained, angular to subangular, poorly sorted; sand - limestone, with quartz and arkose; Light Brown 5YR5/6; strong reaction with HCl.

365'-370' (recovered as cuttings) Sand with minor silt; sand - very fine to coarse grained with approximately 80% medium grains, angular with minor subangular to subrounded; sand - limestone with minor quartz and arkose; Light Brown 5YR5/6; strong reaction with HCl.

370'-375' (recovered as cuttings) Silty sand with clay; sand - very fine to fine grained with < 3% medium to coarse grains, angular to subangular; sand - limestone, quartz and arkose; Light Brown 5YR5/6; strong reaction with HCl.

375'-385' (recovered as cuttings) Sand with pebbles; sand - very fine to medium grained, pebbles < 1% and $\leq$ to 6 mm, sand - angular to subrounded, pebbles - mostly subrounded to rounded with fracture faces (due to drilling); sand - predominately quartz with less amounts of feldspar, pebbles - limestone; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

385'-390' (recovered as cuttings) Sand with pebbles; sand - fine to coarse grained, pebbles < 5% and ≤ 4 mm, sand - angular to subrounded, pebbles - subrounded; sand - predominately quartz with less feldspar, pebbles - limestone, quartz; Light Brown 5YR5/6; strong reaction with HCl.

390'-395' (recovered as cuttings) Sand with pebbles; sand - fine to very coarse grained, pebbles < 3% and ≤ 4 mm, sand - angular to subrounded, pebbles - subangular; sand - predominately quartz, feldspar, and minor limestone, pebbles - limestone and quartz; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

395'-400' (recovered as cuttings) Pebbly sand; sand - fine to very coarse grained, pebbles approximately 30% ≤ 20 mm; sand and pebbles - angular to subrounded; sand - quartz, feldspar, limestone, pebbles - limestone, minor cherty limestone, quartz; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

400'-405' (recovered as cuttings) Sand; medium to coarse grained, angular to subangular; quartz, feldspar, limestone; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

405'-410' (recovered as cuttings) Sand with gravel; medium to very coarse grained, sand - angular to subangular, gravel - subrounded to angular, (angularity probably due to drilling); sand - quartz, feldspar, gravel - limestone, quartz, feldspar; strong reaction with HCl.

410'-415' (recovered as cuttings) Sand; medium to very coarse grained, angular to subangular; feldspar, quartz, limestone; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

415'-420' (recovered as cuttings) Pebbly sand; sand - medium to very coarse grained, pebbles - approximately 30% and ≥ 10 mm, angular; sand and pebbles - quartz, feldspar, limestone; Moderate Brown 5YR4/4; strong reaction with HCl.

420'-440' (recovered as cuttings pulled every 5') Pebbly sand with minor clay; sand - fine to coarse grained, pebbles 30 to 50%, mostly rock fragments ≤ 10 mm, predominately < 4 mm with 5% 4 to 10 mm, sand and pebbles - angular to subrounded; predominately limestone with quartz, arkose, and sandstone; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl (due to digestion of fragments).

440'-445' (recovered as cuttings) Sandy pebbles; pebbles occur mostly as rock fragments and are ≤ 5 mm with 5% 5 to 10 mm, sand - 20% and fine to coarse grained, pebbles - angular, sand - angular to subrounded; predominately limestone, minor quartz and sandstone; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

445'-460' (recovered as cuttings) Sand; fine to medium grained with 10% coarse to very coarse grains, angular to subrounded; limestone with quartz and arkose; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

460'-465' (recovered as cuttings) Sand and pebbles; sand - fine to very coarse grained, pebbles predominately ≤ 4 mm with some clasts up to 12 mm, angular to subangular; 98% limestone; Pale Yellowish Brown 10YR6/2; strong reaction with HCl.

465'-470' (recovered as cuttings) Pebbles with sand; pebbles predominately 8 to 12 mm with some clasts up to 18 mm, sand - fine to very coarse grained, angular to subangular; 95% limestone; Pale Yellowish Brown 10YR6/2; strong reaction with HCl.

470'-480' (recovered as cuttings) Pebbles with sand; pebbles predominately 8 to 12 mm with some clasts up to 18 mm, sand - fine to very coarse grained, angular to subangular; 95% limestone; Pale Yellowish Brown 10YR6/2; strong reaction with HCl.

480'-485' (recovered as cuttings) Sand and pebbles; sand - fine to very coarse grained, pebbles - 98% are < 3 mm, angular to subrounded; limestone with some quartz and sandstone; Dark Yellowish Brown 10YR4/2; strong reaction with HCl.

485'-490' (recovered as cuttings) Pebbles with sand; pebbles occur as rock fragments < 6 mm with some clasts up to 15 mm, sand - fine to very coarse grained, mostly angular; pebbles and sand - 98% limestone fragments; Light Brown 5YR5/6; strong reaction with HCl.

490'-500' (recovered as cuttings) Sand and pebbles with clay (rock flour) in lower portion; sand - fine to very coarse grained, pebbles - 90% are $\leq$ to 6 mm with some clasts up to 12 mm, angular to subrounded; 98% fractured limestone; Moderate Yellowish Brown 10YR5/4; strong reaction with HCl.

500'-510' (recovered as cuttings) Pebbles with sand and clay (rock flour); pebbles - 6-10 mm, sand - fine to very coarse grained, angular to subangular; 97% limestone; Pale Yellowish Brown 10YR6/2; strong reaction with HCl.

Verified and edited on 08DEC92 and 14JAN93 by Cynthia Abeyta and on 25SEP92 by Joe Szalona, USGS

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LITHOLOGIC LOG - *Continued*

South Fence Road - 1 Deep (SFR-1D)

Note: Core was collected from 0' to 317'. Cuttings were collected from 311' to 510' (6' of overlap).

Lithologies logged by U.S. Geological Survey Geologists Cynthia Abeyta, Joe Szalona, Bill Dam and Conde Thorn as follows:

<u>Depth</u>	<u>Date</u>	<u>Geologist</u>
0' to 19'	27May92 to 29May92	C. Abeyta
19' to 31'	29May92 to 29May92	B. Dam
31' to 140.5'	29May92 to 12Jun92	C. Abeyta
140.5' to 171.6'	12Jun92 to 12Jun92	C. Thorn
171.6' to 273'	12Jun92 to 26Jun92	C. Abeyta
238' to 246'	15Jul92 to 15Jul92	J. Szalona*
273' to 375'	01Jul92 to 13Jul92	J. Szalona
375' to 420'	22Jul92 to 22Jul92	C. Abeyta
420' to 510'	25Jul92 to 26Jul92	J. Szalona

* Part of core was stuck in barrel, J. Szalona described the core when it was retrieved from barrel

Percentage of hole logged by each geologist:

C. Abeyta	53.1%
J. Szalona	38.6%
C. Thorn	6.0%
B. Dam	2.3%

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LITHOLOGIC LOG

South Fence Road - 2 Deep (SFR-2D)

Ground Elevation: 5428 feet Drilling Method/Fluids: Sonic/Dry (cuttings were washed out with water while driving 6 inch casing. Core was pushed out of barrel with air and water)
Logged by: U.S. Geological Survey (Abeyta and Szalona)
Drilling began: 08JUL92 Drilling completed: 14JUL92 Total depth: 365 feet
Color Chart: Goddard, E.N., and others, 1984, Rock color chart: Geological Society of America, Boulder, Colo.

0'-2' (2.0' recovered) Sandy silt; sand - very fine to fine grained with < 1% pebbles $\leq$ 6 mm, angular to subrounded, fairly well sorted; pebbles - limestone, minor quartz; Light Brown 5YR5/6; loose, strong reaction with HCl; very slightly moist.

2'-4' (3.6' plus recovered) Sandy silt with caliche; sand - very fine to fine grained with < 1% pebbles $\leq$ 21 mm, subangular to rounded, poorly sorted; pebbles - limestone; Grayish Orange 10YR7/4; loose in upper 1', moderately compacted in lower 2.6', caliche abundant in matrix throughout core, also as nodules, strong reaction with HCl; dry.

4'-7' (3.0' plus recovered) Sandy silt with caliche and pebbles; sand - very fine to fine grained with < 5% very coarse grains, pebbles < 3% and $\leq$ 50 mm, angular to rounded, very poorly sorted; pebbles - limestone; Grayish Orange 10YR7/4; loose, caliche abundant in matrix throughout core, strong reaction with HCl; dry.

7'-10' (2.8' recovered) Gravely sandy silt with caliche; sand - very fine to fine grained with approximately 15% very coarse sand and gravel $\leq$ 70 mm, angular to subrounded, very poorly sorted; gravel mostly limestone with minor quartz and granite; Grayish Orange 10YR7/4; loose, caliche abundant in matrix throughout core, strong reaction with HCl; dry to very slightly moist.

10'-12.5' (2.3' recovered) Pebbly sandy silt with caliche; sand - very fine to fine grained with approximately 15% very coarse sand and pebbles $\leq$ 39 mm, angular to subrounded, very poorly sorted; pebbles - limestone; Grayish Orange 10YR7/4; loose, caliche abundant in matrix throughout core, strong reaction with HCl; very slightly moist.

12.5'-14' (2.4' recovered) Pebbly sandy silt with caliche; sand - very fine to fine grained with approximately 15% very coarse sand and pebbles $\leq$ 32 mm; angular to subrounded, very poorly sorted; pebbles - limestone; Grayish Orange 10YR7/4; loose, caliche abundant in matrix throughout core, strong reaction with HCl; very slightly moist.

14'-18' (4.0' recovered) Upper 1.3' - Silty sand with pebbles; sand - very fine to very coarse grained, pebbles < 3% and $\leq$ 60 mm, angular to subangular, very poorly sorted; pebbles - predominately limestone, minor granite; Grayish Orange 10YR7/4; loose, minor caliche in matrix, strong reaction with HCl; very slightly moist; gradational basal contact. Middle 1.4' - Sandy silt with cobbles and caliche; sand - very fine to fine grained, cobbles $\leq$ 100 mm and abundant in lower section, subangular, poorly sorted; cobbles - limestone;

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LITHOLOGIC LOG - Continued

South Fence Road - 2 Deep (SFR-2D)

Very Pale Orange 10YR8/2; loose, caliche abundant in matrix, strong reaction with HCl; very slightly moist; abrupt basal contact. Lower 1.3' - Sand with pebbles; sand - very fine to very coarse grained, pebbles $\leq$ 28 mm, subangular to subrounded, very poorly sorted; sand - arkose, pebbles - arkosic and limestone; fine matrix - Dark Yellowish Orange 10YR6/6; loose, strong reaction with HCl; very slightly moist.

18'-23.5' (3.6' plus recovered) Pebbly sandy silt with caliche; sand - very fine to very coarse grained, pebbles $<$ 10% and $\leq$ 45 mm, subangular to subrounded, very poorly sorted; sand - arkose, pebbles - limestone and granite; Grayish Orange 10YR7/4; loose, caliche abundant in matrix, strong reaction with HCl; very slightly moist.

23.5'-27' (3.9' recovered) Pebbly sandy silt with caliche; sand - very fine to very coarse grained, pebbles $<$ 20% and $\leq$ 50 mm, subangular to subrounded, very poorly sorted; sand - arkose with limestone, pebbles - predominately limestone, granite; Grayish Orange 10YR7/4; loose, strong reaction with HCl; very slightly moist.

27'-30' (4.7' recovered) Pebbly sandy silt with caliche and cobble; sand - very fine to very coarse grained, pebbles $<$ 20% and $\leq$ 50 mm, one cobble 65 mm, subangular to subrounded, very poorly sorted; sand - arkose with limestone, pebbles - predominately limestone, granite; Grayish Orange 10YR7/4; loose, strong reaction with HCl; very slightly moist.

30'-33' (3.2' plus recovered) Upper 0.3' - Pebbly sandy silt with caliche; sand - very fine to very coarse grained, pebbles $<$ 20% and $\leq$ 50 mm, subangular to subrounded, very poorly sorted; sand - arkose with limestone, pebbles - predominately limestone, granite; Grayish Orange 10YR7/4; loose, strong reaction with HCl; very slightly moist; abrupt basal contact. Middle 0.5' - Sandy silt with pebbles and caliche; sand - very fine to fine grained, $<$ 3% pebbles $\leq$ 6 mm, subrounded to subangular, very poorly sorted; pebbles - limestone; Very Pale Orange 10YR8/2; loose, powdery, caliche abundant in matrix and as nodules, strong reaction with HCl; dry; gradational basal contact. Lower 2.4' - Silty sand with pebbles; sand - very fine to fine grained, $<$ 3% very coarse sand and pebbles $\leq$ 6 mm, subrounded to subangular, poorly sorted; very coarse sand and pebbles - limestone and granite; Light Brown 5YR6/4; coarse grained sand lens approximately 25 mm thick and cemented with CaCO_3 at top of section; loose, strong reaction with HCl, caliche in matrix and minor as nodules; very slightly moist.

33'-38' (7.5' recovered) Upper 2' - Pebbly silty sand with caliche; sand - very fine to very coarse grained, pebbles $\leq$ 53 mm, subangular to subrounded, very poorly sorted; pebbles - limestone, shale; fine matrix - Grayish Orange 10YR7/4; coarse grained sand lenses $\leq$ 25 mm thick and cemented with CaCO_3 ; loose with sand lenses at bottom of section, strong reaction with HCl; very slightly moist; fairly abrupt basal contact. Upper middle 1.2' - Sandy silt with pebbles and caliche; sand - very fine to fine grained, pebbles $<$ 5% and $\leq$ 6 mm, one pebble 55 mm, subangular to subrounded, poorly sorted; pebbles - limestone, 55 mm pebble - quartzite; Very Pale Orange 10YR8/2; fine to very

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LITHOLOGIC LOG - *Continued*

South Fence Road - 2 Deep (SFR-2D)

coarse grained sand lenses ≤ 25 mm thick and cemented with CaCO_3 ; loose matrix with CaCO_3 cemented sand lenses, strong reaction with HCl ; very slightly moist; gradational basal contact. Lower middle 0.6' - Silty sand; sand - very fine to fine grained, fairly well sorted; Light Brown 5YR6/4; slightly compacted, sand as matrix and in CaCO_3 cemented lenses, some caliche in matrix, strong reaction with HCl ; very slightly moist; abrupt basal contact. Upper lower 1.1' - Sandy silt (possibly volcanic ash); sand - very fine to fine grained, $< 3\%$ very coarse grains, fairly well sorted, subangular; very coarse sand - limestone and arkose; Pinkish Gray 5YR8/1; loose, powdery, moderate reaction with HCl ; abrupt basal contact. Lower lower 2.6' - Pebbly sand; sand - fine to very coarse grained, pebbles approximately 20% and ≤ 50 mm, subangular to subrounded, very poorly sorted; sand - arkose, pebbles - granite, limestone; matrix - Light Brown 5YR5/6; loose with coarse grained sand lenses ≤ 20 mm thick cemented with CaCO_3 , strong reaction with HCl ; very slightly moist.

38'-42' (5' plus recovered) Upper 1.5' - Sand; sand - very fine to fine grained, well sorted; arkose; Dark Yellowish Orange 10YR6/6; moderately compacted, friable, strong reaction with HCl ; slightly moist. Lower 3.5' - Welded and CaCO_3 cemented sand with interwelded sand and silt; welded and CaCO_3 cemented sand - fine to medium grained, sand - very fine to fine grained, poorly sorted; welded and CaCO_3 cemented sand - arkose, sand - quartz and arkose; Light Brown 5YR6/4; sand content increases towards bottom; welded and CaCO_3 cemented sand - strongly welded/cemented to friable, sand - moderately cemented/welded, moderate to strong reaction with HCl ; dry. NOTE: further analyses are necessary for description of this interval.

42'-46' (3.5' recovered) Upper 2.2' - Silty sand with cobbles; sand - very fine to fine grained, cobbles $< 1\%$ and ≤ 70 mm, subangular to subrounded, poorly sorted; Moderate Yellowish Brown 10YR5/4; cobbles - quartz sandstone; loose, scattered cobbles are very strongly cemented with CaCO_3 and very hard, strong reaction with HCl ; dry to slightly moist. Lower 1.3' - Sandy silt (possibly volcanic ash) with pebbles; sand - very fine to fine grained with $< 3\%$ pebbles ≤ 50 mm, subangular to subrounded, poorly sorted; pebbles - quartz sandstone; matrix - Very Pale Orange 10YR8/2; loose matrix, sandstone pebbles cemented with CaCO_3 , strong reaction with HCl , very slightly moist.

