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Summary of South Fence Road Phase II 1993 Field Operations at Site SFR-3

W. L. Foutz, J. P. McCord

Prepared by
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SUMMARY OF SOUTH FENCE ROAD PHASE II 1993 FIELD OPERATIONS AT SITE SFR-3

Site-Wide Hydrogeologic Characterization Project

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ABSTRACT

This report is a basic data report for field operations associated with the drilling, logging, completion, and development of South Fence Road Wells SFR-3P and SFR-3T. These test/monitoring wells were installed as part of Sandia National Laboratories, New Mexico, Environmental Restoration Project.

SUMMARY OF SOUTH FENCE ROAD PHASE II
1993 FIELD OPERATIONS AT SITE SFR-3

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1.0 EXECUTIVE SUMMARY

This report provides a summary of the field operations associated with the installation of the SFR-3P and SFR-3T test/monitoring wells. These wells were installed in 1993 as part of Phase II of the Site-Wide Hydrogeologic Characterization task South Fence Road project. The Site-Wide Hydrogeologic Characterization task is part of Sandia National Laboratories, New Mexico, Environmental Restoration Project carried out by the Environmental Operations Center, 7500.

SFR-3P was drilled to a total depth of 913 feet, through the Santa Fe Group into the underlying bedrock. The Santa Fe Group/bedrock contact in this well was at a depth of 485 feet. After drilling to total depth the borehole was logged, and then plugged back to a depth of 210 feet. The borehole was then completed as a Santa Fe Group test/monitoring well. The sand pack completion interval for this well is 144 feet to 210 feet.

SFR-3T was drilled to a total depth of 1,152 feet. through the Santa Fe Group into the underlying bedrock. The Santa Fe Group/bedrock contact in this well was at a depth of approximately 530 feet. After drilling to total the borehole was logged, and then plugged back to a depth of 760 feet. The borehole was then completed as a bedrock test/monitoring well. The sand pack completion interval for this well is 651 feet to 760 feet.

During these field operations, important subsurface geologic and hydrologic data were obtained. Subsurface geologic data include drill cuttings, core, and borehole geophysical logs. These data will improve the understanding of fault displacement across the Hubbell Springs fault, define the lithologic framework within the Santa Fe Group at this location, identify the stratigraphic relationship across the Santa Fe Group/bedrock contact, and establish the local stratigraphic sequence in the uppermost 600 feet of the underlying bedrock. Subsurface hydrologic data include borehole geophysical logs, and qualitative information obtained during well completion/well development. These data will help define the local hydrostratigraphic framework within the Santa Fe Group water-table aquifer, and the hydraulic potential between this water-table aquifer and the underlying confined bedrock aquifer. In addition, the test/monitoring wells (including SFR-3S and SFR-3D installed during the Phase I field operations [Neel and McCord, 1994]) provide an excellent grouping of aquifer test and observation wells. This grouping of wells is referred to as the SFR-3 hydropad. Future aquifer testing at the SFR-3 hydropad will generate data for the interpretation of aquifer parameters (transmissivity and storativity), and may yield information on anisotropy within the Santa Fe Group and the hydraulic connection between the Santa Fe Group aquifer and the bedrock aquifer.

2.0 INTRODUCTION

The Environmental Restoration (ER) Project at Sandia National Laboratories, New Mexico (SNL/NM), is managing the program to assess and, when necessary, to remediate sites on Kirtland Air Force Base (KAFB) that were potentially contaminated by SNL/NM operations. Within the ER Department, the Site-Wide Hydrogeologic Characterization (SWHC) task is responsible for the area-wide hydrogeologic investigation. The purpose of this project is to reduce the uncertainty about the rate and direction of groundwater flow beneath KAFB and across its boundaries. Phase II of the South Fence Road project is part of the SWHC task.

2.1 Background

The South Fence Road (SFR) project area is located along the southern boundary of SNL/KAFB. This area is structurally and stratigraphically complex, primarily because it is crossed by the north-trending Hubbell Spring fault and the northeast-trending Tijeras fault zone. Figure 1 shows the location of the South Fence Road project area.

The South Fence Road project was initiated to assess characteristics of subsurface lithologies in the vicinity of these faults, and to provide information on the rate and direction of groundwater flow in Santa Fe Group and underlying bedrock aquifers. Initial activities (Phase I) took place during the summer of 1992 and included installing monitoring wells at four sites along South Fence Road (Neel and McCord, 1994). Four additional boreholes were drilled at the SFR-3 and SFR-4 locations during 1993 (Phase II). This report provides a summary of the Phase II field operations at the SFR-3 location. A complete set of all the data obtained at the SFR-3 location is on file in the SNL ER Records Center.

2.2 Objective

The South Fence Road wells were drilled to investigate the subsurface geology and hydrology along the southern boundary of SNL/KAFB. Geologic objectives included: 1) identifying depth to bedrock; 2) determining and locating displacements of the Hubbell Spring and Tijeras fault zones; and 3) characterizing subsurface lithologies. Hydrologic objectives included obtaining information to reduce uncertainty about rates and directions of groundwater flow within the alluvial and bedrock aquifers, and installing monitoring/test wells in the Santa Fe Group and underlying bedrock aquifers.