46'-49' (3.2 recovered) Sandy silt (possibly volcanic ash) with pebbles; sand - very fine to fine grained with $< 3\%$ pebbles ≤ 50 mm, subangular to subrounded, poorly sorted; pebbles - quartz sandstone; matrix - Very Pale Orange 10YR8/2; loose matrix, sandstone pebbles cemented with CaCO_3 , strong reaction with HCl ; very slightly moist.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 2 Deep (SFR-2D)

49'-52' (3.6' recovered) Upper 3' - Cobbley sandy silt (possibly volcanic ash) with minor clay; sand - very fine to fine grained, cobbles $\leq$ 30% variable up to $\geq$ 70 mm, subrounded to subangular, very poorly sorted; cobbles - quartz sandstone; matrix - Pinkish Gray 5YR8/1, minor clay nodules - Moderate Brown 5YR4/4; loose powdery matrix, cobbles cemented with CaCO_3 , loosely compacted sand nodules $\leq$ 40 mm at bottom of section; slightly moist; very abrupt basal contact. Lower 0.6' - Sandstone; medium grained with minor very coarse grains, subangular to subrounded sand grains, well sorted; quartz sandstone; very strongly cemented with CaCO_3 cement, moderate to strong reaction with HCl; dry.

52'-57' (5' plus recovered) Silty sand with clay, pebbles and caliche; sand - very fine to fine grained with $< 1\%$ pebbles $\leq$ 50 mm, fairly well sorted, pebbles - subangular; pebbles - rhyolite (?) with quartz and mafic phenocrysts; matrix - Light Brown 5YR5/6; clay content increases towards bottom; loose, friable, nodular, caliche in matrix and as nodules, moderate to strong reaction with HCl; slightly moist.

57'-63' (5' plus recovered) Upper 2.7' - Clay with caliche; Moderate Brown 5YR4/4; moderately compacted, caliche is somewhat nodular in clay matrix, caliche reacts strongly with HCl, clay does not react with HCl; slightly moist; gradational basal contact. Middle 0.8' - Silty sand with abundant caliche and minor clay; sand - very fine to fine grained, fairly well sorted; Grayish Orange 10YR7/4, Pinkish Gray 5YR8/1 where caliche is very prominent; moderately compacted, caliche abundant in matrix and as nodules, strong reaction with HCl; very slightly moist; gradational basal contact. Lower 1.5' - Clay with caliche; clay - Moderate Brown 5YR4/4, caliche - Pinkish Gray 5YR8/1; strongly compacted but friable, caliche is abundant as nodules, caliche reacts strongly with HCl, clay does not react with HCl; slightly moist.

63'-66' (3.2' recovered) Silty clay with caliche; Moderate Brown 5YR4/4; caliche as blebs and stringers in upper and lower sections, strongly compacted, moderate to strong reaction with HCl; moist.

66'-70' (3.7' recovered) Upper 1.3' - Silty clay with caliche; Moderate Brown 5YR4/4; strongly compacted, strong reaction with HCl; moist; gradational basal contact. Middle 2.1' - Silty sand with clay; sand - very fine to medium grained, subrounded and subangular, fairly well sorted, medium grained sand - angular; sand - arkose; Pale Yellowish Brown 10YR6/2; slightly moist. Lower 0.3' - Sandstone; fine to medium grained, subangular to subrounded; Light Gray N7; sandstone also nodular - 50 mm diameter; moderately to well cemented with CaCO_3 , strong reaction with HCl.

70'-75' (5.8' recovered) Silty sand; sand - fine to medium grained, subangular to subrounded, fairly well sorted; sand - arkose; fine matrix - Pinkish Gray 5YR8/1; laminations of alternating sand and silt approximately 3 mm thick in lower 1' of section, lenses of CaCO_3 cemented sandstone (quartz) approximately 7 mm thick in upper 1.5'; loose to moderately compacted, CaCO_3 cementing in some zones, caliche coating on sandstone lenses, strong to no reaction with HCl; slightly moist.

ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG - Continued

South Fence Road - 2 Deep (SFR-2D)

75'-80' (5.5' plus recovered) Upper 1.5' - Silty sandy clay with abundant caliche; sand - very fine to fine grained; matrix - Moderate Yellowish Brown 10YR5/4, Grayish Orange 10YR7/4 where caliche is more abundant; lenses of rhyolite(?) / sandstone (?) ≤ 20 mm thick, also as rock fragments ≤ 50 mm, angular (possibly broken by drill bit); moderately compacted but friable, strong reaction with HCl; slightly moist; abrupt basal contact. Note: further analyses are required for description of this section. Lower 4' - Silty clay with minor caliche; Moderate Brown 5YR4/4 to Light Brown 5YR5/6; strongly compacted, caliche as nodules and veins, no reaction with HCl in clay, strong reaction with HCl in caliche; slightly moist.

80'-83.5' (4.1' recovered) Silty clay with caliche; Moderate Brown 5YR4/4; strongly compacted, caliche present as nodules, more abundant in top 3' and in lower 0.2' of core, moderate to strong reaction with HCl; slightly moist.

83.5'-87' (4.7' recovered) Silty clay with caliche; Moderate Brown 5YR4/4; strongly compacted, caliche present as nodules and as veins, no to weak reaction with HCl in clay, strong reaction with HCl in caliche zones; moist.

87'-90' (3.3' plus recovered) Clay with silt; Moderate Brown 5YR4/4; sand zone approximately 1' below top of core - nodular, medium grained, well sorted, angular, quartz; strongly compacted, no visible caliche, no to slight reaction with HCl; moist.

90'-93' (3' plus recovered) Silty sandy clay with caliche and pebbles; sand - very fine to fine grained, poorly sorted, angular, $< 1\%$ pebbles ≤ 10 mm, subangular to subrounded - more abundant in lower core; sand - quartz, pebbles - limestone and minor quartz; Moderate Brown 5YR4/4; strongly compacted, caliche in matrix and as nodules and significantly more abundant towards bottom, strong reaction with HCl; moist.

93'-96' (3' plus recovered) Upper 0.9' - Clay with minor sand; sand - $< 3\%$ and very fine to fine grained, one 20 mm decomposed quartz sand nodule and one 20 mm subangular limestone pebble in clay matrix; matrix - Moderate Brown 5YR4/4; strongly compacted, moderate reaction with HCl; moist; abrupt basal contact. Lower 2.1' - Clayey sandy silt with pebbles and caliche; sand - very fine to fine grained with $< 7\%$ very coarse sand and pebbles ≤ 15 mm, subangular, very poorly sorted; sand - quartz, very coarse sand and pebbles - limestone; matrix - Grayish Orange 10YR7/4, clay nodules - Moderate Brown 5YR3/4; loose to strongly compacted, clay in nodules, silt - powdery, strong reaction with HCl; very slightly moist.

96'-99' (3' plus recovered) Sandy silty clay with minor pebbles; sand - very fine to fine grained, pebbles $< 1\%$ and ≤ 60 mm, angular to subangular, pebbles scattered; pebbles - microcrystalline limestone; matrix - Moderate Yellowish Brown 10YR5/4, limestone - Light Brown 5YR6/4; sand content increases towards middle and lower end of core and becomes poorly sorted; moderately compacted, minor caliche present in upper core, moderate reaction with HCl, stronger reaction in upper core; moist.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 2 Deep (SFR-2D)

99'-102' (3' plus recovered) Upper 1.4' - Sandy clay with caliche; sand - very fine to fine grained, < 1% nodules $\leq$ 30 mm scattered in core, subangular to subrounded; nodules - limestone; matrix - Pale Yellowish Brown 10YR6/2, nodules - Light Brown 5YR6/4; some nodules are decomposed in matrix material; strongly compacted, moderate reaction with HCl; slightly moist; gradational basal contact. Lower 1.6' - Clayey sand; sand - very fine to very coarse grained with < 1% pebbles $\leq$ 10 mm, subangular to subrounded, very poorly sorted; sand - arkose, pebbles - limestone; Moderate Brown 5YR4/4; strongly compacted; moderate reaction with HCl; slightly moist.

102'-104.5' (2.5' plus recovered) Clayey sand with pebbles; sand - very fine to very coarse grained, pebbles approximately 10% and $\leq$ 60 mm, subrounded to subangular, very poorly sorted; pebbles - quartz, limestone, cherty limestone, feldspar, olivine; clay - Pale Yellowish Brown 10YR6/2; moderately cemented with CaCO_3 cementing, some weathered/decomposed pebbles, clay present in matrix and as nodules.

104.5'-106' (2.3' plus recovered) Clayey silty sand; sand - very fine to fine grained with < 3% very coarse grains, subangular to subrounded, poorly sorted; coarse sand - limestone and limy sandstone; Grayish Orange 10YR7/4; moderately to strongly compacted, moderate to strong reaction with HCl; slightly moist.

106'-108' (2.3' plus recovered) Clayey silty sand with caliche; sand - very fine to fine grained, well sorted; Grayish Orange 10YR7/4 to Light Brown 5YR6/4; strongly compacted, caliche in matrix and minor as veins, clay content increases towards bottom, strong reaction with HCl at top grading to moderate reaction towards bottom as clay content increases; slightly moist.

108'-110' (2.2' recovered) Sandy silty clay with caliche; sand - very fine to fine grained; Moderate Yellowish Brown 10YR5/4; strongly compacted, caliche abundant in matrix and minor as nodules, moderate to strong reaction with HCl; slightly moist.

110'-118' (8.4' plus recovered) Sandy silty clay with caliche; sand - very fine to fine grained with subangular to subrounded sandstone nodules $\leq$ 40 mm 3.4' - 4.4' below top of section; matrix - Moderate Yellowish Brown 10YR5/4; strongly compacted, caliche in matrix and as nodules, caliche minor at top of core increasing to abundant towards bottom, very slight reaction with HCl at top of core to strong reaction with HCl towards bottom; moist.

118'-123' (5.4' plus recovered) Upper 2.7' - Sandy silty clay with caliche; sand - very fine to fine grained with < 1% subangular sandstone nodules $\leq$ 50 mm scattered throughout core; Moderate Yellowish Brown 10YR5/4; strongly compacted, caliche in matrix and minor as nodules, very slight to moderate reaction with HCl; moist; abrupt basal contact. Lower 2.7' - Pebbly sand; sand - very fine to very coarse grained, pebbles approximately 15% and $\leq$ 15 mm, angular to subangular, very poorly sorted; pebbles - limestone, feldspar and quartz; Moderate Yellowish Brown 10YR5/4; sand laminated in lower 1'; moderately compacted, friable, caliche in matrix and minor as veins, moderate to strong reaction with HCl.

ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG - Continued

South Fence Road - 2 Deep (SFR-2D)

123'-127' (3.9' plus recovered) Pebbly sand; sand - very fine to very coarse grained, pebbles approximately 15% and ≤ 10 mm, angular to subangular, very poorly sorted; sand - quartz and feldspar, pebbles - mostly limestone; Moderate Yellowish Brown 10YR5/4; moderately compacted, minor caliche, moderate to strong reaction with HCl; moist.

127'-138' (11.3' recovered) Upper 3.9' - Sandy clay with pebbly zones; sand - very fine to very coarse grained, pebbles (zonal) $< 7\%$ and ≤ 30 mm, well sorted zones of very fine to fine grained sand, very poorly sorted pebbly zones of very fine to very coarse sand with pebbles, subangular; sand-arkose, pebbles - limestone, quartz; Moderate Yellowish Brown 10YR5/4; strongly compacted, no to minor reaction with HCl; moist; abrupt basal contact. Middle 0.7' - Sandy clay with sandstone nodules; sand - very fine to fine grained, bedded sandstone nodules ≤ 50 mm; clay - Moderate Yellowish Brown 10YR5/4, nodules - Very Pale Orange 10YR8/2; nodular, strongly compacted, sandstone has CaCO_3 cementing, slight reaction with HCl in clay, strong reaction with HCl on nodules; moist; very abrupt basal contact. Lower 6.7' - Sandy clay; sand - very fine to fine grained, well sorted, with $< 1\%$ nodular sandstone zone 2.8' below top of section and scattered through rest of core, nodules are ≤ 30 mm (some are broken up by drilling); matrix - Moderate Yellowish Brown 10YR5/4; strongly compacted, becomes very abundant in CaCO_3 in lower 1.2', slight to very strong reaction with HCl toward bottom; moist.

138'-147' (8.8' recovered) Upper 6.8' - Sandy clay; sand - very fine to fine grained, well sorted, with $< 1\%$ nodular sandstone ≤ 50 mm, very fine to fine grained, scattered throughout section; matrix - Moderate Yellowish Brown - 10YR5/4; nodules - quartz sandstone; strongly compacted, CaCO_3 throughout section, moderate to strong reaction with HCl; moist; very abrupt basal contact. Lower 2' - Sandy silt with lenses of sandstone and sand with pebbles; sand - very fine to fine grained, poorly sorted, lenses approximately 20 mm thick, sandstone lenses - very fine to fine grained, sand with pebbles lenses - very coarse sand with pebbles ≤ 10 mm, pebbles ≤ 35 mm in one lens, subangular; pebbles - ≤ 10 mm are limestone, feldspar, and granite, 10 mm to ≤ 35 mm are limestone; matrix - Pinkish Gray 5YR8/1; lenses abundant throughout section, lenses lie horizontal in core; CaCO_3 cemented sandstone and sand with pebbles lenses, recovered as loose/powdery to moderately cemented, CaCO_3 abundant as powder and in matrix, moderate to strong reaction with HCl; dry.

147'-154' (6.4' plus recovered) Sandy clay; sand - very fine to fine grained, well sorted, with $< 1\%$ nodular sandstone ≤ 30 mm scattered throughout core; Moderate Yellowish Brown 10YR5/4; nodules - quartz sandstone; strongly compacted, CaCO_3 throughout core decreasing towards bottom, sand content decreases towards bottom of core, strong reaction with HCl at top of core decreasing to no reaction at bottom; moist.

ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG - *Continued*

South Fence Road - 2 Deep (SFR-2D)

154'-163' (10.2' recovered) Upper 6.8' - Sandy clay with zones of calcareous silty sand with clay; sand - very fine to fine grained, well sorted, with < 1% nodular sandstone ≤ 40 mm scattered through section; sandy clay - Moderate Yellowish Brown 10YR5/4, calcareous silty sand with clay - Grayish Orange 10YR7/4; very calcareous zones at 2.25' to 2.8' and 4.2' to 4.6' from top of section where it becomes calcareous silty sand with clay, sand content increases significantly towards bottom of section becoming clayey sand in lower 1.2'; strongly compacted, brittle in calcareous zones, CaCO_3 minor in clay matrix, weak reaction with HCl in clay, strong reaction in CaCO_3 zones; very moist; good gradational basal contact. Lower 3.4' - Silty sand with clay; sand - upper 0.5' of section is fine to very coarse grained with minor pebbles ≤ 4 mm, very poorly sorted, lower section is fine to medium grained, well sorted, sand and pebbles are angular to subangular; sand - arkose; silt matrix - Dark Yellowish Brown 10YR4/2; moderately compacted, friable; very moist to wet.

163'-178' (13.7' recovered) Silty sand; sand - very fine to very coarse grained, angular to subangular, poorly sorted; sand - arkose; matrix - Dark Yellowish Brown 10YR4/2; minor clay from 3.4' from top of core-through bottom; moderately compacted, no to minor reaction with HCl in upper 3.4' of core, moderate reaction towards bottom; very moist.