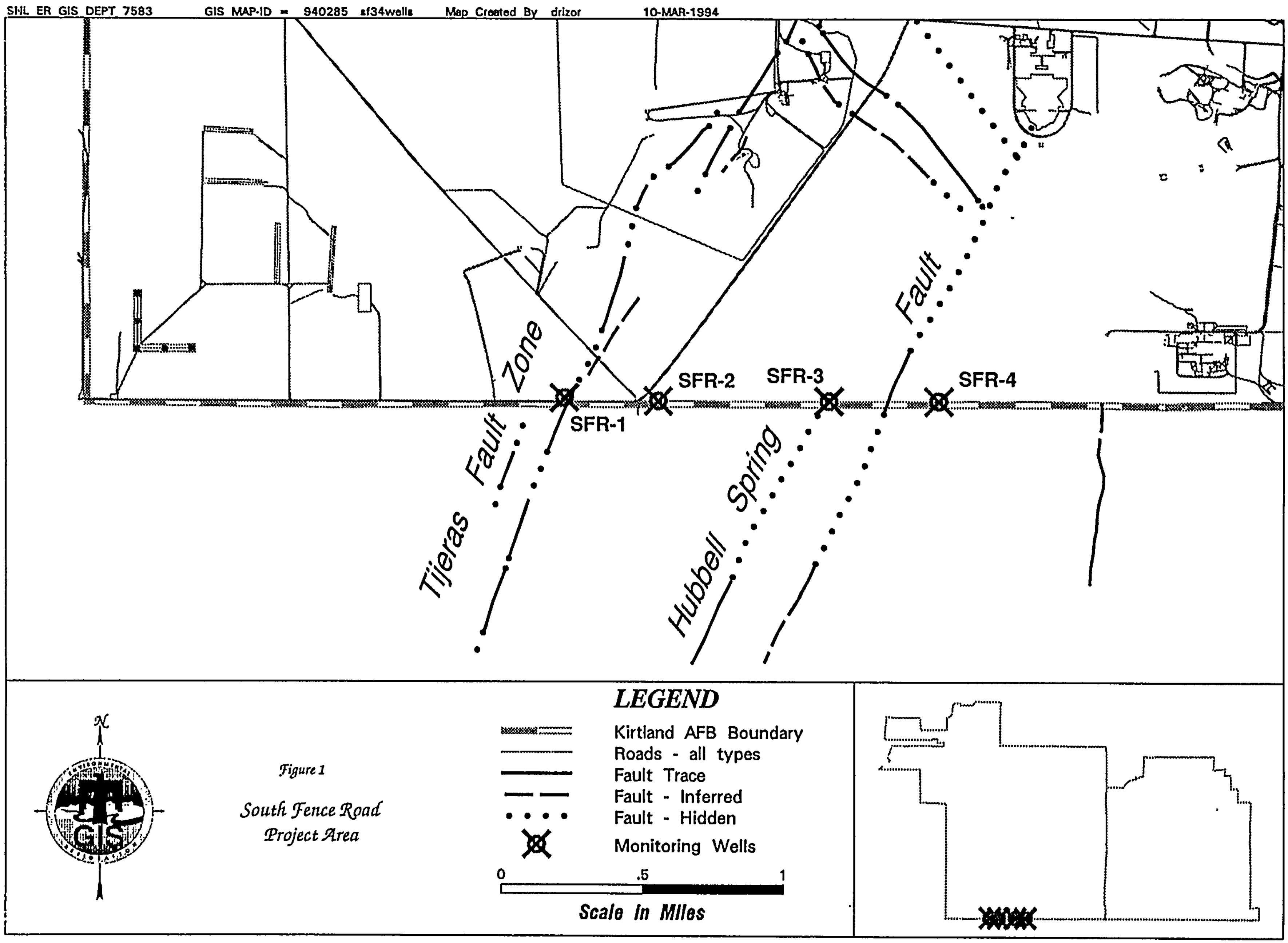


Figure 1

South Fence Road Project Area

3.0 WELL-SITE GEOLOGY

The following discussion of the well-site geology at the SFR-3 location is a brief summary of the area geology included in the Site-Wide Hydrogeologic Characterization Project Calendar Year 1993 Annual Report (SNL, 1994).

3.1 Surface Geology

South Fence Road is located on the broad, west-sloping piedmont that makes up the Upper Llano de Manzano geomorphic subprovince. The piedmont is dissected by numerous drainages that flow west to closed depressions in the McCormick Ranch geomorphic subprovince or to Hells Canyon Wash. Surficial deposits within the area are derived from the Manzanita Mountains, located about 3.1 miles to the east. Previous investigations show that the South Fence Road is underlain by piedmont-slope alluvium (gravelly sand/silt/clay) (Hawley and Haase, 1992).

3.2 Stratigraphy

The subsurface stratigraphy along the south boundary of KAFB is impacted by local and regional structural complexities, and the presence of significant unconformities. It is not well understood due to sparse sedimentary outcrops and the lack of drillholes that penetrate the full sedimentary section. The expected surface and subsurface stratigraphy is summarized in Figure 2.

The deepest and oldest bedrock formation penetrated by South Fence Road wells is tentatively identified as the Permian Yeso Formation (SNL, 1994). The top was penetrated at 865 feet at the SFR-3 site. Unconformably overlying the Yeso Formation is a grey interbedded shale, siltstone, and sandstone tentatively dated as Lower Tertiary. At SFR-3, Lower Tertiary rocks are tentatively correlative to the Galisteo/Baca/Nacimiento Formations (SNL, 1994). Depths to bedrock and total depths for the SFR-3P and SFR-3T wells are shown in Table 1.

Unconformably overlying bedrock is the Upper Tertiary Santa Fe Group that thickens dramatically from east to west. Thickness of the Santa Fe Group increases from 35 feet at SFR-4 to about 500 feet at SFR-3. The Santa Fe Group is composed of yellowish-brown, predominantly unconsolidated sandy gravel in a silty clay matrix with grain sizes that vary from cobbles to silt. The largest clasts are mainly limestone and dolomite, with trace amounts of igneous and metamorphic gravel.

KAFB AREA STRATIGRAPHY

Erathem	System	Series	Unit/Formation		Strat. Column	Description
Cenozoic	Neogene	Holocene to Middle Pleistocene	Surficial Units			Cross-bedded, fine-to-medium eolian sand Poorly sorted silty sandy cobble to boulder gravel Local unconformity Poorly sorted silty sandy cobble to boulder gravel with relict and buried soils
						← Unconformity
Cenozoic	Neogene	Early Pleistocene to Early Miocene	Santa Fe Group	Upper Santa Fe Unit		Basinal: coarse-to-fine grained sandstones; common buried soils Marginal: pebbles, cobbles in fine-grained matrix
				Middle Santa Fe Unit		Basinal: Medium- to fine-grained sandstone and mudstone; common buried soils Marginal: conglomeratic sandstone to pebbles and cobbles; common buried soils
				Lower Santa Fe Unit		Basinal: medium-to-fine sandstones, sandy mudstones Marginal: conglomeratic sandstone and mudstone
						← Unconformity
Cenozoic	Paleogene	Oligocene	Unit of Isleta # 2 Well			Fine-to-coarse-grained sandstone with claystones and silty interbeds
						← Unconformity
		Eocene to Paleocene	Baca/Galisteo/Nacimiento Formations			Sandstone, variegated mudstone, and conglomerate
						← Unconformity
Upper Mesozoic		Upper Cretaceous	Mancos Equivalent			Claystone w/ calcareous lenses, carbonaceous beds
						← Unconformity
Upper Paleozoic		Lower Permian	Yeso Formation			Upper: gypsiferous sandstone, siltstone, limestone Lower: fine-grained sandstone and siltstone
			Abo Formation			Fine- to coarse-grained sandstone and conglomerate with interbedded siltstone
		Upper to Middle Pennsylvanian	Madera Formation	Wild Cow Member		Rhythmically bedded sequence: conglomerate, sandstone, siltstone, shale, limestone
				Los Moyos Limestone		Gray calcarenite with chert
		Middle Pennsylvanian	Sandia Formation			Fining-upwards clastic sequence: conglomerate to calcareous siltstone
		Mississippian	Arroyo Peñasco Group			Dense, gray, fine-grained to oolitic limestone
						← Unconformity
Precambrian			Sandia Granite Tijeras Greenstone Coyote Canyon Sequence Sevillita Rhyolite			Microcline and biotite granite; metarhyolite; quartzite; greenstone

182.29A/4 1.3LAI012

Figure 2. Generalized Stratigraphic Column for KAFB

Table 1. Depth to Bedrock* and Total Depth of the SFR-3P and SFR-3T Wells

BOREHOLE	SFR-3P	SFR-3T
Estimated Bedrock Depth from Gravity Data (ft. bgs) [1992 Revision]	408	408
Total Depth of Wells (ft. bgs)	913	1152
Actual Depth to Bedrock Contact of Wells Drilled in 1993 (ft. bgs)	485	530
Difference [Actual-Estimated (ft.)]	77	122

* - Bedrock defined as consolidated rock below Santa Fe Fm.

3.3 Structure

Several regional faults intersect in the South Fence Road area and are shown in Figure 1. The Hubbell Spring fault is a normal fault with down-to-the-west displacement. The northeast-southwest Tijeras fault zone has numerous documented horizontal and vertical displacements. The interaction of these major faults resulted in a complexly faulted area, with a number of short cross faults.

The main western strand of the Hubbell Spring fault is directly east of the SFR-3 site and is penetrated by SFR-3P and SFR-3T at 485 feet and 530 feet, respectively. Based on core evidence from both SFR-3 site wells, beds in the faulted zone are highly contorted and fractured. This fault, with a disrupted zone of approximately 60 feet true thickness, juxtaposes Santa Fe Group and lower Tertiary bedrock. There is an estimated 900 feet or greater pre-Santa Fe Group displacement on the fault, which precludes correlation with SFR-4 wells (SNL, 1994).

4.0 BOREHOLE/WELL CONSTRUCTION INFORMATION

Drilling operations at the SFR-3 site were conducted by the United States Geological Survey (USGS) and supervised by SNL/NM personnel. The drilling techniques included air rotary, mud rotary, and mud rotary coring. The following sections summarize the drilling, well installation, and well development operations carried out at the SFR-3 site.

4.1 Background

Drilling activities for the South Fence Road (SFR) project were conducted in two phases over a period of 18 months. Phase I, undertaken during the summer of 1992, involved drilling four boreholes and completing five monitoring wells (including two dual completions) (Neel and McCord 1993). Phase II, undertaken during the spring/summer of 1993, involved drilling four boreholes, and completing three monitoring/test wells and one observation well. The well names are based on a system where a number designates the well site location, and various letters designate the type of well; the letters are "S" for shallow, "D" for deep, "P" for pilot, and "T" for test. Phase I resulted in the installation of the SFR-1S, SFR-1D, SFR-2, SFR-3S, SFR-3D, and SFR-4D test/monitoring wells. Phase II resulted in the installation of the SFR-3P, SFR-3T, SFR-4P, and SFR-4T test/monitoring wells. Figure 3 shows a map view of the different wells at the SFR-3 and SFR-4 locations. This report provides a summary of the field operations associated with SFR-3P and SFR-3T.

4.2. SFR-3 Well Installation Plan

The SFR-3 location is located approximately 2,500 feet west of SFR-4 (Figure 3). The total depth of the Phase I borehole (SFR-3S/3D) at this site was 408 feet. Bedrock had not been encountered. Therefore the Phase II plan was to drill a pilot hole (SFR-3P) to reach bedrock with a maximum projected depth of 1000 feet. This borehole would then be plugged back to an appropriate screen interval in the Santa Fe Group to complete a shallow alluvial test well. Based on the information gained from this pilot hole, a bedrock test/monitoring well (SFR-3T) would then be drilled and installed adjacent to SFR-3P. A schematic map and cross section of the SFR-3 location is shown in Figure 4. Because this location will provide the opportunity to accomplish aquifer testing involving multiple boreholes and different aquifer units, it is referred to as the SFR-3 hydropad.

4.3 Drilling Operations

Drilling chronologies for both wells at the SFR-3 location are presented in graphic format in Figures 5 and 6. All drilling, well completion and well development was performed by USGS personnel and equipment. Typically, drilling operations were conducted in 10-day work cycles.