178'-183' (5.3' recovered) Upper 0.7' - Sandy clay; sand - approximately 30%, very fine to fine grained, < 3% very coarse grains, angular, < 1% pebbles ≤ 6 mm and rounded, poorly sorted; very coarse sand - quartz, feldspar, limestone, pebbles - limestone; Light Brown 5YR5/6; strongly compacted, slight to moderate reaction with HCl; moist; good gradational basal contact. Middle 2.9' - Pebbly sandy clay; sand - very fine to very coarse grained, pebbles - approximately 17% and ≤ 50 mm, angular to subangular, larger pebbles - subangular to subrounded, very poorly sorted; pebbles - quartz, feldspar, sandstone, and limestone; clay - Light Brown 5YR5/6; 30 mm piece of limestone with slickensides; strongly compacted but friable, moderate reaction with HCl; moist; abrupt basal contact. Upper lower 0.9' - Sandy silt with pebbles; sand - very fine to fine grained with approximately 5% very coarse grains, pebbles approximately 8% and ≤ 40 mm, very poorly sorted, predominately angular, minor subrounded - limestone only; coarse sand and pebbles - abundant limestone, some fossiliferous, feldspar, quartz, granite; matrix - Pinkish Gray 5YR8/1; two CaCO_3 cemented and clay bound sand lenses ≤ 30 mm thick containing very coarse sand with pebbles ≤ 30 mm, angular to subangular, feldspar, limestone and quartz, very poorly sorted, pebbly lenses lie horizontal and parallel to each other in core; loose/powdery to moderately compacted, CaCO_3 abundant as powder in matrix, moderate to strong reaction with HCl; dry; gradational basal contact. Lower 0.8' - Calcareous clayey sand with pebbles; sand - very fine to very coarse grained, pebbles approximately 7% and ≤ 25 mm, angular to subangular, very poorly sorted; coarse sand and pebbles - limestone and feldspar; Light Brown 5YR5/6; strongly cemented with CaCO_3 , strong reaction with HCl; dry to very slightly moist.

ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG - Continued

South Fence Road - 2 Deep (SFR-2D)

183'-191' (8.3' recovered) Upper 6.7' - Sandy clay with pebbles; sand - very fine to very coarse grained, pebbles - approximately 7% and ≤ 40 mm, angular to subangular, very poorly sorted; sand - arkose, pebbles - limestone and feldspar; Light Brown 5YR5/6; sand content increases significantly at bottom of section; strongly to moderately compacted, weak to moderate reaction with HCl; moist; fairly abrupt basal contact because of color change. Lower 1.6' - Gravely silty sand; sand - very fine to very coarse grained, gravel approximately 15% and ≤ 70 mm, angular to subangular, very poorly sorted; sand - arkose, gravel abundant limestone, feldspar; Light Brown 5YR6/4, abrupt color change in lower 0.3' - Pale Yellowish Brown 10YR6/2; 70 mm limestone cobble capping section (broken by drilling); moderately to strongly compacted, CaCO_3 cementing, moderate to strong reaction with HCl; slightly moist.

191'-217' (27.7' plus recovered) Sandy clay; sand - very fine to fine grained, well sorted with 1% fine grained sandstone nodules ≤ 50 mm from 12.6'-16.5' below top of section; Light Brown 5YR5/6; strongly compacted, nodules have CaCO_3 cement, becomes very calcareous towards bottom of section, slight to moderate reaction with HCl at top of interval, strong reaction with HCl towards bottom; very moist.

217'-228' (10.7' recovered) Upper 5.7' - Sandy clay; sand - very fine to fine grained, well sorted with $< 1\%$ fine grained sandstone nodules ≤ 50 mm scattered throughout section; matrix - Light Brown 5YR5/6; 2 limestone pebbles ≤ 40 mm, angular (rectangular) at 3.6' below top of section; strongly compacted, nodules - CaCO_3 cemented, matrix - no to very slight reaction with HCl; very moist to wet; abrupt basal contact. Upper middle 0.8' - Silty sand; sand - very fine to medium grained, well mixed; sand - arkose; Pale Yellowish Brown 10YR6/2; loose, no reaction with HCl; wet; abrupt basal contact. Lower middle 2.3' - Clayey sand with sandstone nodules; sand - fine to medium grained, nodules approximately 10% and ≤ 20 mm, medium to very coarse grained, angular to subangular grains, poorly sorted; sand nodules - arkose; Moderate Yellowish Brown 10YR5/4; moderately compacted, nodules - CaCO_3 cemented, matrix - no to very slight reaction with HCl; very moist to wet; abrupt basal contact. Upper lower 0.5' - Pebbly sandy silt; sand - very fine to very coarse grained, pebbles - approximately 30% and ≤ 20 mm, subangular to subrounded, very poorly sorted; sand and pebbles - feldspar, limestone, quartz; silt matrix - Pinkish Gray 5YR8/1, CaCO_3 cement - White N9; strongly cemented with CaCO_3 , also loose and powdery (probably due to drilling), strong reaction with HCl; abrupt basal contact. Lower 1.4' - Clayey sand with pebbles; sand - very fine to very coarse grained, pebbles approximately 7% and ≤ 32 mm, sand - angular to subangular, pebbles - subrounded, very poorly sorted; sand - arkose, gravel - limestone; Moderate Yellowish Brown 10YR5/4; moderately compacted, slight reaction with HCl; very moist to wet.

228'-263.5' (48.5' recovered) Upper 1.9' - Sandy clay with pebbles; sand - very fine to medium grained, $< 5\%$ very coarse grains, pebbles approximately 5% and ≤ 15 mm, subangular to angular, poorly sorted; coarser material - limestone, feldspar, granitic material; matrix - Light Brown 5YR5/6; strongly compacted, moderate reaction with HCl; moist; abrupt basal contact. Middle 3' - Clayey silty sand with gravel; sand - approximately 40%, very fine to medium grained with very coarse grains (approximately 5% of sand content), silt - approximately 30%, clay - approximately 25%, gravel $< 5\%$, angular to

ALBUQUERQUE ENVIRONMENTAL RESTORATION PROGRAM

LITHOLOGIC LOG - *Continued*

South Fence Road - 2 Deep (SFR-2D)

subangular, very poorly sorted; gravel - limestone and medium grained sandstone; matrix - Pale Yellowish Brown 10YR6/2; loose to moderately compacted due to clay binding, moderate to strong reaction with HCl; wet; very abrupt basal contact, approximately 45 degree angle with underlying zone. Lower 43.6' - Sandy clay; sand - very fine to fine grained, well sorted with occasional, < 1%, sand nodules ≤ 30 mm; Moderate Brown 5YR4/4 at top of section, Light Brown 5YR5/6 towards bottom, calcareous zones - Very Pale Orange 10YR8/2 to Grayish Orange 10YR7/4; strongly compacted in upper 25', very strongly compacted in lower 23.5', CaCO_3 becomes very apparent and abundant in lower 23.5', CaCO_3 in matrix and as nodules, moderate to strong reaction with HCl; moist.

263.5'-291.0' (32.8' recovered) Upper 15.4 - Sandy clay; sand - very fine to fine grained, well sorted, with medium grained sandstone nodules > 90 mm at top of section; Moderate Brown 5YR4/4; becomes sandier towards bottom of section; tightly compacted, no to slight reaction with HCl; very moist to wet; gradational basal contact. Middle 15.9' - Clayey sand with pebbles; sand - mostly fine to very fine grained with medium to very coarse grains in some zones, pebbles - mostly zonal, < 7% and ≤ 30 mm, angular to subrounded, poorly sorted; sand - arkose and limestone, pebbles - limestone; Moderate Brown 5YR4/4; one subangular limestone cobble at 18.1' below top of interval; very compacted, CaCO_3 cementing and clay binding, CaCO_3 abundant in matrix and minor as nodules, moderate to strong reaction with HCl; moist; gradational basal contact. Lower 1.5' - Calcareous silty sand with pebbles; sand - very fine to very coarse grained, pebbles approximately 12% in zones and ≤ 30 mm, angular to subangular, very poorly sorted; coarse sand and pebbles - arkose and limestone; matrix - Grayish Orange Pink 5YR7/2, CaCO_3 cement - White N9; strongly cemented with CaCO_3 , friable, strong reaction with HCl; slightly moist.

291'-315' (25.6' recovered) Clayey sand; sand - mostly very fine to fine grained with medium to very coarse grains in some zones, < 0.5% sandstone nodules composed of fine grained sand and ≤ 60 mm scattered through core, angular to subangular, fairly well sorted, except in medium to very coarse zones where it is poorly sorted; Light Brown 5YR5/6 to Moderate Brown 5YR4/4 where clay is more abundant; loose to moderately compacted, CaCO_3 in matrix, moderate to strong reaction with HCl; very moist to wet.

315'-318' (3.5' recovered) Calcareous silty sand with sandstone lens; sand - very fine to medium grained, angular to subangular, poorly sorted, sandstone lens - 0.4 inches thick at 2.7'-3.1' from top of interval, very fine to very coarse grained sand, angular to subangular, very poorly sorted; sand - arkose, sandstone lens - limestone, quartz and feldspar; Moderate Yellowish Brown 10YR5/4; sand - strongly to moderately compacted, friable, strong reaction with HCl, sandstone lens - strongly cemented with CaCO_3 , strong reaction with HCl; moist.

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LITHOLOGIC LOG - *Continued*

South Fence Road - 2 Deep (SFR-2D)

318'-344' (26.1' plus recovered) Upper 2.0' - Silty sand; sand - very fine to fine grained, well sorted; Light Brown 5YR5/6; moderately compacted, little to no reaction with HCl, moist; abrupt basal contact (possible slough). Next 4' - Silty gravelly sand; sand - fine to very coarse grained, gravel - approximately 30% and ≥ 70 mm, very poorly sorted, angular; coarse sand and gravel - limestone, feldspar, quartz and metagranite; matrix - Light Brown 5YR6/4; lower section is very gravelly, approximately 50%; compacted 3 inch cap on top of section, strongly cemented with CaCO_3 , rest of section is loose, slight reaction with HCl; wet; gradational basal contact. Middle 13.7' - Clayey silty sand; sand - very fine to fine grained, well sorted; Moderate Brown 5YR4/4; medium to very coarse grained sand with $< 12\%$ pebbles ≤ 12 mm at 5.7'-7.2' from top of section, very poorly sorted; moderately to strongly compacted, little to no reaction with HCl except in pebbly zone where there is a strong reaction with HCl; very moist to moist; abrupt basal contact. Lower 6.4' - Calcareous silty sand; sand - very fine to fine grained, well sorted; Pinkish Gray 5YR8/1 with minor Moderate Brown 5YR4/4 zones scattered through section; 1 mm thick very fine sand laminations in CaCO_3 cemented silty sand about 10 cm apart; very strongly cemented with CaCO_3 except in zones of darker color differentiation where it is moderately compacted, moderate to weak reaction with HCl, strong reaction with HCl where cementing is abundant; moist.

344'-365' (21.4' plus recovered) Upper 3.2' - Sand; very fine to fine grained, well sorted; Moderate Yellowish Brown 10YR5/4; loose, no to very slight reaction with HCl; very moist; abrupt basal contact. Next 3.4' - Silty clayey pebbly sand; sand - very fine to very coarse grained, pebbles - approximately 20% and ≤ 30 mm, angular to subangular, some pebbles are rounded, very poorly sorted; sand - arkose, pebbles - limestone, cherty limestone; Light Brown 5YR5/6; 0.2' sandstone lenses 2' below top of section, very fine to very coarse grained sand, angular to subangular, arkose with limestone fragments, very poorly sorted; moderately compacted, sandstone lenses - strongly cemented with HCl, slight to moderate reaction with HCl; wet; abrupt basal contact. Upper lower 14.3' - Clayey sand; sand - very fine to fine grained, well sorted, CaCO_3 as nodules $< 1\%$ and in matrix increasing towards bottom; Light Brown 5YR5/6 to Moderate Brown 5YR4/4, Pinkish Gray 5YR8/1 where CaCO_3 is very abundant; $< 1\%$ very coarse sand and pebbles ≤ 10 mm, fragmented, scattered in some areas; moderately to strongly compacted, slight reaction with HCl at top of section grading to very strong reaction towards bottom; very moist; abrupt basal contact. Lower 0.5' - Calcareous sandy pebbles; pebbles ≤ 35 mm, sand - very fine to very coarse grained, rounded to angular, very poorly sorted; coarse sand and pebbles - limestone, granite and feldspar; Moderate Brown 5YR4/4 to Pinkish Gray 5YR8/1 where CaCO_3 cementing is very abundant; moist.

Verified and edited on 22SEP92 and 13OCT92 by Cynthia Abeyta and on 25SEP92 by Joe Szalona, USGS

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LITHOLOGIC--Concluded

South Fence Road - 2 Deep (SFR-2D)

Note: Core was collected from 0.0' to 365'.

Lithologies logged by U.S. Geological Survey Geologists Cynthia Abeyta and Joe Szalona as follows:

<u>Depth</u>	<u>Date</u>	<u>Geologist</u>
0' to 63'	08JUL92 to 08JUL92	C. Abeyta
63' to 70'	09JUL92 to 09JUL92	J. Szalona
70' to 365'	09JUL92 to 14JUL92	C. Abeyta

Percentage of hole logged by each geologist:

C. Abeyta	98%
J. Szalona	2%

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LITHOLOGIC LOG

South Fence Road - 3 Deep (SFR-3D)

Ground Elevation: 5494 feet Drilling Method/Fluids: Sonic/Dry (cuttings were washed out with water while driving 6 inch casing. Core was pushed out of barrel with air and water). EZ-mud was used to drill 334' to 345'.
Logged by: U.S. Geological Survey (Abeyta, Basabilvazo, and Szalona)
Drilling began: 21JUL92 Drilling completed: 01NOV92 Total depth: 408 feet
Color Chart: Goddard, E.N., and others, 1984, Rock color chart: Geological Society of America, Boulder, Colo.

0'-16.5' (11.1' plus recovered) Sandy silt with pebbles and cobbles; sand - very fine to fine grained with minor medium to very coarse grains, pebbles and cobbles approximately 8% and ≤ 100 mm, subangular, very poorly sorted; pebbles and cobbles - limestone, granite, feldspar; Grayish Orange 10YR7/4; pebbles and cobbles scattered, more abundant in middle of section, root zone in upper 1.2'; loose and powdery with indurated nodules, CaCO_3 coating on limestone, strong reaction with HCl; dry.

16.5'-24' (8.5' plus recovered) Upper 0.9' - Sandy silt; sand - very fine to fine grained, fairly well sorted; Pale Yellowish Brown 10YR6/2; abundant roots (sloughed from surface); loose, powdery, minor indurated nodules, strong reaction with HCl; dry; abrupt basal color change. Middle 3.1' - Silty sand; sand - very fine to fine grained, pebbles $< 1\%$ and ≤ 20 mm, subangular to subrounded, moderately well sorted; sand - arkose, pebbles - limestone, feldspar; Light Brown 5YR5/6; loose to moderately compacted (broken up by drilling), moderate to strong reaction with HCl; very slightly moist to dry; abrupt basal contact. Upper lower 0.6' - Sandy silt; sand - very fine to fine grained, pebbles $< 1\%$ and ≤ 15 mm, angular to subangular, moderately well sorted; pebbles - limestone, minor granite; Pale Yellowish Brown 10YR6/2; loose, powdery, strong reaction with HCl; very slightly moist to dry; gradational basal contact, abrupt basal color change. Lower 3.9' - Silty sand with pebbles and cobbles; sand - very fine to fine grained with minor very coarse grains; pebbles and cobbles approximately 10% and ≤ 150 mm, very poorly sorted, subangular to subrounded; very coarse sand - feldspar and limestone, pebbles and cobbles - limestone, quartzite; Light Brown 5YR6/4; loose, strong to moderate reaction with HCl; very slightly moist to dry.

24'-28' (5.4' recovered) Silty sand with pebbles and cobbles; sand - very fine to fine grained with minor medium to coarse grains, pebbles and cobbles approximately 10% and ≤ 130 mm, sand - moderately well sorted to poorly sorted, pebbles and cobbles poorly sorted, subangular to subrounded; sand - arkose, pebbles and cobbles - limestone, with less granite and minor quartzite and feldspar; Light Brown 5YR5/6; pebbles and cobbles increasing in abundance in lower 0.9' with a coarse to very coarse grained sand stringer near bottom; loose, moderate reaction with HCl; very slightly moist to dry.

28'-32' (3.2' plus recovered) Silty sand; sand - very fine to fine grained, $< 3\%$ gravel, angular to subrounded, moderately well sorted; gravel - limestone; Light Brown 5YR5/6; loose to moderately compacted near bottom, moderate reaction with HCl at top of core to strong reaction at bottom; very slightly moist.

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LITHOLOGIC LOG--*Continued*

South Fence Road - 3 Deep (SFR-3D)

32'-36' (4.0' plus recovered) Silty sand; sand - very fine to fine grained, well sorted; upper 1' - Light Brown 5YR5/6, lower 3' - Grayish Orange 10YR7/4; upper 1' - moderately compacted, moderate reaction with HCl, lower 3' - strongly compacted, abundant caliche in matrix and strong reaction with HCl; upper 1' - very slightly moist, lower 3' - dry.