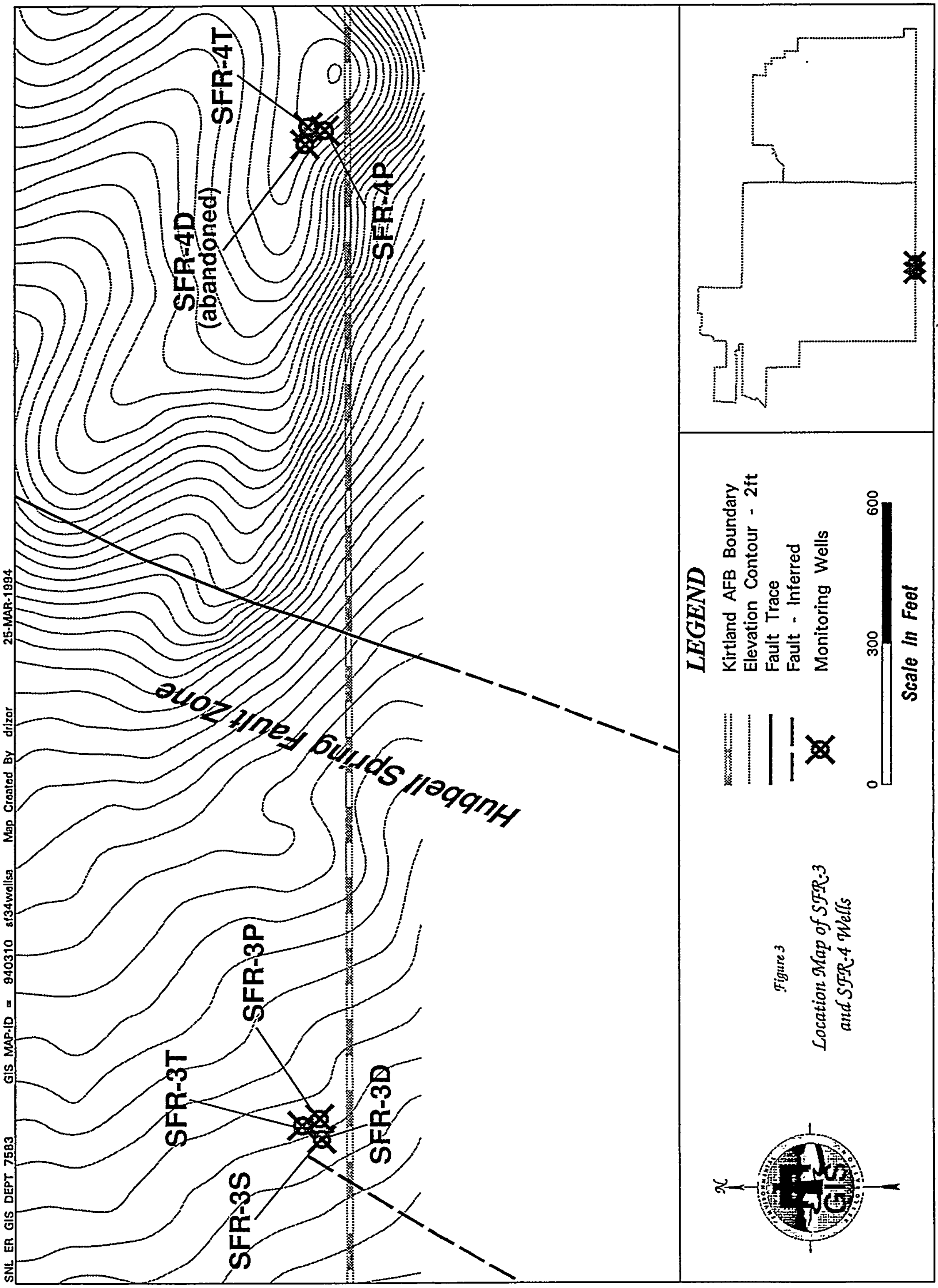


Figure 3

Location Map of SFR-3 and SFR-4 Wells

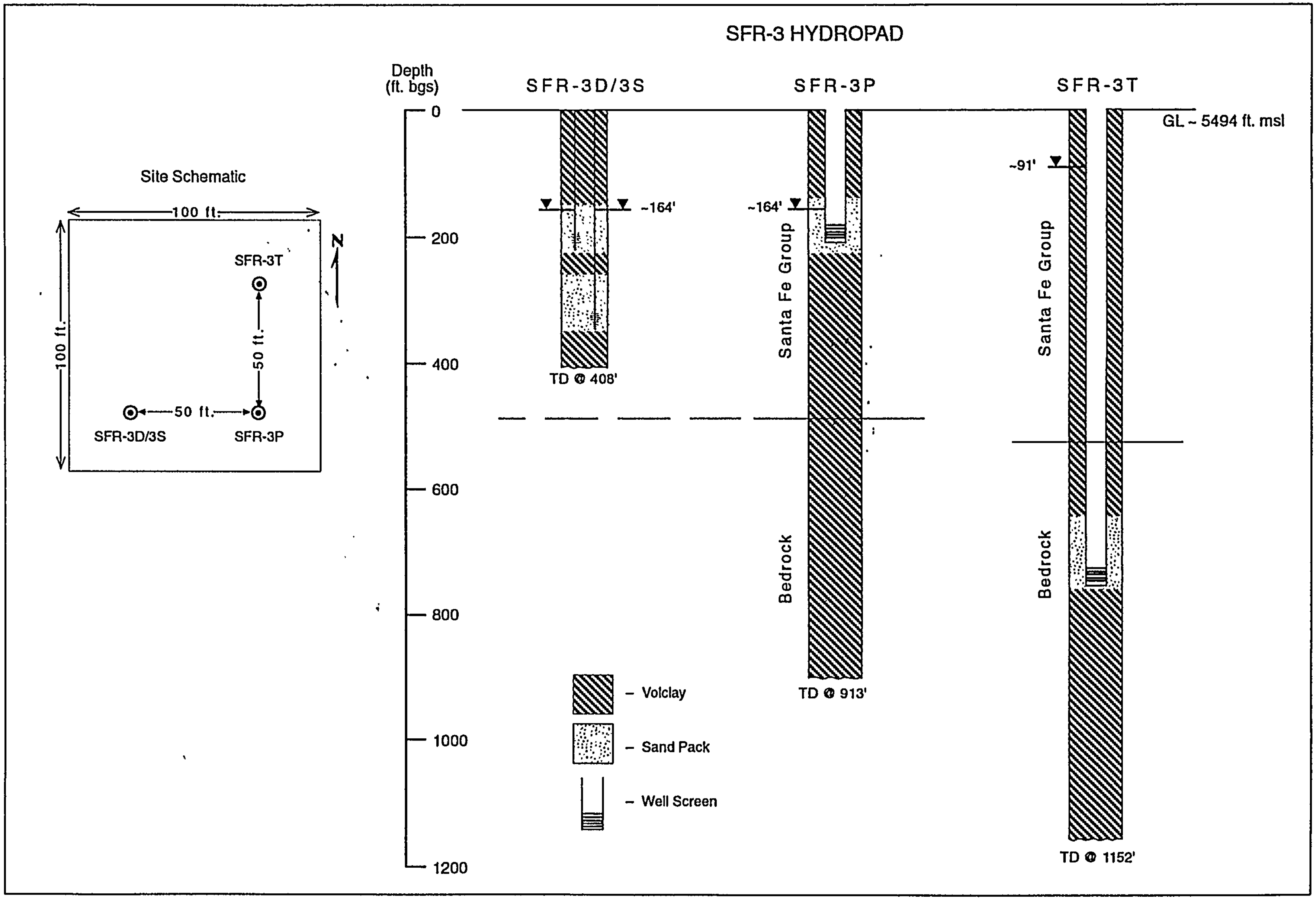


Figure 4. Schematic Map and Cross-Section of the SFR-3 Hydropad

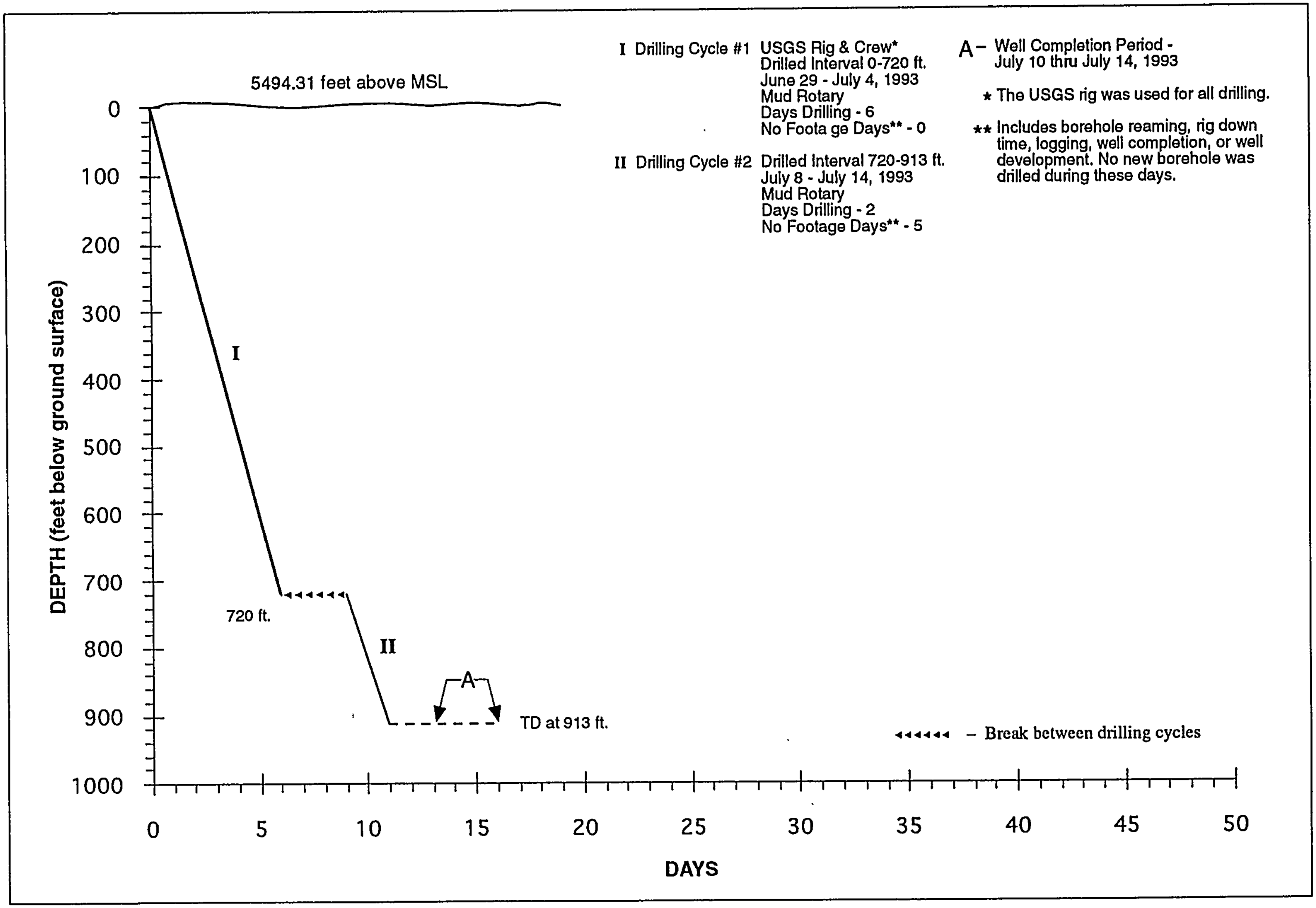


Figure 5. Summary of Drilling Chronology for SFR-3P

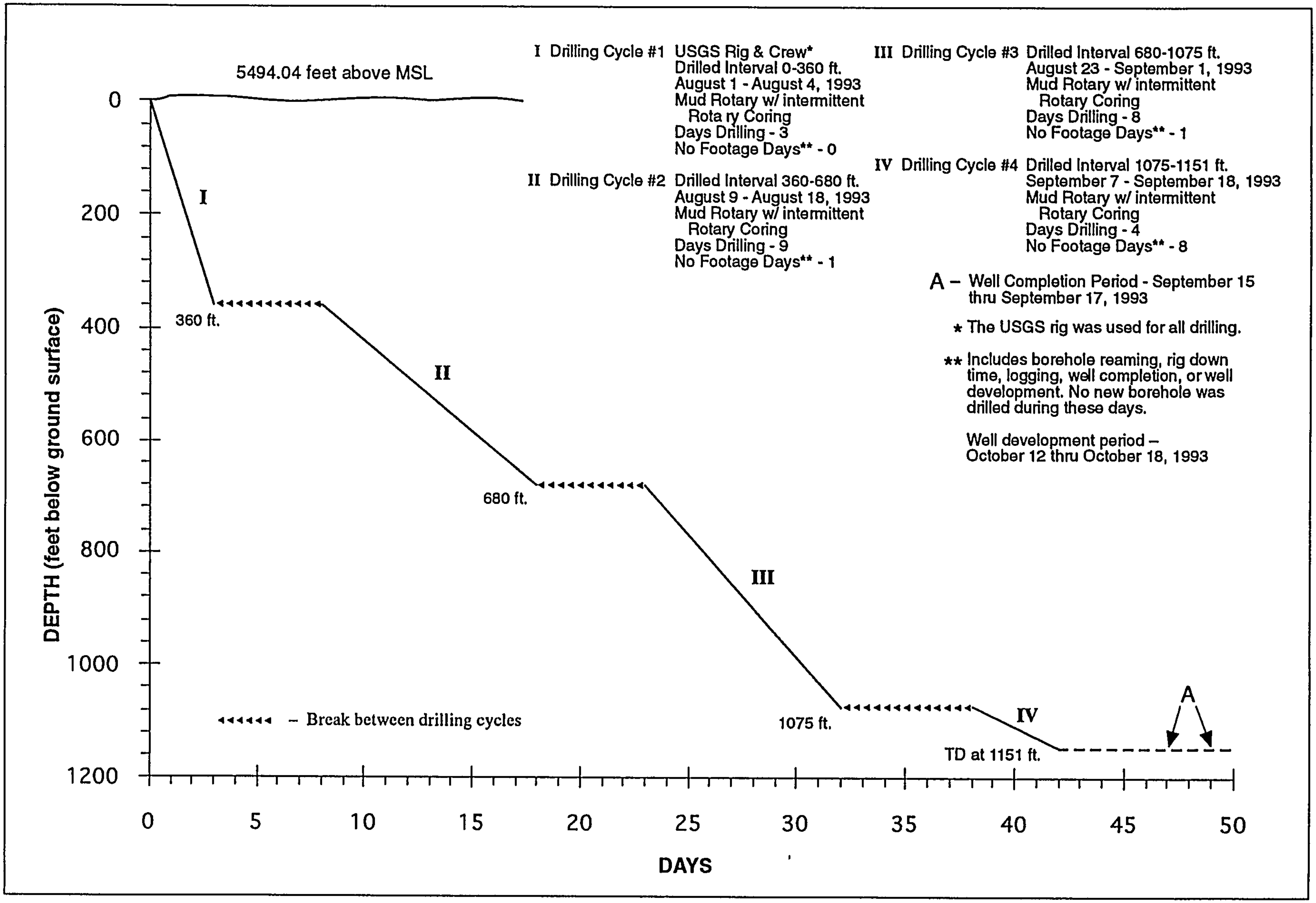


Figure 6. Summary of Drilling Chronology for SFR-3T

4.3.1 SFR-3P Drilling Operations

Drilling commenced on June 29 using mud rotary technique. During drilling the borehole diameter changed with depth as follows: an 8-inch borehole was drilled from surface to 520 feet; a 6-3/4 inch borehole was drilled from 520 to approximately 600 feet; and a 5-7/8 inch borehole was drilled from 600 feet to the total depth of 913 feet. Figure 7 shows the generalized bedrock lithology, and a well completion schematic for SFR-3P. A total of 8 days of drilling in two cycles were required to reach this total depth. The open hole was then logged by USGS and COLOG, and the well was completed by July 14.

4.3.2 SFR-3T Drilling Operations

Drilling commenced on August 1 using mud rotary drilling with intermittent coring in zones of interest. During drilling the borehole diameter changed with depth as follows: a 10-inch borehole was drilled from surface to approximately 765 feet; a 6-3/4 inch borehole was drilled from surface to approximately 920 feet; and a 5-7/8 inch borehole was drilled from 920 feet to the total depth of 1,152 feet. Figure 8 shows the generalized bedrock lithology, and a well completion schematic for SFR-3T. Cores were taken in seven intervals, resulting in a total of 118 feet of core. A total of 24 days of drilling in 4 cycles were required to reach total depth on September 10, 1993. The open hole was logged by USGS and the well was completed by September 17.