36'-38' (2' recovered) Silty sand; sand - very fine to fine grained, well sorted, < 1% fragmented rock (pebbles or cobble fractured during drilling) ≤ 10 mm; rock fragments - limestone; Grayish Orange 10YR7/4; strongly compacted, abundant caliche in matrix and minor as veins, strong reaction with HCl; very slightly moist to dry.

38'-45' (4.3' recovered, 2.7' lost from top of interval during retrieving core from barrel) Upper 1.2' - Silty sand; sand - very fine to very coarse grained, subrounded to angular, very poorly sorted; sand - arkose and limestone (calcareous litharonite); Dark Yellowish Brown 10YR4/2; moderately compacted, moderate reaction with HCl; very moist to wet (probably due to water used when driving casing); gradational basal contact. Lower 3.1' - Silty sand; sand - very fine to fine grained, well sorted, < 5% fragmented rock ≤ 25 mm, angular (pebbles or cobble fractured during drilling); sand - arkose, rock fragments - limestone, granite; Grayish Orange 10YR7/4; caliche abundant in matrix and as nodules ≤ 15 mm, strong reaction with HCl; dry to slightly moist.

45'-52' (7.3' plus recovered) Upper 1.9' - Sandy silt; sand - very fine to fine grained, well rounded, well sorted, minor pebbles ≤ 20 mm, well rounded to subangular; pebbles - limestone, granite; Grayish Orange 10YR7/4; loose to slightly compacted, moderate reaction with HCl; slightly moist; abrupt basal contact. Middle 1.6' - Sandy silt with pebbles and cobbles; sand - very fine to fine grained, well sorted, approximately 5% pebbles and cobbles ≤ 110 mm, subangular to subrounded; pebbles and cobbles - limestone, minor granite; Grayish Orange Pink 10YR8/2; loose, powdery, caliche as coating on slightly to moderately compacted silt clasts, strong reaction with HCl; slightly moist to dry; gradational basal contact. Lower 3.8' - Silty sand; sand - very fine to fine grained, well sorted, minor pebbles and cobbles ≤ 70 mm, more pebbles and cobbles at top of bottom 3.8'; Grayish Orange 10YR7/4; loosely compacted at top 1.8' of section, lower 2' - moderately to strongly compacted, moderate reaction with HCl.

52'-60' (6.2' recovered) Sandy silt; sand - very fine to fine grained, well sorted, minor pebbles and cobbles < 2% and ≤ 80 mm, subrounded to subangular; pebbles and cobbles - limestone, granite; Grayish Orange 10YR7/4; upper 4' - moderately compacted to loose with moderate to strong reaction with HCl, bottom 2.2' - moderately to strongly compacted, some caliche in matrix and as nodules ≤ 2 mm, moderate to strong reaction with HCl; slightly moist to dry.

60'-65' (5' plus recovered) Sandy silt; sand - very fine to fine grained, well sorted, minor gravel - one clast 110 mm; average clasts size approximately 60 mm, more gravel near bottom of core, subrounded to angular; gravel - limestone, granite; Grayish Orange 10YR7/4; upper 4' - strongly to moderately

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LITHOLOGIC LOG--Continued

South Fence Road - 3 Deep (SFR-3D)

compacted with filaments of caliche and some in matrix, moderate reaction with HCl, lower 1' - moderately compacted, caliche nodules ≤ 2 mm, some caliche in matrix and as coating on gravel, moderate to strong reaction with HCl; slightly moist.

65'-76' (11.2' recovered) Upper 4.3' - Sandy silt with pebbles and cobbles; sand - very fine to fine grained, well sorted, cobbles and pebbles ≤ 70 mm, pebbles predominately < 4 mm, pebbles and cobbles - well rounded to subrounded; pebbles and cobbles - granite and limestone, larger clasts are limestone, minor granitic clasts; Grayish Orange 10YR7/4; loosely compacted, some caliche coating on pebbles and cobbles, caliche nodules ≤ 1 mm, moderate reaction with HCl; slightly moist; gradational basal contact. Middle 4.9' - Sandy silt with pebbles; sand - very fine to fine grained, well sorted, pebbles 10% and ≤ 30 mm, well rounded, moderately well sorted; pebbles - limestone, granite; Grayish Orange 10YR7/4; loosely compacted, finer portion powdery, caliche in matrix and as coatings on pebbles, moderate reaction with HCl; slightly moist; gradational basal contact. Lower 2' - Sandy silt with pebbles; sand - very fine to fine grained, well sorted, pebbles ≤ 50 mm, subrounded to subangular, poorly sorted; pebbles - limestone; Very Pale Orange 10YR8/2; loosely compacted to powdery, caliche as nodules < 2 mm and as coating on grains, strong to moderate reaction with HCl; slightly moist.

76'-87' (10.8' plus recovered) Upper 5.3' - Sandy silt with pebbles and cobbles; sand - very fine to fine grained with minor very coarse grains, subrounded, moderately well sorted, pebbles and cobbles approximately 5% and ≤ 90 mm, poorly sorted; very coarse sand - arkose with 10% calcareous sand - grains, pebbles and cobbles - limestone and granite; Grayish Orange 10YR7/4; loosely compacted, pebbles and cobbles coated with caliche, moderate to strong reaction with HCl; slightly moist; gradational basal contact. Lower 5.5' - Sandy silt with pebbles and cobbles; sand - very fine to fine grained, well sorted, pebbles and cobbles approximately 12% and ≤ 80 mm; pebbles and cobbles - predominately limestone, less granite; Very Pale Orange 10YR8/2 to about 1' from bottom of section, gradational color change to Grayish Orange 10YR7/4; loosely compacted at top of section, moderately to strongly compacted at bottom (probably due to drilling), caliche in matrix and as nodules ≤ 20 mm, also as coating on pebbles and cobbles, moderate to strong reaction with HCl; slightly moist to dry.

87'-97' (10.1' recovered) Upper 2.5' - Sandy silt with pebbles and cobbles; sand - very fine to fine grained, well sorted, pebbles and cobbles approximately 10% and ≤ 110 mm, subrounded to angular, poorly sorted; pebbles and cobbles - predominately limestone with very minor granite and quartzite; Grayish Orange 10YR7/4; less pebbles and cobbles towards bottom of section; loosely compacted, caliche as coatings on pebbles and cobbles, medium to strong reaction with HCl; slightly moist; abrupt basal contact. Upper middle 0.7' - Silty sand; sand - very fine to fine grained, well sorted, 1% pebbles ≤ 6 mm, subrounded to subangular; pebbles - limestone and granite; Dark Yellowish Orange 10YR6/6; moderately to strongly compacted, caliche in matrix and minor as nodules < 20 mm, strong reaction with HCl; slightly moist; abrupt

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LITHOLOGIC LOG--*Continued*

South Fence Road - 3 Deep (SFR-3D)

basal contact. Lower middle 5.4' - Sandy silt with pebbles and cobbles; sand - very fine to fine grained, well sorted, approximately 15% very coarse sand, rounded to subangular, poorly to moderately sorted in stringers, pebbles and cobbles - ≤ 70 mm, subrounded to angular, poorly sorted; sand - arkose and calcareous arkose, pebbles and cobbles - limestone, granite, and minor quartzite; Grayish Orange 10YR7/4; loosely compacted, about 1% caliche nodules sparsely distributed throughout section, also occurs as coating on pebbles and cobbles, moderate reaction with HCl; very slightly moist; gradational basal contact. Lower 1.5' - Silty sand with clay; sand - very fine to fine grained, well sorted, with $< 1\%$ pebbles ≤ 3 mm, subrounded; pebbles - limestone, granite; Moderate Yellowish Brown 10YR5/4; silty horizontal laminations 1 mm thick, some root traces with black iron/organic stain and definite organic carbonaceous material; strongly consolidated (broken up by drilling), caliche nodules approximately 2% and ≤ 2 mm, strong reaction with HCl; slightly moist.

97'-104.5' (8.1' recovered) Upper 5.2' - Silty sand; sand - fine to very fine grained, well sorted with approximately 1% pebbles ≤ 8 mm, subrounded to angular, minor clay; pebbles - limestone and granite; Moderate Yellowish Brown 10YR5/4; laminations of very fine arkosic sand and silt < 1 mm thick, some laminations have organic material at top; strongly compacted, caliche nodules ≤ 2 mm and ≤ 20 mm dispersed throughout section, strong reaction with HCl; moist; gradational basal contact. Lower 2.9' - Sandy silt; sand - fine to very fine grained, well rounded, well sorted, with approximately 2% pebbles ≤ 30 mm; sand - arkose, pebbles - limestone and granite; Very Pale Orange 10YR8/2; strongly compacted, caliche coated pebbles, strong reaction with HCl; slightly moist to dry.

104.5'-107.5' (3.8' plus) Sandy silt; sand - fine to very fine grained, subrounded, with about 2% very coarse grains and pebbles ≤ 30 mm, subangular to angular, poorly sorted; sand - arkose, pebbles - limestone and granite; Very Pale Orange 10YR8/2; clay partings ≤ 4 mm, sandy to silty laminations 1 mm to 2 mm thick; strongly compacted, cemented with CaCO_3 cement (broken up due to drilling), caliche coating on grains, strong reaction with HCl; dry.

107.5'-112' (4.8' recovered) Sandy silt; sand - very fine to fine grained, approximately 1% pebbles ≤ 5 mm, subrounded, poorly sorted; Very Pale Orange 10YR8/2; pebbles sparsely distributed throughout core, laminations of sandy silt ≤ 1 mm thick, lower 2.5' contains some silty zones with clay; strongly compacted, CaCO_3 cement, caliche nodules ≤ 10 mm, strong reaction with HCl; dry near top of interval, very slightly moist in lower 2.0'.

112'-115' (3.2' recovered) Sandy silt with pebbles; sand - very fine to fine grained, approximately 5% pebbles ≤ 25 mm, subangular to subrounded; pebbles - limestone and granite; Very Pale Orange 10YR8/2; about 1% organic material sparsely distributed throughout core; strongly compacted, CaCO_3 cement, caliche in matrix and as coating on pebbles, strong reaction with HCl; very slightly moist to dry.

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LITHOLOGIC LOG--*Continued*

South Fence Road - 3 Deep (SFR-3D)

115'-117' (2.7' recovered) Upper 0.7' - Gravely sand; sand - fine to medium grained, subrounded to subangular, poorly sorted, gravel approximately 15%, subangular to subrounded, poorly sorted; sand - arkose, gravel - granite approximately 70%, limestone 30%; Grayish Orange Pink 5YR7/2; strongly compacted, very strongly cemented with CaCO_3 cement, strong reaction with HCl; dry; gradational basal contact. Lower 2.0' - Sandy silt; sand - very fine to fine grained, well sorted; sand - arkose with abundant quartz, limestone; Grayish Orange Pink 5YR7/2; gravel stringer 10 mm to 30 mm thick, poorly sorted subangular, granite and limestone; moderately to strongly cemented, moderately to loosely compacted, weak to moderate reaction with HCl; dry to very slightly moist.

117'-126.5' (9.5' recovered) Upper 1.3' - Silty sand with pebbles and clay; sand - very fine to fine grained, well sorted, approximately 5% pebbles $\leq$ 10 mm, average pebble size approximately 4 mm, subangular; pebbles - granite with less limestone; moist - Moderate Yellowish Brown 10YR5/4, dry - Very Pale Orange 10YR8/2; moderately consolidated and moderately cemented, strong reaction with HCl; slightly moist; gradational basal contact. Upper middle 2.0' - Silty sand with pebbles and cobbles; sand - very fine to fine grained, well sorted, pebbles and cobbles $\leq$ 100 mm, subrounded to angular, poorly sorted; sand - arkose; dry - Grayish Orange Pink 5YR7/2; pebbles and cobbles occur as stringers, approximately 10% limonitic areas approximately 1 mm to 2 mm thick, subsurface weathering of iron rich areas; moderately to strongly compacted, strong reaction with HCl; slightly moist; abrupt basal contact. Lower middle 1.7' - Silty sand with pebbles and clay; sand - very fine to medium grained, pebbles $\leq$ 5 mm, clay $<$ 10%, poorly sorted; sand - arkose, pebbles - granitic fragments and limestone; Moderate Yellowish Brown 10YR5/4; pebbles increase in size toward bottom of section, clay holds sand and pebbles together, strongly compacted, strong reaction with HCl; slightly moist; gradational basal contact. Lower 4.5' - Silty sand with pebbles, cobbles and clay; sand - very fine to fine grained, pebbles and cobbles approximately 10% with one clast $>$ 200 mm, variable size increasing toward bottom, poorly sorted; pebbles and cobbles - limestone and granite; Moderate Yellowish Brown 10YR5/4, lower 0.4' - Very Pale Orange 10YR8/2; lenses of pebbles and cobbles, approximately 10% limonitic zones $\leq$ 2 mm thick; loosely compacted to moderately compacted, lower 0.4' - powdery to loosely compacted, strong reaction with HCl; slightly moist.

126.5'-130.5' (4.0' plus recovered) Upper 2.0' - Silty sand with clay; sand - very fine to fine grained with $<$ 3% coarse grains, subangular to subrounded; Moderate Orange Pink 5YR8/4; moderately compacted, strong reaction with HCl; slightly moist. Lower 2.0' - Pebbly silty sand with clay; sand - very fine to fine grained with $<$ 3% coarse grains, subangular to subrounded, pebbles 20% and predominantly 40-60 mm, subangular with some surface fractures (due to drilling); pebbles - limestone, some granitic gneiss and quartz; Moderate Orange Pink 5YR8/4; moderately compacted, strong reaction with HCl; slightly moist.

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LITHOLOGIC LOG--*Continued*

South Fence Road - 3 Deep (SFR-3D)

130.5'-134.5' (4.0' recovered) Silty sand with clay and pebbles; sand - predominantly very fine to fine grained, pebbles predominately ≤ 5 mm, < 20 mm in upper core, subangular to subrounded; pebbles - larger pebbles are limestone, finer pebbles are quartz and arkose; Very Pale Orange 10YR8/2; pebbles are scattered, pebbles ≤ 5 mm also occur in lenses ≤ 20 mm thick; powdery in the central 2 plus feet, lenses are poorly to moderately cemented with CaCO_3 , strong reaction with HCl; slightly moist, lower 0.5' - moist.

134.5'-140' (5.5' recovered) Upper 0.6' - Sandy silt with clay and pebbles; sand - very fine to fine grained, well sorted, pebbles approximately 2% and ≤ 5 mm, poorly sorted; pebbles - granite, limestone and feldspar; dry - Very Pale Orange 10YR8/2, moist inner core - Light Brown 5YR5/6; pebbles dispersed throughout section; loosely packed and powdery (probably partly due to drilling) to strongly compacted, strong reaction with HCl; moist; gradational basal contact. Lower 4.9' - Silty sand with clay and pebbles; sand - very fine to fine grained, well sorted, pebbles approximately 10% and ≤ 15 mm, predominately ≤ 5 mm, subangular to subrounded, poorly sorted; sand - arkose, pebbles - ≤ 5 mm granite clasts predominate, 1% limestone clasts ≤ 15 mm; Moderate Orange Pink 5YR8/4; moderately to strongly compacted, caliche in matrix and as scattered nodules approximately 1-2% and 2 mm in diameter, strong reaction with HCl; very slightly moist to slightly moist.

140'-148' (4.8' recovered) Upper 1.8' - Sand with pebbles and cobbles and clay; sand - medium to very coarse grained, subrounded to subangular, moderately to poorly sorted, approximately 10% pebbles and cobbles, average size is 3 mm, largest clast is 85 mm; sand, pebbles and cobbles - quartz, feldspar, limestone, 85 mm clast is limestone; sand - Pale Red 10R6/2; zones of strongly cemented medium sand and gravel, sand grains pushed apart with CaCO_3 cement occurs between grains, no to few clasts supported, strong reaction with HCl, loose sand in lower third of section with a few clasts of strongly cemented sand and gravel within; dry; abrupt basal contact. Middle 1.8' - Silty sand with clay and pebbles and cobbles; sand - well sorted, pebbles and cobbles - approximately 5%, average size approximately 6 mm, largest approximately 70 mm, subangular and angular to subrounded, poorly sorted; sand - arkose, pebbles and cobbles - limestone and granite; Light Brown 5YR5/6; several 20 mm to 40 mm stringers of gravel; moderately compacted, minor ≤ 2 mm caliche nodules, moderate to strong reaction with HCl; moist (some moisture may be from driller using water to core strongly cemented sand above); gradational basal contact, abrupt color change. Lower 1.2' - Sand with clay and pebbles grading to silty sand with clay and pebbles; sand - medium to fine grained, subrounded to subangular, poorly sorted, pebbles - approximately 5% and 20 mm, subangular to subrounded, poorly sorted, lower silty sand - very fine to fine grained, poorly sorted, pebbles - average size approximately 3 mm, subrounded, poorly sorted; sand - arkose, pebbles - granite and limestone; Grayish Orange Pink 5YR7/2; moderately compacted, some caliche in matrix, strong reaction with HCl; slightly moist.

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LITHOLOGIC LOG--Continued

South Fence Road - 3 Deep (SFR-3D)

148'-157.5' (10.2' plus recovered) Upper 2.1' - Sandy clay with pebbles; sand - very fine to fine grained, pebbles < 4% and ≤ 6 mm, angular to subrounded, well sorted with pebbles scattered through section; pebbles - limestone, sandstone, quartz; Light Brown 5YR5/6; strongly compacted, caliche scattered in zones, no to strong reaction with HCl; moist; gradational basal contact. Middle 6.1' - Clayey sand with pebble zone; sand - very fine to fine grained, well sorted, pebble zone 1.1'-1.4' from top of section consisting of very fine to fine grained sandstone nodules ≤ 50 mm; Moderate Yellowish Brown 10YR5/4; moderately compacted, caliche scattered through section, moderate reaction with HCl; slightly moist; abrupt basal contact. Lower 2.6' - Calcareous sandy silt with sandstone nodules and lenses; sand - very fine to fine grained, sandstone nodules and lenses - abundant, some broken during drilling, fine to very coarse grained sand, angular, very poorly sorted; sandstone nodules contain limestone, quartz, and feldspar fragments in a quartz matrix; matrix - Grayish Orange 10YR7/4, nodules and lenses Grayish Orange 10YR7/4; loose/powdery, CaCO_3 abundant, CaCO_3 cementing of nodules and lenses, strong reaction with HCl; dry; abrupt basal contact.

157.5'-167' (9.7 recovered) Upper 2.9' - Sandy clay with sandstone nodules; sand - very fine to fine grained with < 1% pebbles ≤ 10 mm, subangular to angular, sandstone nodules - very fine to fine grained sand, two 50 mm nodules in clay matrix; pebbles - limestone, quartz, feldspar, nodules - quartz sandstone; Moderate Yellowish Brown 10YR5/4; moderately to slightly compacted, CaCO_3 cementing in sandstone nodules, moderate to strong reaction with HCl; moist; abrupt basal contact. Middle 1.3' - Calcareous sandy silt with conglomeratic lenses; sand - very fine to fine grained, silty matrix with < 5% coarse to very coarse sand and minor pebbles ≤ 6 mm, angular, poorly sorted, lenses - CaCO_3 cemented rock fragments ≤ 10 mm, angular, poorly sorted; pebbles - granite, lenses - granite and limestone rock fragments; Very Pale Orange 10YR8/2; lenses ≤ 10 mm thick coated with CaCO_3 ; matrix - loose and powdery, strong reaction with HCl; dry; gradational basal contact. Lower 5.5' - Silty sand with clay, nodules and conglomeratic lenses; sand - very fine to fine grained with minor medium to very coarse grains, two pebble clasts ≤ 30 mm, angular, very poorly sorted; coarse sand grains - granite, pebbles - metagranite, quartzite; Moderate Yellowish Brown 10YR5/4; nodules and lenses scattered especially in middle and lower sections of core, calcareous rock fragments ≤ 10 mm, very poorly sorted, angular, nodules and lenses coated with CaCO_3 ; strongly compacted at top to loose towards bottom, moderate to strong reaction with HCl; moist.

167'-177' (4.5' recovered) CaCO_3 cemented conglomerate lenses; rock fragments ≤ 80 mm, angular to subangular, very poorly sorted; granite, larger fragments are limestone; cement matrix - Very Pale Orange 10YR8/2; fine matrix washed away during drilling, lenses 10 to 50 mm thick; lenses - strongly cemented with CaCO_3 , silica crystals in void spaces in areas; strong reaction with HCl; wet (from drill water). Note: Lower 0.5' had some matrix material still around lenses, matrix material was same as that described in the lower section of the 157.5'-167' interval.

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LITHOLOGIC LOG--Continued

South Fence Road - 3 Deep (SFR-3D)

177'-195' (7' recovered) Upper 3.9' - Pebbles, cobbles and conglomeratic lenses, (finer matrix washed out during drilling); pebbles - ≤ 63 mm, cobbles - ≤ 75 mm, angular to subangular, poorly sorted, lenses are conglomeratic with very coarse sand and approximately 80% rock fragments ≤ 30 mm, angular to subangular, very poorly sorted; pebbles, cobbles, and rock fragments - granite, limestone, sandstone, gneiss, metagranite, sandstone is very fine to fine grained with less medium to very coarse grains, angular to subangular sand with CaCO_3 cement, very poorly sorted; lenses - 15mm to 50 mm thick with CaCO_3 cementing, and silica crystals; pebbles and cobbles - loose, lenses - strongly cemented with CaCO_3 , lenses react strongly with HCl; wet from drilling; abrupt basal contact. Lower 3.1' - Pebbly sandy clay; sand - very fine to very coarse grained, pebbles approximately 15% and ≤ 35 mm, angular to subangular, very poorly sorted; sand - quartz, feldspar, limestone, pebbles - limestone, granite, quartz; Moderate Yellowish Brown 10YR5/4; pebble content increases towards bottom; strongly compacted, strong reaction with HCl; moist.

195'-208' (12.7' recovered) Upper 5.7' - Sandy clay; sand - very fine to fine grained with $< 5\%$ very coarse grains and $< 1\%$ pebbles and sandstone nodules ≤ 20 mm, pebbles - angular to subangular, poorly sorted, sandstone nodules - fine grained sand with minor very coarse grains, angular, poorly sorted; pebbles - limestone, feldspar, quartz, sandstone nodules; Moderate Yellowish Brown 10YR5/4; sandstone lens 16 mm thick, fine grained sand with minor very coarse grains, angular, poorly sorted; moderately compacted, nodules and lens CaCO_3 cemented, moderate to strong reaction with HCl; moist; abrupt basal contact. Next 1.0' - Clayey sand; sand - very fine to fine grained with $< 5\%$ very coarse grained sand and pebbles ≤ 10 mm, angular to subangular, very poorly sorted, silty in upper 0.3'; very coarse sand and pebbles - granite, limestone; Grayish Orange 10YR7/4 to Moderate Yellowish Brown 10YR5/4 where no silt; loose to moderately compacted, strong reaction with HCl; dry to moist; gradational basal contact. Next 2.8' - Sandy clay with pebbles; sand - very fine to fine grained with $< 5\%$ very coarse grains and $< 3\%$ pebbles ≤ 50 mm and one 70 mm cobble, angular to subangular, poorly sorted; pebbles - granite, quartz, feldspar, cobble - limestone; Moderate Yellowish Brown 10YR5/4; moderately compacted, moderate reaction with HCl; moist; gradational basal contact. Next 2.5' - Clayey sand; sand - very fine to fine grained with $< 5\%$ very coarse sand and pebbles ≤ 28 mm, angular to subangular, very poorly sorted, silty in upper 0.3'; very coarse sand and pebbles - limestone, granite, sandstone nodules; Grayish Orange 10YR7/4 to Moderate Yellowish Brown 10YR5/4 where no silt; loose to slightly compacted, moderate to strong reaction with HCl; moist; gradational basal contact. Lower 0.7' - Sandy clay; sand - very fine to fine grained with approximately 3% very coarse sand and $< 1\%$ pebbles ≤ 6 mm, angular to subrounded, poorly sorted; very coarse sand and pebbles - limestone, feldspar, quartz; Moderate Brown 5YR4/4; very coarse sand occurs as stringers with CaCO_3 lining, moderately compacted, no to very slight reaction with HCl in clay, strong reaction with HCl in stringers; moist.

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LITHOLOGIC LOG--*Continued*

South Fence Road - 3 Deep (SFR-3D)

208'-222' (14.6' plus recovered) Upper 2.2' - Sandy clay with cobbles; sand - very fine to fine grained approximately 5% very coarse sand and < 1% pebbles $\leq$ 20 mm, angular to subangular, poorly sorted, cobbles - 90 mm; very coarse sand and pebbles - limestone, sandstone, cobbles - limestone; Moderate Yellowish Brown 10YR5/4; cobbles at bottom of section; compacted/bound, no reaction with HCl; wet; abrupt basal contact because of cobbles. Next 1.3' - Pebbly clayey sand; sand - very fine to very coarse grained, pebbles approximately 15% and $\leq$ 13 mm, subangular to subrounded, very poorly sorted; coarse sand and pebbles - granite, limestone and quartz; Moderate Yellowish Brown 10YR5/4; loose to slightly compacted, bound by clay, no reaction with HCl; moist; gradational basal contact. Next 4' - Sandy clay; sand - very fine to fine grained with < 2% very coarse sand and < 1% pebbles $\leq$ 25 mm, angular to subrounded, well sorted clay with coarse sand and pebbles scattered; coarse sand and pebbles - sandstone nodules, limestone, quartz; Moderate Yellowish Brown 10YR5/4; moderately compacted, no to minor reaction with HCl; wet; abrupt basal contact. Next 5.3' - Pebbly clayey sand; sand - very fine to very coarse grained, pebbles approximately 15% and $\leq$ 60 mm, subangular to subrounded; coarse sand and pebbles - granite, limestone, quartz; Moderate Yellowish Brown 10YR5/4; clay more abundant in some zones; loose to slightly compacted, minor to no reaction with HCl; moist to wet; abrupt basal contact. Lower 1.8' - Sandy clay with CaCO_3 ; sand - very fine to fine grained with < 2% very coarse grains, angular to subangular, fairly well sorted; very coarse sand - limestone, quartz, feldspar, biotite; Moderate Yellowish Brown 10YR5/4; strongly to moderately compacted, moderate to strong reaction with HCl; moist.

222'-238' (20' plus recovered) Sandy clay; sand - very fine to fine grained with < 2% very-coarse sand and < 1% gravel $\geq$ 45 mm, < 1% cobbles $\leq$ 75, subangular, fairly well sorted; very coarse sand - feldspar, quartz, gravel - limestone, cobbles - sandstone; Moderate Yellowish Brown 10YR5/4; sandstone cobbles - very fine to fine grained with < 5% very coarse grains, CaCO_3 coated; very calcareous in some zones where limestone gravel is abundant and decomposing; CaCO_3 in matrix and as nodules, moderately to strongly compacted, no reaction with HCl to strong reaction where CaCO_3 is abundant; very moist.

238'-242' (4.0' plus recovered) Upper 1.0' - Pebbly sandy clay; sand - very fine to very coarse grained, pebbles 15% and $\leq$ 30 mm, coarse sand - subangular, pebbles - subangular to rounded, very poorly sorted; sand - limestone feldspar and quartz, pebbles - mostly limestone, also quartz and feldspar; Pale Yellowish Brown 10YR6/2; decomposing gravel and sands in clay matrix, 1 limestone cobble at top of section; moderately compacted, minor to moderate reaction with HCl; moist; abrupt basal contact. Middle 1.5' - Sandy silt; sand - very fine to fine grained with < 1% very coarse grains, subangular, fairly well sorted, cobble > 85 mm; very coarse sand - limestone, cobble - limestone; Pinkish Gray 5YR8/1; limestone cobble > 85 mm at base of section with limestone fragments (broken from drilling); loose, powdery, moderate to strong reaction with HCl; dry; abrupt basal contact.

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LITHOLOGIC LOG--*Continued*

South Fence Road - 3 Deep (SFR-3D)

Lower 1.5' - Pebbly clayey sand; sand - very fine to fine grained with less medium to very coarse grains, pebbles ≤ 23 mm, angular to subrounded, very poorly sorted; very coarse sand and pebbles - granite, limestone, quartz; Pale Yellowish Brown 10YR6/2; pebbly material decomposing; moderately to strongly compacted, friable, minor to strong reaction with HCl; moist.

242'-250' (9' recovered) Upper 6.5' - Pebbly sandy clay; sand - very fine to very coarse grained, pebbles approximately 15% and ≤ 30 mm, one cobble 80 mm, sand - angular to subangular, pebbles - angular to subrounded, cobble - subrounded, very poorly sorted; pebbles - limestone, granite; Moderate Yellowish Brown 10YR5/4; sand content increases towards bottom, decomposing gravel less abundant than previous interval; moderately compacted to loosely compacted towards bottom of section, weak to moderate reaction with HCl; moist; gradational basal contact. Lower 2.5' - Pebbly sand with silt and clay; sand - very fine to very coarse grained, $\leq 15\%$ pebbles ≤ 35 mm, very poorly sorted, subangular to subrounded, some rounded limestone pebbles; pebbles - limestone, granite; Grayish Orange 10YR7/4, silty zones - Very Pale Orange 10YR8/2; decomposing limestone abundant, section includes zones of silty pebbly sand and clayey pebbly sand; slightly compacted to loose, moderate to strong reaction with HCl; slightly moist to dry.

250'-259' (7.8' plus recovered) Upper 3.2' - Gravely clayey sand; sand - medium to coarse grained, subrounded to subangular, moderately sorted, gravel - average size is approximately 25 mm with largest clast > 180 mm (edges broken from drilling), subrounded to angular, poorly sorted; sand - arkose, gravel - approximately 80% limestone, 20% granitic clasts; Moderate Yellowish Brown 10YR5/4; moderately compacted, very sticky from clay, mild to moderate reaction with HCl; moist; abrupt basal contact due to color change and moisture content change. Lower 4.6' - Gravely sand with clay; gravel - ≤ 120 mm, subrounded to angular, poorly sorted; gravel - approximately 60% granitic clasts, largest granitic clast approximately 40 mm, average granitic clast size approximately 5 mm, approximately 40% limestone, largest limestone clast approximately 120 mm, average limestone clast size approximately 8 mm (broken on all sides from drilling); Pale Red 10R6/2; moderately compacted, strong reaction with HCl to moderate reaction towards bottom; dry to slightly moist.

259'-265' (6.2' recovered) Upper 1.2' - Sandy pebbles with clay; sand - fine to coarse grained, subrounded, poorly sorted, pebbles ≤ 45 mm, predominately 10 mm, subrounded to subangular, moderately well sorted; sand - arkose, pebbles - approximately 70% limestone (larger clasts) and approximately 30% granitic clasts; matrix - Pale Red 10R6/2; moderately compacted, moderate reaction with HCl; moist (some from water adding during drilling). Lower 5.0' - Sandy gravel with clay to gravely sand with clay; sand - fine to coarse grained, gravel - subrounded to angular, poorly sorted; sand - arkose, gravel - approximately 50% limestone and 50% granite fragments; moist - Pale Red 10R6/2; moderately to strongly compacted, moderate reaction with HCl in upper 1' of section, strong reaction in middle 3.5' of section, and moderate reaction in lower 0.5' of lower 5.0'; moist (some from drilling water).