4.4 Well Completion

Well completion relationships at the SFR-3 hydropad are shown in Figure 4. Standard SNL well completion diagrams for SFR-3 wells are presented in Appendix A. All depths mentioned in the following sections on well completion are feet below ground level (bgl). SFR-3P is an alluvial well, completed in the Santa Fe Group. SFR-3T is completed in Lower Tertiary (?) consolidated bedrock.

4.4.1 SFR-3P Well Completion

This borehole was plugged back from a total depth of 913 feet to 255 feet with volclay (powdered bentonite slurry). A size 10/20 sand pack was added to 217 feet and then topped with a bentonite pellet seal to 210 feet. SFR-3P was completed in the Santa Fe Group as a 4-inch Schedule 80 PVC well with a 10-foot stainless steel sump below a 20-foot 0.020-inch slotted stainless steel screen. The screened interval is from 175 feet to 195 feet. The sand pack in the completion interval includes size 10/20 silica sand from 210 feet to 150 feet, and size 16/40 sand from 150 feet to 144 feet. Overlying this sand pack is a 10-foot thick bentonite pellet seal (144 to 134 feet). Above this seal, the annulus is filled with a volclay bentonite slurry (134 feet to surface). The surface completion is a steel protective casing with a locked lid, surrounded by a concrete apron. Well completion details and water-level elevations for SFR-3P are summarized in Table 2.

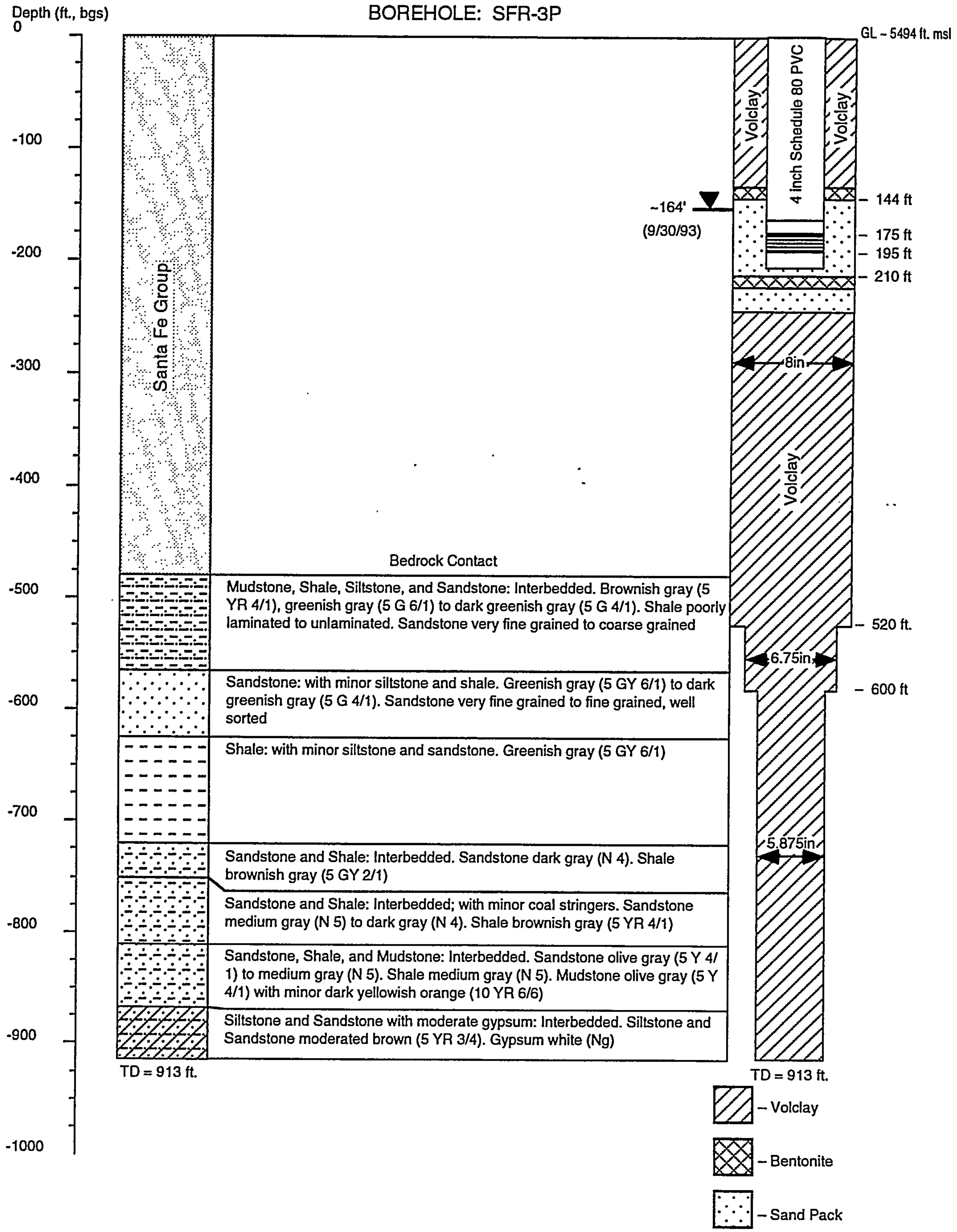


Figure 7. Generalized Bedrock Lithology and Well Completion SFR-3P

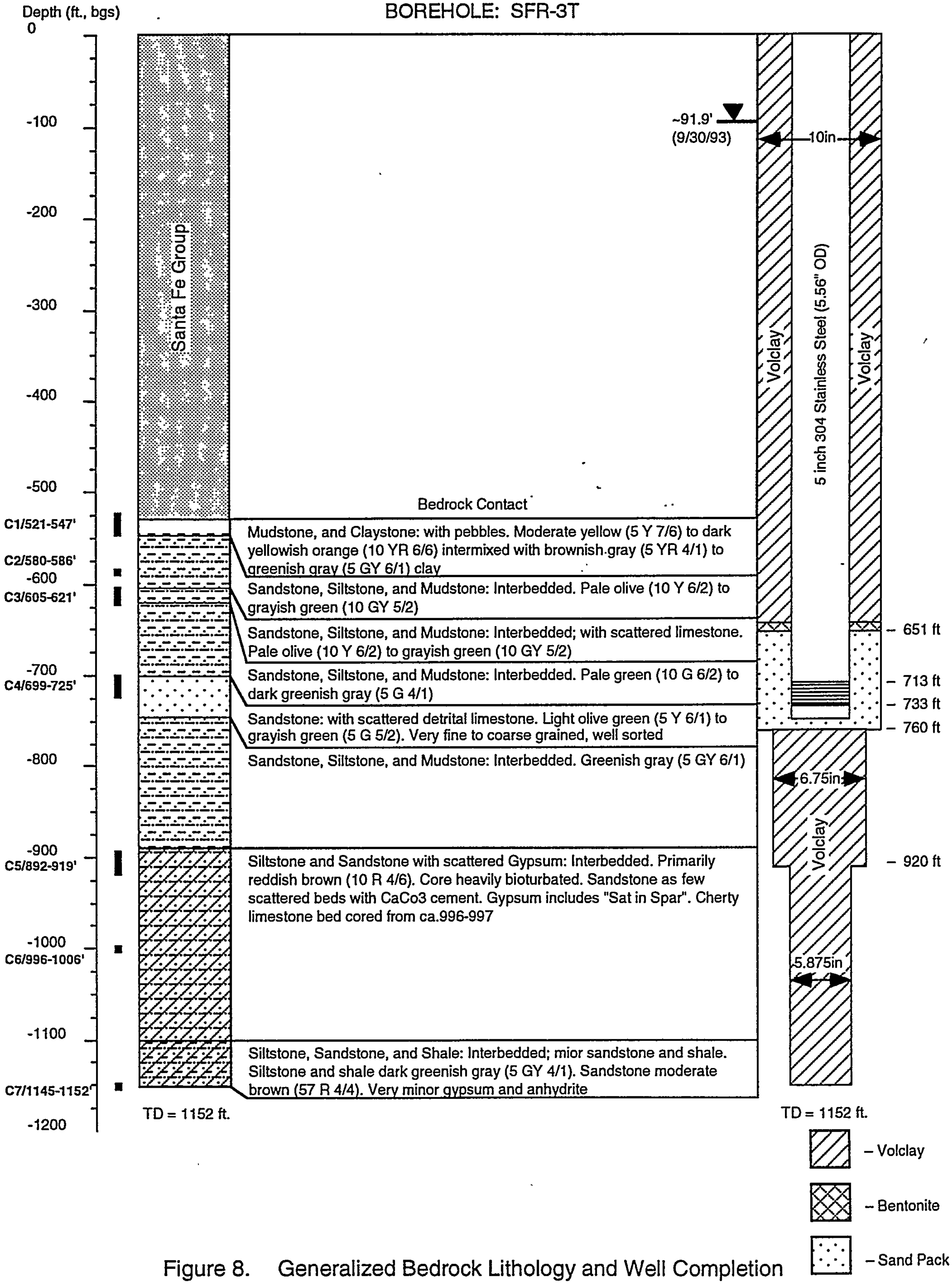


Figure 8. Generalized Bedrock Lithology and Well Completion SFR-3T

Table 2 -Well Completion Information for the SFR-3P and SFR-3T Wells

SURVEYED ELEVATIONS SFR WELLS 1/19/94	SFR-3P	SFR-3T
Ground Elevation (ft. above MSL)	5494.31	5494.04
Elevation of Top of Casing (ft. above MSL)	5496.96	5495.99
Water Level[1] (ft. below top of casing) Measured 1/19/94	164.01	87.42
Water Level Elevation (ft. above MSL)	5332.95	5408.57
Monitored Formation	Santa Fe Group	Lower Tertiary Bedrock
Gravel Pack Depth Interval (ft. below ground level)	144-210	651-760
Gravel Pack Elevation Interval (ft. above MSL)	5350-5284	4843-4734
Screen Depth Interval (ft. below ground level)	175-195	713-733
Screen Elevation Interval (ft. above MSL)	5319-5299	4718-4761

[1] - Measurement date - January 19, 1994

4.4.2 SFR-3T Well Completion

This borehole was plugged back from total depth of 1,152 feet to 760 feet with a volclay bentonite slurry. SFR-3T was completed in bedrock as a 5-inch stainless steel well with a 20-foot sump below a 20-foot 0.020-inch slot continuous wire-wound stainless steel screen. The screened interval is 713 feet to 733 feet. The sand pack in the completion interval includes 10/20 silica sand from 760 feet to 651 feet, and includes a one foot interval of 16/40 sand at 654 feet. Overlying this sand pack is a 2-foot thick bentonite pellet seal (652 to 654 feet). Above this seal, the annulus is filled with a volclay bentonite slurry (652 feet to surface). The surface completion is a steel protective casing with a locked lid, surrounded by a concrete apron. Well completion details and water-level elevations for SFR-3T are summarized in Table 2.

4.5 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 the drilling/well completion process. Well development was performed according to the ER department procedure, PRO 92-08 (Wood, 1992). This field operations procedure (FOP) identifies the methodology and standards for developing a well until representative formation water can be accessed through the well. Representative formation water is defined as water produced from the formation that is considered to be free of drilling fluids, cuttings, and other material introduced into a well during the drilling/well completion process. Standards used to make this determination include water that is visually clear (low turbidity), and water with relatively stable (+/- 10%) pH, temperature, and specific conductivity. In addition, the FOP calls for the removal of a minimum of 5 well-bore volumes. Well development information for SFR-3P and SFR-3T are summarized in Table 3.

4.5.1 SFR-3P Well Development

Well development occurred immediately after well completion in July 1993. Drilling mud was evacuated from the well by airlifting, which is accomplished by jetting the hole with compressed air. The well was then surged with 50 gallons of clean water and airlifted dry several times. Water clarity improved quickly and the well was pumped at about 5 gpm. Turbidity measurements stabilized at <10 NTU after one day of pumping, and well development was completed in a total of a day and a half.

4.5.2 SFR-3T Well Development