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LITHOLOGIC LOG--*Continued*

South Fence Road - 3 Deep (SFR-3D)

265'-271' (6.3' plus recovered) Upper 3.2' - Clayey sand with pebbles; sand - very fine to fine grained, < 3% medium to very coarse grains, pebbles approximately 3% and predominately < 4 mm but up to 20 mm, subangular, poorly sorted; sand - arkose, pebbles - limestone, quartz and feldspar; Light Brown 5YR5/6; iron oxide stain in upper 1'; moderately compacted, CaCO_3 in matrix and as veins, moderate to strong reaction with HCl; moist; gradational basal contact. Upper middle 0.9' - Pebbly silty sand; sand - very fine to fine grained, < 3% medium to very coarse grains, pebbles 30% and ≤ 61 mm, angular to subangular, poorly sorted; sand - quartz, arkose, pebbles - chert, limestone, sandstone (graywacke); Light Brown 5YR6/4 and Moderate Olive Brown 5Y4/4; significant pebble decomposition in this section, one 61 mm chert pebble with horizontal and vertical micro fractures, pebble is angular with conchoidal fracture at side; moderately compacted, CaCO_3 in matrix, moderate to strong reaction with HCl; slightly moist; abrupt basal contact. Lower middle 0.3' - Sandy silt; sand - very fine to fine grained, fairly well sorted; Very Pale Orange 10YR8/2; loose and powdery to moderately compacted, moderate reaction with HCl; dry; gradational basal contact. Lower 1.9' - Pebbly sand; sand - very fine to very coarse grained, pebbles $\leq 15\%$ and ≤ 40 mm, predominately ≤ 6 mm, subangular with minor angular clasts, very poorly sorted; sand - quartz, arkose, limestone, pebbles - limestone, chert, quartz, feldspar; fine matrix - Light Brown 5YR6/4; some decomposing pebbles; slightly compacted to loose, CaCO_3 abundant in upper 1.5', strong reaction with HCl at top of section to no reaction at bottom; moist.

271'-279' (7.6' plus recovered) Upper 5.8' - Pebbly sand with sandy silt zones; sand - very fine to very coarse grained, pebbles $\leq 15\%$ and ≤ 30 mm; predominately ≤ 6 mm, subangular with minor angular, very poorly sorted; sand - arkose, quartz, pebbles - limestone, fossiliferous cherty limestone, granite; Light Brown 5YR6/4, sandy silt zones - Grayish Orange 10YR7/4; sandy silt zones 0.9' to 1.2' and 2.2' to 2.7' from top of core, sand - very fine to fine grained, fairly well sorted, decomposition of pebbles in pebbly sand; moderately compacted, sandy silt zones are loose/powdery to slightly compacted, moderate reaction with HCl; moist, dry in sandy silt zones; gradational basal contact. Lower 1.8' - Clayey sand with pebbles; sand - very fine to fine grained, < 3% coarse to very coarse grains, pebbles approximately 3% and ≤ 45 mm, predominately ≤ 6 mm, subangular, moderately sorted; sand - arkose, quartz abundant, pebbles - limestone, chert, granite; Moderate Brown 5YR4/4; moderately compacted, CaCO_3 in matrix, moderate reaction with HCl; moist.

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LITHOLOGIC LOG--Continued

South Fence Road - 3 Deep (SFR-3D)

279'-283' (4.6' plus recovered) Upper 3.1' - Clayey sand with pebbles and cobbles; sand - mostly very fine to fine grained, < 2% medium to very coarse grains, pebbles < 2% and $\leq$ 40 mm, predominately $\leq$ 6 mm, cobbles - < 0.5 % and $\leq$ 71 mm, subangular to angular, poorly sorted; sand - arkose, pebbles - limestone, cherty limestone, granite; Dark Yellowish Brown 10YR4/2; decomposing pebbles; moderately compacted, moderate reaction with HCl; wet (due to drill water); gradational basal contact. Lower 1.5' - Silty sand with clay and pebbles; sand - very fine to very coarse grained, pebbles < 5% and $\leq$ 30 mm, predominately $\leq$ 6 mm, subangular, poorly sorted; sand - arkose, quartz; pebbles - limestone, quartz; Moderate Yellowish Brown 10YR5/4; moderately compacted, slight to no reaction with HCl; wet (due to drill water).

283'-296' (14.4' plus recovered) Upper 10.9' - Sandy clay with pebbles; sand - mostly very fine to fine grained with approximately 2% medium to very coarse grains, pebbles approximately 2% and $\leq$ 30 mm, predominately < 10 mm, subangular to subrounded, poorly sorted; sand - arkose, pebbles - limestone, feldspar; Moderate Yellowish Brown 10YR5/4; silty sand with pebbles and cobble zone at 10' to 12.3' from top of core, sand - very fine to fine-grained, pebbles approximately 4% and $\leq$ 10 mm, cobble - > 63 mm (fracture by drilling), subangular, poorly sorted; moderately to strongly compacted, moderate to slight reaction with HCl, strong reaction with HCl in silty-sand zone; moist; abrupt basal contact. Lower 3.5' - Sandy silt with pebbles and cobbles; sand - mostly very fine to fine grained, approximately 3% medium to very coarse sand increasing to approximately 10% towards bottom, pebbles < 2% and $\leq$ 30 mm with pebble and cobble zone from 1.6' to 2.6' below top of section where pebbles are 8% and cobbles are < 1%, cobbles - 65 to 70 mm, angular to subrounded, well sorted in upper 1.6' to poorly sorted in lower 1.9'; sand - arkose, pebbles - limestone, granite, petrified wood, cobbles - limestone, cherty limestone; Grayish Orange 10YR7/4; loose/powdery, limestone broken up and abundant in lower 1.9'; slight to moderate reaction with HCl; dry, wet in lower 1.5'.

296'-301' (5.6' plus recovered) Upper 3.4' - Sandy clay with pebbles; sand - mostly very fine to fine grained with 4% medium to very coarse grains, pebbles < 1% and $\leq$ 30 mm, some up to 60 mm, subangular, poorly sorted; sand - arkose, pebbles - limestone, cherty limestone, minor granite; Light Brown 5YR5/6; sand/clay ratio is 50:50; moderately to strongly compacted, slight to no reaction with HCl; moist; gradational basal contact. Lower 2.2' - Silty sand with pebbles; sand - very fine to very coarse grained, pebbles approximately 3% and $\leq$ 45 mm, predominately $\leq$ 20 mm; sand - arkose, limestone, pebbles - limestone; fine matrix - Grayish Orange 10YR7/4; decomposing gravel in lower part of section; loose to moderately compacted, CaCO₃ present in matrix and as veins, moderate reaction with HCl; moist.

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LITHOLOGIC LOG--Continued

South Fence Road - 3 Deep (SFR-3D)

301'-312' (10.8' recovered) Upper 0.5' - Silty sand with pebbles; sand - predominately very fine to fine grained with less medium to very coarse grains, pebbles approximately 3% and ≤ 25 mm; sand - arkose, limestone, pebbles - limestone, granite; Grayish Orange 10YR7/4; loose to moderately compacted, moderate reaction with HCl; very slightly moist to dry; abrupt basal contact. Lower 10.3' - Sandy clay with pebbles; sand - very fine to fine grained with $< 3\%$ medium to very coarse grains, pebbles $< 1\%$ and ≤ 6 mm, one pebble 50 mm, subangular, fairly well sorted; sand - arkose, pebbles - limestone, granite, 50 mm pebble is granite; Moderate Yellowish Brown 10YR5/4; moderately compacted, slight to very slight reaction with HCl; moist.

312'-317' (6.2' plus recovered) Sandy silt with pebbles and cobbles; sand - mostly very fine to fine grained becoming very fine to very coarse grained in lower 3.5', pebbles $< 1\%$ at top of section to $\leq 5\%$ towards bottom, 2 cobbles > 70 mm in upper 1.5', subangular, very poorly sorted; sand - arkose with abundant quartz, pebbles - granite, limestone, cobbles - limestone; Pale Pink 5RP8/2; decomposing pebble material in lower 1'; mostly loose/powdery with some compacted CaCO_3 cemented zones, moderate to strong reaction with HCl; very slightly moist to mostly dry.

317'-325' (6.4' recovered, lower 3' fell out of barrel back into hole) Upper 2.9' - Sandy silt; sand - predominately very fine to fine grained with approximately 5% medium to very coarse grains, subangular, moderately sorted; sand - arkose with abundant quartz; wet - Dark Yellowish Brown 10YR4/2; compacted, some mushy; wet, mostly due to water in barrel, abrupt basal contact. Lower 3.5' - Clayey silty sand with pebbles; sand - predominately very fine to fine grained with approximately 5% medium to very coarse grains, pebbles $\leq 3\%$ and ≤ 37 mm, sand - subangular, pebbles - subangular to subrounded, poorly sorted; sand - arkose, pebbles - granite, limestone; Moderate Yellowish Brown 10YR5/4; decomposing gravel in upper 1' of section; strongly compacted at top to moderately compacted in middle to slightly compacted and friable at bottom; moist.

325'-334' (9.5' recovered plus recovered 1.5' of 3' dropped from barrel during previous interval) 1.5' and Upper 2.2' - Clayey silty sand with pebbles; sand - mostly very fine to fine grained with $< 5\%$ medium to very coarse grains, pebbles $< 1\%$ and ≤ 50 mm, predominately < 6 mm, sand - subangular, pebbles - subangular to subrounded, fairly well sorted; sand - arkose, pebbles - limestone; Moderate Yellowish Brown 10YR5/4; moderately to strongly compacted, moderate reaction with HCl; moist; gradational basal contact. Lower 7.3' - Silty sand with pebbles; sand - predominately very fine to fine grained, approximately 5% medium to very coarse grains, pebble $\leq 2\%$ and ≤ 60 mm, predominately < 6 mm, sand - subangular, pebbles - subangular to subrounded, fairly well sorted; sand - arkose, pebbles - limestone, granite; Moderate Yellowish Brown 10YR5/4 where sandier, Grayish Orange 10YR7/4 where silt is abundant; sandy silt zone at 3' to 3.7' from top of core; strongly to loosely compacted, CaCO_3 abundant in matrix and as veins, moderate to strong reaction with HCl; moist, wet in lower 1.3'.

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LITHOLOGIC LOG--Continued

South Fence Road - 3 Deep (SFR-3D)

334'-336' (1' recovered) Silty sandy pebbles grading to pebbles with silt and sand; pebbles - 70% and ≤ 25 mm and predominately 2 to 10 mm in upper core, 90 to 95% and 15 to 35 mm in lower core, angular to subrounded, sand - very fine to very coarse grained, angular to subangular, very poorly sorted; pebbles - 99% limestone, 1% quartzite and greenstone, sand - limestone, quartz and feldspar; matrix - Dark Yellowish Brown 10YR4/2; loose (?), matrix has strong reaction with HCl; wet.

336'-345' (7.7' plus recovered) Upper 2.4' - Silty clay with sand and pebbles; sand - 5% and very fine to very coarse grained, angular to subangular, pebbles 8% and variable 10 to 60 mm, subangular to subrounded; sand - arkose and limestone, pebbles - limestone; Pale Yellowish Brown 10YR6/2; moderately compacted, strong reaction with HCl; wet. Middle 1.8' - Silty clay with sand; sand - 5% and very fine to very coarse grained, angular to subangular; sand - arkose and limestone; Pale Yellowish Brown 10YR6/2; moderately compacted, strong reaction with HCl; wet. Lower 3.5' - Silty clay with CaCO_3 grading to Sandy CaCO_3 with silty clay; sand - very coarse, angular, minor pebbles ≤ 6 mm; sand - arkose; matrix - Very Pale Orange 10YR8/2; pebble clasts are separated by CaCO_3 ; upper section is powdery and weakly cemented, lower section is weakly to moderately cemented, CaCO_3 as matrix throughout core, strong reaction with HCl; moderately moist.

345'-354' (13.7' plus recovered) Interbedded clayey silt and silty clay with pebbles, cobble, sand and CaCO_3 ; sand - predominately very fine to fine grained, absent where clayey, pebbles 7% and 5 to 40 mm, cobble - 80 mm, widely scattered, subangular to subrounded; pebbles - limestone, minor chert; Light Brown 5YR5/6; moderately to strongly compacted, weak reaction with HCl where clayey, moderate reaction with HCl where silty, and strong reaction with HCl in zone 4.5' to 8.3' from top of core where CaCO_3 occurs as matrix and scattered blebs; wet.

354'-361' (No recovery)

361'-372' (10.1' recovered) Upper 5.1' - Sandy silt with clay and pebbles; sand - very fine to fine grained with 5% coarse grains, pebbles 2% and 10 to 30 mm, pebbles are 10% and 2 to 5 mm in lower 0.3', subangular to subrounded; pebbles - larger clasts are limestone, minor granite; Light Brown 5YR5/6; moderately to strongly compacted, moderate reaction with HCl; wet. Middle 0.7' - Clayey sandy silt with pebbles; sand - very fine to fine grained with 5% coarse grains, pebbles 10% and 2 to 30 mm, subangular to subrounded; pebbles - larger clasts are limestone, minor granite; Light Brown 5YR5/6; moderately to strongly compacted, moderate reaction with HCl; wet. Lower 4.3' - Sandy silt with clay, pebbles and CaCO_3 ; sand - very fine to fine grained with 15% coarse grains, pebbles 3% and 20 to 40 mm, pebbles are 15 to 25% and 5 to 30 mm in 1' zones above CaCO_3 zones, subangular to subrounded, very poorly sorted; pebbles - larger clasts are limestone; Light Brown 5YR5/6, CaCO_3 zones - Moderate Orange Pink 5YR8/4; moderately to strongly compacted, CaCO_3 as matrix and abundant in central and lower zones of section, strong reaction with HCl; wet.

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LITHOLOGIC LOG--*Continued*

South Fence Road - 3 Deep (SFR-3D)

372'-380' (7.6' plus recovered) Upper 5.3' - Clayey sandy silt with pebbles and CaCO_3 ; sand - very fine to medium grained with 10% coarse grains, pebbles $\leq 3\%$ and 10 to 60 mm, subangular, widely scattered; pebbles - mostly limestone; Light Brown 5YR6/4; moderately to strongly compacted, CaCO_3 as matrix, strong reaction with HCl; wet; gradational basal contact. Lower 2.3' - Silty clay with sand and pebbles; sand - very fine to coarse grained, subangular to subrounded, pebbles 15% and 10 to 60 mm, subangular, minor subrounded; sand - quartz and arkose, pebbles - limestone and quartz; Light Brown 5YR6/4; pebbles are concentrated in 0.5' zones in the upper, middle and lower areas of section, clayey laminations; moderately to strongly compacted, moderate reaction with HCl; wet.

380'-394' (16.2' recovered) Clayey silt and silty clay with sand, pebbles and CaCO_3 ; sand - very fine to medium grained with 5% coarse grains, pebbles 5% and 10 to 60 mm, one cobble - 70 mm, subangular to subrounded; pebbles - mostly limestone; Light Brown 5YR5/6; pebbles are concentrated in 0.3' to 0.5' zones; moderately to strongly compacted, CaCO_3 as matrix in lower 3' of core, moderate reaction with HCl, strong reaction with HCl in lower core; wet.

394'-408' (14.1' recovered) Silty clay with sand, pebbles and CaCO_3 ; sand - very fine to very coarse grained, pebbles 10% and 10 to 50 mm, subangular to subrounded, poorly sorted; sand - arkose, pebbles - predominately limestone; Light Brown 5YR5/6; moderately to strongly compacted, moderate reaction with HCl, strong reaction with HCl 9' to 11.8' from top of core where CaCO_3 is abundant as matrix; very moist to wet in and near CaCO_3 zone, very wet in other zones.

Verified and edited on 24SEP92 and 21JAN93 by Cynthia Abeyta and OCT92 by George Basabilvazo, USGS

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LITHOLOGIC--*Concluded*

South Fence Road - 3 Deep (SFR-3D)

Note: Core was collected from 0.0' to 408'.

Lithologies logged by U.S. Geological Survey Geologists Cynthia Abeyta and George Basabilvazo as follows:

<u>Depth</u>	<u>Date</u>	<u>Geologist</u>
0' to 24'	21JUL92 to 21JUL92	C. Abeyta
24' to 36'	21JUL92 to 21JUL92	G. Basabilvazo
36' to 45'	21JUL92 to 21JUL92	C. Abeyta
45' to 126.5'	22JUL92 to 23JUL92	G. Basabilvazo
126.5' to 134.5'	23JUL92 to 24JUL92	J. Szalona
134.5' to 148'	24JUL92 to 24JUL92	G. Basabilvazo --
148' to 250'	25JUL92 to 26JUL92	C. Abeyta
250' to 265'	27JUL92 to 27JUL92	G. Basabilvazo
265' to 334'	10OCT92 to 21OCT92	C. Abeyta
334' to 408'	30OCT92 to 01NOV92	J. Szalona

Percentage of hole logged by each geologist:

C. Abeyta	50%
G. Basabilvazo	30%
J. Szalona	20%

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LITHOLOGIC LOG

South Fence Road - 4 Deep (SFR-4D)

Ground Elevation: 5568 feet Drilling Method/Fluids: Sonic/Dry to 114 feet; drilled with water from 114 to 168 feet (cuttings were washed out with water while driving 6 inch casing. Core was pushed out of barrel with air and water) Logged by: U.S. Geological Survey (G. Basabilvazo and J. Szalona) Drilling began: 28JUL92 Drilling completed: 05AUG92 Total depth: 168 feet Color Chart: Goddard, E.N., and others, 1984, Rock color chart: Geological Society of America, Boulder, Colo.