Development of SFR-3T was conducted in October 1993 after drilling operations had ceased for the season. This well is by far the best water producer of all the SFR wells drilled in 1993, and also has the largest hydrostatic head above the well screen (approximately 620 feet). Due to the relatively fast recharge of this well, it was developed by pumping down to the pump intake and allowing it to recover before starting the pump again. A submersible

Table 3. Well Development Information for SFR-3P and SFR-3T

WELL DEVELOPMENT	SFR-3P	SFR-3T
Casing Diameter [O.D.] (inches)	4	5
Well Bore Volume (gal.)	28 (.65 gal/ft)	681 (1.02 gal/ft)
Volume Purged (gal.)	900	< 10,000
Method	Air Lift & Surge	Submersible Pump
Discharge Rate (gpm)	5	3 to 30
Date	July 13-14, 1993	Oct 14-26, 1993
Water Level [Start/End] (ft.)	161.9/161.5	84.9/nm
Temperature [Start/End] (°C)	21.8/21.7	nm
pH[1] [Start/End]	8.03/8.27	nm
Conductivity[2] [Start/End] (mmhos)	1417/1210	nm
Turbidity[3] [Start/End] (NTU)	295/9.3	variable <1000 to 23

[1] Measured with Orion pH/ISE meter.
[2] Measured with Hach 44600 Conductivity/TDS meter.
[3] Measured with Hach 2100P Turbidimeter.
nm - not measured.

pump on a timer was used to pump the well, and more than 10,000 gallons of water were produced in the course of development. Pumping rates varied from 3 to 30 gpm, and turbidity measurements varied from greater than 1,000 NTU to less than 25 NTU. There seemed to be little correlation between discharge rate and measured turbidity. In spite of pumping more than 10 well-bore volumes from the well, turbidity measurements were relatively high and not stable at the end of development. Therefore, it is recommended that SFR-3T be further developed in the future. Other water quality parameters were not measured during development.

5.0 BOREHOLE GEOLOGY

The oldest subsurface unit encountered at this location is interpreted as possibly the lower Permian Yeso Formation . The interval was first encountered in SFR-3P at 865 feet and identified on the basis of cuttings samples. The lithology is primarily siltstone with varying amounts of white gypsum. The section was significantly different from the overlying bedrock because of its characteristic reddish-brown color and the presence of gypsum. The gypsum was misidentified as kaolinite on the well-site lithologic log, but was later identified as gypsum by X-ray-diffraction. At SFR-3T, the same unit was encountered in a cored interval at 892 feet. Cores consisted of reddish-brown siltstone and claystone that displayed mottling from possible bioturbation prior to lithification, and rare limestone with chert (at 996.5 feet). Fractures within the unit contained white gypsum (SNL,1994).

Unconformably overlying the Yeso (?) Formation is a sequence of interbedded medium to dark gray sandstone, siltstone and shale with carbonaceous intervals (SNL, 1994). Based on palynological analysis of two SFR-3P samples, this unit is Paleocene to Eocene in age. These ages were obtained from the dark gray to black carbonaceous intervals at 755 feet-765 feet and 855 feet-865 feet. This bedrock section is tentatively age correlated to the lower Tertiary Galisteo/Baca/Nacimiento Formations. It is designated as "Lower Tertiary". Based on the pollen and spore information, these sediments were deposited in a broad, shallow nonmarine basin with swampy areas surrounded and perhaps filled with floral growth (SNL, 1994).