0'-4.5' (4.5' recovered) Upper 0.7' - Gravely silty sand with clay; sand - very fine to fine grained, gravel - ≤ 90 mm, subrounded to angular, poorly sorted; sand - arkose, gravel - 95% limestone (larger clasts), 5% granite; Moderate Yellowish Brown 10YR5/4; numerous recent roots; loosely compacted, caliche coating on gravel, slight reaction with HCl; moist; abrupt basal contact. Middle 2.2' - Gravely sandy silt; sand - rounded to subangular, gravel - ≤ 110 mm and subrounded to angular, poorly sorted; sand - arkose, gravel - approximately 95% limestone, approximately 5% or less granite; upper 1.4' of section - Very Pale Orange 10YR8/2, lower 0.8' - Light Brown 5YR6/4; loose, powdery, caliche coating on gravel, moderate to strong reaction with HCl; dry to very slightly moist; abrupt basal contact. Lower 1.6' - Gravely sandy silt; sand - very fine to fine grained, gravel - ≤ 160 mm (and larger), subrounded to angular, poorly sorted; sand - arkose, gravel - approximately 95-98% limestone, 3-5% granite; Very Pale Orange 10YR8/2; loose, powdery, caliche coating on limestone grains, strong reaction with HCl; dry.

4.5'-7' (3.2' recovered) Gravely sandy silt with clay; sand - poorly sorted, gravel - ≤ 110 mm, subrounded to angular, poorly sorted; sand - arkose, $< 1\%$ limestone, gravel - clasts ≤ 5 mm are predominately granite, clasts > 10 mm are predominately limestone; Grayish Orange Pink 10R8/2; loose, powdery, caliche coating on limestone gravel, strong reaction with HCl, very slightly moist.

7'-14' (3.8' recovered) Upper 1.7' - Sandy silt with gravel and clay; sand - well rounded, gravel - ≤ 100 mm, subrounded to subangular, poorly sorted; sand - arkose, gravel - larger clasts - limestone, smaller clasts, granite; Grayish Orange Pink 5YR7/2; loose, powdery, caliche coating on limestone gravel, strong reaction with HCl; slightly moist; abrupt basal contact. Middle 0.6' - Clayey silt with sand and pebbles; sand - very fine grained, pebbles - ≤ 40 mm; pebbles - limestone and approximately 2% granite; Grayish Orange Pink 5YR7/2; loose, powdery, caliche coatings on limestone pebbles, strong reaction with HCl; very slightly moist; abrupt basal contact. Lower 1.5' - Pebbly silty sand with clay; sand - poorly sorted, subrounded, pebbles - ≤ 60 mm, subrounded to angular, poorly sorted; sand - arkose, pebbles - clasts ≥ 5 mm are limestone, clasts ≤ 4 mm are granite; Moderate Yellowish Brown 10YR5/4; loosely compacted, caliche coatings on limestone clasts, moderate reaction with HCl; moist.

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LITHOLOGIC LOG--Continued

South Fence Road - 4 Deep (SFR-4D)

14'-18' (4.0' recovered) Upper 2.3' - Silty sand with gravel and clay; sand - very fine to fine grained, well sorted, gravel - ≤ 80 mm, poorly sorted, subrounded to subangular; sand - arkose; gravel - limestone; Moderate Yellowish Brown 10YR5/4; loose, powdery in places, caliche coating on limestone clasts, strong reaction with HCl; slightly moist; gradational basal contact. Lower 1.7' - Sandy silt with gravel and clay; sand - very fine to fine grained, gravel - ≤ 85 mm, subrounded to angular, poorly sorted; sand - arkose, gravel - limestone, granite; Grayish Orange Pink 5YR7/2; loose, powdery, caliche coating on limestone clasts, strong reaction with HCl; very slightly moist.

18'-24' (5.2' plus recovered) Gravely sandy silt with clay; sand - very fine to fine grained, well sorted, gravel - ≤ 120 mm, subrounded to angular, poorly sorted; sand - arkose, gravel - approximately 95% limestone, 5% granite and metamorphics; Grayish Orange Pink 5YR7/2; lenses of gravely sand cemented with CaCO_3 in lower 1.5'; loose, powdery except where the CaCO_3 cemented gravely zones occur, caliche coating on limestone clasts, strong reaction with HCl; very slightly moist.

24'-27' (3.0' plus recovered) Silty sand with gravel and clay; sand - very fine to fine grained, well sorted, gravel - ≤ 70 mm, poorly sorted; sand - arkose, gravel - 80% granite, 20% limestone; powdery silty clay - Grayish Pink 5R8/2, fresh broken surface of silty sand with gravel - Pale Red 10R6/2; lenses of silty sand with gravel and CaCO_3 cement ≤ 50 mm thick and subhorizontal occur throughout interval; loose and powdery between cemented silty sand with gravel, strongly cemented lenses of silty sand with gravel, caliche on some limestone clasts, strong reaction with HCl; very slightly moist.

27'-30' (3.3' recovered) Gravely silty sand with clay; sand - very fine to fine grained, well sorted, gravel - ≤ 110 mm, average size approximately 6 mm, poorly sorted, subrounded to angular; sand - arkose, gravel - 90% granite, 10% limestone; Grayish Pink 5R8/2, cemented lenses on fresh surface - Pale Red 10R6/2; approximately 50% loose/powdery, approximately 50% lenses, ≤ 35 mm thick, of strongly to moderately CaCO_3 cemented gravely silty sand with clay, CaCO_3 , caliche coatings on limestone clasts, strong reaction with HCl; slightly moist to moist.

30'-31' (1.0' plus recovered) Pebbles with sand and clay; pebbles - ≤ 50 mm, average size approximately 4 mm, sand - approximately 5%, very fine to coarse grained, pebbles - subrounded to subangular, sand - subrounded, pebbles - moderately well sorted to poorly sorted, sand - poorly sorted; pebbles - 98% granite (quartz and feldspar), 2% limestone and sandstone clasts, sand - arkose; cemented pebbles - Pale Red 5R6/2, clay - Moderate Yellowish Brown 10YR5/4; strongly cemented pebbles with sand, strong reaction with HCl; dry.

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LITHOLOGIC LOG--Continued

South Fence Road - 4 Deep (SFR-4D)

31'-41' (8.6' recovered) Upper 2.7' - Sandy gravel; gravel - ≤ 80 mm, poorly sorted to moderately well sorted in a few lenses, subrounded to subangular; clasts ≥ 20 mm - limestone, clasts ≤ 19 mm - granite, sand - arkose; Pale Red 5R6/2; lenses of strongly cemented sandy gravel, strong reaction with HCl; dry; gradational basal contact. Middle 3.6' - Claystone; silt $\leq 1\%$; Dark Yellowish Orange 10YR6/6; subhorizontal laminations, ≤ 1 mm thick, of silt and black iron stained silt; moderately compacted, approximately 1% caliche grains ≤ 2 mm, no reaction with HCl in claystone, strong reaction with HCl around caliche grains; moist; gradational basal contact, abrupt basal color change. Lower 2.3' - Silty sand with clay; sand - very fine to fine grained, well sorted, well rounded; sand - quartz; Yellowish Gray 5Y7/2; moderately to loosely compacted, strong reaction with HCl on outer weathered surface of sand and loose silty clay, no reaction with HCl on fresh broken surface except where calcite fractures and calcite spar occurs; slightly moist.

41'-48' (7.1' recovered) Claystone with silt; Yellowish Gray 5Y7/2; silty laminations, < 1 mm thick, with iron stain in lower 3.2', increasing silt towards bottom of core; moderately to strongly compacted, no reaction with HCl; moist.

48'-51' (3.3' recovered) Silty claystone; Yellowish Gray 5Y7/2; laminations, ≤ 1.5 mm thick, of silt interbedded in claystone, silt increases towards bottom, thin, ≤ 1 mm, Grayish Red 5R4/2 clay laminations in bottom 40 mm of core; moderately to strongly compacted (broken up from drilling) no reaction with HCl; moist.

51'-66' (15.5' recovered) Upper 2.2' - Silty sandstone; sandstone - very fine to fine grained, well sorted; abundant quartz; Moderate Yellow 5Y7/6, mottled zones - Dark Reddish Brown 10R3/4 and White N9; irregular mottling of Moderate Yellow 5Y7/6 and Dark Reddish Brown 10R3/4 zones, subhorizontal to wavy laminations of silty sand ≤ 1 mm to 2 mm thick, some black iron stain scattered throughout; moderately to strongly compacted, White N9 mottled zones (some vertical) react strongly with HCl, probably some gypsiferous material in matrix; dry to very slightly moist; gradational basal contact. Middle 5.2' - Silty sandstone with clay; sandstone - very fine to fine grained, well rounded, well sorted; sandstone - quartz, probably gypsiferous; Dusky Yellow 5Y6/4; laminations, ≤ 1 mm to 2 mm thick, and interbedded clay in lower 1' of section, some black iron stain in matrix, slightly fractured (probably from drilling); strongly to moderately compacted, calcareous from about 2.0' to 4.0' from top of section, strong reaction with HCl; dry to very slightly moist; abrupt basal contact. Lower 8.1' - Silty claystone with sand; sand - very fine to fine grained, well rounded, well sorted; sandstone - quartz with some gypsiferous material; Dark Reddish Brown 10R3/4 with some Dusky Yellow 5Y6/4 mottled zones; yellow silty zones occur throughout, some zones are vertical; upper part of section has White N9 zones that react strongly with HCl; strongly compacted; moist to slightly moist to dry at bottom.

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LITHOLOGIC LOG--Continued

South Fence Road - 4 Deep (SFR-4D)

66'-71' (5.4' recovered) Silty claystone; 85% is Grayish Red 5R4/2, approximately 10% is Light Brownish Gray 5YR6/1 clay towards bottom of core, approximately 5% is Dark Yellowish Orange 10YR6/6 where silty; discontinuous lenses, ≤ 30 mm thick, subhorizontal, bleby mottled zones throughout; moderate reaction with HCl in 40 mm zone 1' from top of core, no reaction with HCl in lower core; slightly moist

71'-77' (10.4' recovered) Upper 3.6' - Claystone; Dark Reddish Brown 10R3/4 with some Dark Yellowish Orange 10YR6/6 and Medium Light Gray N6; some clay has a mottled appearance, minor subhorizontal discontinuous blebs; strongly compacted, no reaction with HCl; moist; gradational color change. Middle 1.7' - Claystone; Grayish Red Purple 5RP4/2 with some Medium Light Gray N6; mottled fabric; strongly compacted, no reaction with HCl; moist; gradational color change. Lower 4.7' - Claystone; Light Gray N7; mottling other colored clays in with the Light Gray N7 claystone; strongly compacted, no reaction with HCl; moist.

77'-90' (20.2' recovered) Upper 5.6' - Claystone; Grayish Red 5R4/2, some claystone Yellowish Gray 5Y7/2; mottled (mixed), some nodular zones ≤ 40 mm Grayish Olive 10Y4/2 (fresh surface); strongly compacted, no reaction with HCl; moist; gradational color change. Upper middle 5.8' - Claystone; Dusky Yellow 5Y6/4, approximately $\leq 5\%$ Grayish Red 5R4/2; mottled (broken up by drilling and removal from core barrel); strongly compacted, no reaction with HCl; moist; gradational color change. Lower middle 4.6' - Claystone; Pale Red 5R6/2, mottled zones - Pale Red 5R6/2 and Yellowish Gray 5Y7/2; subtle horizontal laminations (possibly caused by slip along bond-planes in claystone from differential drill rotation); strongly compacted, no reaction with HCl; moist; gradational color change. Lower 4.2' - Claystone with silt; Dusky Yellow 5Y6/4; discontinuous silty laminations ≤ 1 mm thick in lower section; strongly compacted, no reaction with HCl; slightly moist.

90'-100' (13.4' recovered) Claystone; Olive Gray 5Y4/1 with thin, ≤ 1 mm, zones of discontinuous wavy clay laminations Dusky Yellow 5Y6/4; laminations and vertical partings; strongly compacted, no reaction with HCl; upper 9.4' - moist, lower 4.0' - slightly moist.

100'-106' (10.6' recovered) Claystone; Light Olive Gray 5Y6/1, mottled zones - Dusky Yellow 5Y6/4; mottled zones scattered throughout core; strongly compacted, no reaction with HCl; slightly moist

106'-110' (5.8' recovered) Claystone; Light Olive Gray 5Y6/1, mottled zones - Dusky Yellow 5Y6/4; strongly compacted (broken up from drilling), no reaction with HCl; very slightly moist.

110'-114' (7.6' recovered) Claystone; Olive Gray 5Y4/1 with mottling; irregular wavy lamina dip to 10° from horizontal, minor scattered iron stains, irregular slickenside approximately 20° from horizontal located two-thirds down interval; recovered mostly as nodular-sized pieces due to drilling, moderately compacted with powdery zones in lower part of interval, no reaction with HCl; moist.

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LITHOLOGIC LOG--Continued

South Fence Road - 4 Deep (SFR-4D)

114'-120' (10.3' recovered) Claystone; minor silt; Olive Gray 5Y4/1, shaley bleb with near horizontal bedding 2.7' from top of interval - Olive Black 5Y2/1; crude, irregular, near-horizontal bedding; moderately compacted, no reaction with HCl; moist.

120'-125' (11' recovered) Claystone; minor silt in upper interval; Olive Gray 5Y4/1; irregular slickensides 25° to 40° from horizontal near base of interval; recovered as 10 to 20 mm disks with edges concave down (due to drilling), no reaction with HCl; moist.

125'-129' (6.7' recovered) Claystone; minor silt in zones throughout core; Olive Gray 5Y4/1, lower core - Grayish Olive Green 5GY3/2; moderately compacted, no reaction with HCl; moist.

129'-137' (10.0 recovered) Claystone; minor silt; Olive Black 5Y2/1 grading downward to Olive Gray 5Y4/1, upper portion is frequently discolored green with the lower portion discolored green to iron stained orange/yellow; moderately compacted, no reaction with HCl; moist.

137'-142' (10.1' recovered) Claystone; minor silt; Olive Gray 5Y4/1, scattered light green to orange yellow blebs in upper 2.0' of section; moderately compacted, strong reaction with HCl on top of bleb at 2.0' from top of section, no reaction with HCl on rest of core; moist.

142'-146' (8.4' recovered) Claystone; minor silt in zones throughout core; Light Olive Gray 5Y5/2 to Olive Gray 5Y3/2; upper 4' has yellow blebs and spots of iron stains, lower 3' of interval has irregular slickensides dipping 25° to 45° from horizontal; moderately compacted, no reaction with HCl; moist.

146'-148' (2.8' recovered) Claystone; minor silt; mottled Light Olive Gray 5Y5/2 and Olive Gray 5Y3/2; poorly defined near-horizontal irregular laminations with scattered yellowish iron stains; moderately compacted, no reaction with HCl; moist; abrupt basal contact.

148'-151' (6.3' recovered) Clayey siltstone; Grayish Olive Green 5GY3/2; very poorly defined near-horizontal bedding; moderately to strongly compacted where recovered as 20 to 30 mm thick discs, otherwise powdery, moderately cemented, no reaction with HCl; moist.

151'-168' (6.7' recovered) Upper 0.1' - Sandstone; very fine to fine grained, subangular to subrounded; contains strata of 3 mm marcasite spots; Grayish Green 10GY5/2; strongly compacted, moderately to strongly cemented, recovered as fractured and worn disk (due to drilling), no reaction with HCl. Next 0.1' - Clayey siltstone; Grayish Olive Green 5GY3/2; very poorly defined near-horizontal bedding; moderately to strongly compacted, recovered as 20 to 30 mm thick discs, moderately cemented, no reaction with HCl; moist. Next 4.9' - Clayey to sandy silt with claystone; sand - very fine to fine grained, subangular to subrounded; Grayish Olive Green 5GY3/2; no reaction with HCl. Lower 1.6' - Silty claystone and clayey siltstone; Grayish Olive Green 5GY3/2; center of section has iron stained bleb 0.1' thick; moderately cemented, no reaction with HCl.

Verified and edited on 16SEP92 and 19JAN92 by Cynthia Abeyta, Joe Szalona OCT92, and George Basabilvazo OCT92, USGS

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LITHOLOGIC--*Concluded*

South Fence Road - 4 Deep (SFR-4D)

Note: Core was collected from 0.0' to 168'.

Lithologies logged by U.S. Geological Survey Geologists George Basabilvazo and Joe Szalona as follows:

<u>Depth</u>	<u>Date</u>	<u>Geologist</u>
0' to 110'	28JUL92 to 29JUL92	G. Basabilvazo
110' to 168'	04AUG92 to 05AUG92	J. Szalona

Percentage of hole logged by each geologist:

G. Basabilvazo	65%
J. Szalona	35%

Appendix E: Geophysical Logs

Appendix E contains copies of geophysical logs run during the SFR-Phase I drilling activities and a brief introduction on the benefits and limitations of each logging method/tool. Also contained in this appendix are preliminary log interpretations for the SFR boreholes.

Density Logs

Density logs, also known as gamma-gamma logs, are records of the radiation received at a detector from a gamma source in the probe, after it is attenuated and scattered in the borehole. The logs can be calibrated in terms of bulk density under the proper conditions and converted to porosity if grain and fluid density are known (Keys, 1990). Density logs are not generally used for lithologic distinctions unless they are carefully calibrated; i.e., they do not distinguish between clay and sand layers, but, they can distinguish between gravel and sand layers or bedrock. In addition, they can provide information on large voids adjacent to the borehole; washed-out intervals show up as having a smaller bulk density or larger porosity than the same intact lithology.

The volume of investigation of a gamma-gamma probe has an average radius of 5 to 6 inches; 90% of the pulses recorded originate within this distance. However, the volume of investigation is a function of many factors. The density of the material being logged and any casing, cement, or mud through which the radiation must pass have a substantial effect on the distance the gamma photons will travel before being stopped. Generally, the greater the spacing between the source and the detector, the larger the volume of investigation (Keys, 1990).

Density logs suffer significant effects from borehole-diameter changes, in addition to casing, cement, gravel pack, and mud cake. Casing, cement, and gravel pack will introduce large enough errors that quantitative interpretation of gamma-gamma logs made through these materials is questionable, unless the thickness is constant and core is available for calibration. Substantial background radiation is not a common problem in groundwater investigations, however, it should always be a consideration (Keys, 1990).

Gamma Logs

Gamma logs, also known as gamma-ray logs or natural gamma logs, are the most widely used nuclear logs in groundwater applications. Most gamma rays are produced by the decay of radioactive potassium (K) in natural materials. The most common uses of gamma logs are for identification of lithology and for stratigraphic correlation. Clays have a high K content and therefore, produce a distinctive signal on geophysical logs. As such, natural gamma logs are widely used for establishing clay or shale content of rocks, and for determining the silt and clay percentages in valley-fill sediments (Keys, 1990).

Gamma logs provide a record of the total gamma radiation detected in a borehole that is within a selected energy range. Most laboratory radiation-counting equipment provides a direct reading in pulses or counts per second or minute; this is a convenient way of measuring radiation because it is a direct reading. However, although pulses per unit time are convenient, they cannot

be used for comparing logs quantitatively, i.e., probes with different-size crystals will produce drastically different results from other probes. Hence, calibration with a source of known radiation intensity is critical for the logging system to maintain accuracy (Keys, 1990).

The volume of investigation of a gamma probe depends on several factors: 1) the energy of the radiation measured; 2) the density of the material through which the radiation must pass; and 3) the design of the probe. However, under most conditions, 90% of the radiation detected originates from material within 6 to 12 inches of the borehole wall. Because the detector is located at the center of the volume investigated, radioactivity measured when the detector is located at a bed contact will be an average of the two beds. The actual radioactivity of beds with a thickness less than twice the radius of investigation will not be recorded (Keys, 1990).

Gamma logs are influenced by any borehole conditions that alter the matrix of the material through which the radiation must pass. Hence, casing and cement, in addition to large diameter wells will decrease the recorded radiation. Borehole fluids have little or no effect on the log unless the mud is very heavy or contains radioactive materials. Thick gravel packs or those containing slightly radioactive materials such as dolomite may also decrease the response (Keys, 1990). As with most logging methods, interpretation of natural gamma logs, particularly for correlation of rock units, can be erroneous without some understanding of the geology in the study area. Hence, verification of results by core samples or cuttings is usually required.

Interpretation of gamma logs can be difficult in alluvial material where feldspar, mica and other arkosic materials (other sources of radioactive K) are abundant. The presence of these materials sometimes causes the trace response for sands to be higher than that for adjacent clay layers, whereas generally, sand would impart a lower trace response than clay. These feldspar-rich materials occur at random throughout the Santa Fe Group in the Albuquerque Basin, making correlation of gamma responses to a specific sand/clay ratio difficult, if not impossible.

Neutron Logs

Neutron logs are made with a source of neutrons in the probe and detectors that provide a record of the neutron interactions that occur in the vicinity of the borehole. Most of these neutron interactions are related to the quantity of hydrogen present, which in groundwater environments is largely a function of the water content of the material penetrated by the borehole (Keys, 1990). Thus, neutron logs are most widely used to determine the porosity and/or moisture content of the formations through which the borehole is drilled. Although neutron logs are primarily used to determine porosity and moisture content, they can also be used for lithologic and stratigraphic correlation.

Neutron logs do not measure porosity or moisture content directly. Typically, logs made with a neutron-porosity probe with long spacing and large source will demonstrate a decrease in count rate

with an increase in hydrogen content. Neutron logs are useful in a variety of applications. They can be used to determine the specific yield of unconfined aquifers by measuring the moisture content of saturated material before and after it is drained by a pumping test and to locate depth intervals where porosity may have increased from development or decreased from plugging during artificial recharge. In addition, substantial changes in packing or porosity caused by development in the annular space behind the casing or screen can also be detected by the use of neutron logs, although small changes in porosity are usually only detectable in areas of initial minimal porosity.

The volume of investigation of a neutron probe depends on the content of hydrogen or other strong neutron absorbers in the material surrounding the probe, the spacing between the source and the detector, and the energy of the neutrons. In general, 90% of the recorded signals are within 6 to 10 inches of the borehole wall. However, increased hydrogen content will decrease the radius of investigation. The radius of investigation can be increased by 1 inch with a 4-inch increase in spacing between the neutron tools (Keys, 1990).

Neutron logs are affected by many of the same borehole variables that affect gamma-gamma logs, although usually to a lesser degree. These effects include variations in borehole diameter, thickness of mud cake, salinity of the borehole fluids, mud weight, thickness of casing and cement, temperature and pressure, and elemental composition of rock matrix. Shale and clay cause errors in porosity measurements because these materials usually contain bound water, and neutron probes cannot differentiate between hydrogen in bound water and hydrogen in free water available to pore spaces. Casing causes a slight shift in neutron logs, but laboratory analyses have shown that moisture content can be as reliably measured in cased boreholes as in uncased boreholes (Keys, 1990).

Neutron logs are most effected by changes in thickness or lack of backfill (i.e., voids adjacent to the casing) in the annular space. However, with the use of a density log this anomaly can be distinguished by an experienced log analyst. This problem reinforces the necessity of interpreting logs as a suite, rather than individually.

SFR-1 Preliminary Log Interpretations

The gamma log indicates that the lithology is primarily composed of varying percentages of sand, silt and clay from the ground surface to a depth of approximately 390 ft. From a depth of 390 ft. to 394 ft. bgs, a very dry, possibly caliche layer is encountered, followed by a sand layer to a depth of 410 ft. The caliche layer cannot be verified by the lithologic logs since core was not available at this depth. The casing terminated at a depth of 410 ft. bgs. The caliper and density logs indicate that the borehole diameter is quite variable below this depth. This problem is not unexpected since flowing sands below this depth are confirmed from the logs of the driller and the on-site technical task leader. The driller was able to clean out the hole with compressed air prior to the logging operation, however, the open borehole eventually collapsed below the casing. As mentioned in the introductory geophysical logging sections, borehole variability has a large effect on the reliability of the logs. As such, no accurate interpretation is possible past the depth of 410 ft. bgs.

Areas of saturation are determined from the neutron log. The first area of high water content is located at a depth of 34-38 ft. bgs. However, cross-verification from the gamma log indicates that this area is probably high in clay content. As such, it is high in porosity but is not apt to produce water. This interpretation is verified by a review of the lithologic log, which indicates that this area is slightly moist to moist and composed of silty sandy clay. Further review of the neutron log trace indicates that a potential zone of saturation is encountered at a depth of approximately 72-78 ft. bgs. The lithologic log indicates that the geology at this depth is clayey sand to sandy clay and is moist. The well-site geologist also indicated that a probable perched saturated zone existed from 75.3-76.2 ft. bgs. Several areas of dryness are indicated on the neutron log -- 218 ft. to 222 ft. bgs; 342 ft. to 346 ft. bgs; and 389 ft. to 393 ft. bgs. The first interval from 218 to 222 ft. bgs is verified as clayey sand with abundant caliche from the lithologic logs. However, verification of the other dry areas is not possible from the lithologic logs since only cuttings were obtained at these depths.

The density log indicates that a change in density of the material is encountered from a depth of 50 to 100 ft. bgs. However, the gamma log indicates only varying percentages in clay, sand and silt content in this interval. The lithologic logs support the density change from primarily sand to a clayey sand. Another large density change is indicated for the interval from 210 to 250 ft. bgs. Again, the gamma log does not indicate a serious lithology change. However, the geologist's logs indicate a higher percentage of pebbles and cobbles in this interval which could account for the lower density.

An astute observer may notice that a density change is encountered approximately every 10 ft. on the density log. This change is apparent on all density logs for the SFR wells and is not due to density changes in the formation. Rather, this anomaly occurs every 10 ft. with regularity because of the casing joints. Where two joints of casing are screwed together the resulting casing is denser, causing a slight increase in the density log. As such, the overall trend of the density log should be interpreted instead of individual variations in the trace.

SFR-2 Preliminary Log Interpretations

The gamma log indicates that the lithology is primarily composed of varying percentages of sand, silt, and clay from the ground surface to the depth of 360 ft. bgs. However, a slightly dry, denser layer (observations from the neutron and density logs) occurs at a depth 64-66 ft. bgs that is indicative of a caliche layer as illustrated by the gamma log. The lithologic logs indicate that this interval is composed of silty clay with caliche, paralleling the information from the geophysical logs.

The neutron log shows the material from the ground surface to a depth of approximately 74 ft. bgs to be relatively dry. This analysis is verified by the lithologic logs which indicate this interval to be dry to slightly moist. The interval from 74 ft. to 210 ft. bgs appears to be slightly more saturated, with the water content from the lithologic logs ranging mostly from slightly moist to moist or very moist. The neutron log indicates a dry to very dry interval below the depth of 210 ft. to the total depth of 360 ft. bgs. However, the lithologic logs dispute this interpretation. As such, it is believed that the log is experiencing interference from a possible washout section, i.e., changes in the

borehole diameter which cause unreliability in the log. This conclusion is supported by both the driller's log and the log book of the technical task leader on-site, whose field notes indicated that a large volume of sand and water was blown out of the hole at this interval during drilling.

Generally, the density log could be used to determine possible washout areas behind the casing. However, the density log was terminated at a depth of approximately 205 ft. for this borehole. The only major deviation on the density log occurs at a depth of 90 ft. to 110 ft. bgs. The lithologic logs do not provide a reason for the drastic change in density in this interval; however, it is possible that this area also experienced a washout since the interval of interest is moist and the logs indicate that slough was recovered during each core run.

SFR-3 Preliminary Log Interpretations

The gamma log indicates that the lithology is primarily composed of varying percentages of sand, silt, and clay from the ground surface to the total depth of 408 ft. bgs. However, some particularly sandy lenses are seen in the following intervals: 16-18 ft.; 61-85 ft.; 199-203 ft.; 209-214; and, 301-347 ft. bgs. The lithologic logs verify these intervals to be mostly sandy silt or silty sand. Some predominantly clay lenses are located at the following intervals: 153-161 ft.; 222-236 ft.; 349-351 ft.; and 384-386 ft. bgs. The first two intervals are recorded in the lithologic logs as clayey sand and sandy clay, with the last two intervals described as clayey silt and silty clay.

The neutron log shows a particularly dry layer at a depth of 167 ft. to 190 ft. bgs that is suggestive of a caliche layer or calcerous material. The lithologic logs verify that this interval is calcerous sandy silt with conglomeratic lenses. Although the overall trend of the neutron log indicates that the borehole is dry to approximately 190 ft. bgs, there are a few areas of relatively higher saturation located at the following intervals: 60-66 ft.; 72-78 ft.; 94-129 ft.; and 157-167 ft., with the water table located at a depth of 190 ft. bgs. The lithologic logs describe these intervals as very slightly moist to slightly moist, with the exception of the interval from 157 to 167 ft. and the interval at 190 ft. bgs, which are recorded as being moist. Both the lithologic logs and the neutron trace indicate dry zones below the estimated water table, indicating that the initial water table is perched water. The dry intervals are identified as follows: approximately 238-242 ft.; 270-271 ft.; and 301-317 ft. bgs. The well-site geologist's log recorded these intervals as dry or very slightly moist to dry. Below a depth of 317 ft. the lithologic logs indicate the core to be moist to wet with small interspersed dry lenses.

The density log shows a significant deviation from 10 to 40 ft. bgs. No explanation for this deviation can be found in the lithologic logs. Otherwise, the trace shows no major changes in density from 40 ft. bgs to the total depth of 408 ft. bgs.

SFR-4 Preliminary Log Interpretations

The gamma log indicates an overall high clay content from a depth of 36 ft. bgs to the total

depth of 160 ft. bgs. The high clay content for this interval is verified by the lithologic logs -- 34 ft. bgs is the depth where weathered bedrock (claystone) was encountered. A severe disturbance is recorded by the gamma trace at a depth of approximately 14-26 ft. bgs. The disturbance is characteristic of a high clay content, but both the neutron and lithologic logs dispute this interpretation. Another interpretation for the relatively high gamma response could be a high arkosic content in the material. Indeed, evaluation of the lithologic logs at this interval reveals an arkosic sand which could explain the gamma response.

The uppermost 30 ft. of the neutron log show elevated moisture levels; the lithologic logs indicate that most of this area is slightly moist. An abrupt deviation in the neutron trace occurs at approximately 34 ft. bgs. This deviation coincides with the depth at which the core became non-alluvial fill material -- Abo/Yeso claystone. Below 34 ft. bgs, the neutron trace is consistent with claystone, which is verified by review of the lithologic logs.

The density log shows two major changes in this borehole. The first deviation occurs at a depth of 90-93 ft. bgs. The log indicates that this interval is less dense than the rest of the formation, but the lithologic logs do not provide an explanation for this log response. Thus, it is not known what caused the deviation in the trace for this interval. The second deviation in the trace occurs at a depth of 130-146 ft. bgs. However, this interval lies directly below the point of casing termination. As such, changes in borehole diameter can account for this response.

Well Name: SFR-1D
File Name: SFR01D
Location: KAFB-SNL South Fence Road
Elevation: 0 Reference: Ground Surface
TD = 494' (Logger)
Water Level 145'
Casing (steel) 0-410'

Well Name: SFR-2S
File Name: SFR02s
Location: KAFB-SNL South Fence Road
Elevation: 0 Reference: Ground Surface
TD = 370'
GAMMA and NEUTRON1 run through 6" casing, 0-208ft and 41/2" pipe 0-370ft.
NEUTRON2 and DENSITY run through 6" casing 0-208ft.

Well Name: SFR-3D
 File Name: SFR03D
 Location: KAFB-SNL South Fence Road
 Elevation: 0 Reference: Ground Surface
 Run #1 07/27/92 TD=265'; Run #2 11/03/92 TD=408'
 GAMMA2, NEUTRON2 and DENSITY2: 6" steel casing 0-265'
 GAMMA3, NEUTRON3, and DENSITY3: 6" steel casing 0-408'

Well Name: SFR-4D
File Name: SFR04D
Location: KAFB-SNL South Fence Road
Elevation: 0 Reference: Ground Surface
TD = 168'
6" casing (steel) 0-128ft.

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