Generalized lithology and well completion diagrams are shown in Figures 7 and 8.

6.0 BOREHOLE HYDROLOGY

The SFR-3P well is completed in the alluvium of the Santa Fe Group and has a hydrostatic head of about 20 feet above the middle of the screen (depth to water is approximately 164 feet). Water quality improved quickly during development and airlift pumping remained steady at about 5 gpm. At the conclusion of well development, the water level was monitored during recovery. Twenty minutes after pumping ceased, the well had recovered 8 feet, to within 3 feet of static water level. This is a preliminary indication of a clean saturated sand in the completion zone with a relatively high hydraulic conductivity. However, this is only a qualitative observation since aquifer testing has not yet been accomplished in this well.

The SFR-3T well is completed in a bedrock sandstone interval and has a hydrostatic head of approximately 620 feet above the middle of the screen (depth to water is approximately 87 feet). It is important to note that the static water elevation from the bedrock completion interval is higher than that for the Santa Fe Group alluvial well. This indicates that the hydraulic gradient is upward from the bedrock into the Santa Fe Group. During well development at 30 gpm, the well was drawn down to the pump depth and then allowed to recover. Recovery was fairly rapid. Aquifer tests will be conducted at this site during 1994, which will increase understanding of the bedrock aquifer.

7.0 BOREHOLE GEOPHYSICS

Both SFR-3P and SFR-3T were logged by USGS equipment and personnel. In addition, SFR-3P was logged by a private contractor, COLOG, Inc., of Golden, Colorado. A summary of field operations and a synopsis of the data is presented in this section. A complete interpretation of COLOG data is presented in "Geophysical Logging Results for South Fence Road Project Wells SFR-3P and SFR-4P", COLOG, Inc., November, 1993. Table 4 is a list of geophysical log suites run at SFR-3P and SFR-3T.

The complete suite of logs run by USGS and COLOG is available for copying from the SNL ER Records Center. Digital and analog data are available.

7.1 SFR-3P Borehole Geophysics

SFR-3P reached total depth of 913 feet on July 2, 1993. This was the end of a drilling cycle, so the hole remained open until July 8, 1993, when the hole was re-entered, reamed to bottom and circulated with fresh water and bentonite drilling mud. The hole was logged by USGS on July 9, 1993. The USGS log suite included natural gamma, neutron, gamma density, short/long normal resistivity, and caliper logs. After USGS logging was complete, the hole was re-entered and circulated until the COLOG crew arrived and began logging in the morning of July 10, 1993. The suite of logs produced by COLOG included 16"/64" Normal Resistivity, EM Conductivity/Induced Polarization, Natural Gamma/Guard Resistivity, Caliper/Neutron, Density/Density Porosity, Full Waveform Sonic, and Temperature/Fluid Resistivity. During the logging by COLOG the borehole fluid level dropped from 29 feet to more than 170 feet below ground surface.

The COLOG logs from SFR-3P were analyzed qualitatively and quantitatively. The qualitative evaluation was performed by SWHC personnel immediately after all the logs were run in order to provide input to well completion and development. Preliminary log evaluation concentrated on locating the uppermost saturated interval for well completion purposes. Based on resistivity and neutron logs, the interval 176 feet to 184 feet was identified as the most promising zone. In addition, there was considerable interest in the high-velocity zone at 870 feet that represents a lithologic change and persists to total depth. It was suggested that the offset hole (SFR-3T) be drilled deep enough to investigate this formation. The following discussion is summarized from COLOG, 1993.

Full waveform sonic data was presented as a transit time log, a tube wave amplitude log, and variable density logs. Above approximately 170 feet in SFR-3P, the borehole velocity is generally less than 5000 fps, which is consistent with the velocity of the borehole fluid. These low velocities are consistent with partially saturated unconsolidated sediments. Below 170 feet, velocities typically range from 7000 to 14000 fps with the faster velocity material occurring in the more restrictive coarser grained sand/gravel intervals.

Table 4 - Geophysical Log Suites for SFR-3P and SFR-3T

Log Type	Well	
	SFR-3P	SFR-3T
<u>USGS:</u>		
Natural Gamma	X	X
Neutron	X	X
Density	X	X
Short/Long Normal Resistivity	X	X
Caliper	X	X
<u>COLOG:</u>		
16"/64" Normal Resistivity	X	
Single Point Resistance	X	
Spontaneous Potential	X	
EM Conductivity	X	
Induced Polarization	X	
Neutron	X	
Natural Gamma	X	
Guard Resistivity	X	
Density	X	
Caliper	X	
Density Porosity	X	
Full Wave Form Sonic	X	
Temp/Fluid Resistivity	X	
Depth Logged (feet)	913	1152

Resistivity measurements are consistent with the lithologic log of gravels, sands, and clays. With the exception of a very resistive unit described as a siltstone below 870 feet (actually gypsum in the Yeso Fm.), resistivities in SFR-3P are generally below 100 ohm/m. Resistivities in the Lower Tertiary below about 480 feet are very low, generally about 5 ohm/m. Porosity calculations from the gamma-gamma density log were based on a 2.65 g/cc grain density. Limestone pebbles and other mineralization within the alluvial fan deposits will affect these values, however the density log is still believed to be the best porosity tool at this site. Average density log porosities were calculated and compared to laboratory values for the same interval in SFR-3T. The average density log porosity calculated for the cleanest (low clay) zone of the screened interval in SFR-3P was 11.15%, while the lab analysis was 15%.

Figure 9 shows the separation between the sonic velocity log and density porosity log, plus the resistivity-gamma difference. The scales on the sonic velocity-density porosity difference log were adjusted so that the magnitude of response was similar in rocks that are probably saturated. Porosity increases to the left. When water saturation decreases below 100% there is a very rapid decrease in velocity of acoustic compressional waves. There should also be a decrease in the density measured by the gamma-gamma log, but the change should be small compared to the change in sonic velocity. Because the drainage of sands above the water table is likely to be much faster and more complete than in mudstones or claystones, the difference between the sonic and density logs should be greatest in higher permeability rocks. As shown in Figure 9, there is no significant change in separation of the density porosity and sonic velocity curves, and thus no indication of the bottom of the vadose zone.

7.2 SFR-3T Borehole Geophysics

SFR-3T was logged by the USGS immediately after reaching total depth (1,152 feet, bgl.). The USGS log suite included natural gamma, neutron, gamma density, short/long normal resistivity, and caliper logs. A weakness of USGS logs is a lack of calibration data that can be used to calculate quantitative values, such as water saturation and percent clay. USGS resistivity logs correlate very well with COLOG logs (at SFR-3P). The USGS neutron probe is not regularly calibrated and uses a NaI crystal that is subject to significant degradation. For these reasons, neutron porosity, and other values calculated from the neutron log are not reliable. The USGS also uses an old Cobalt-60 source that is significantly decayed and produces a weak gamma density log. The USGS logs run on SFR wells should only be used for qualitative purposes (Foutz and Hyndman, 1993).

A total of seven core samples were taken and analyzed in the laboratory for bulk density and porosity. Six of these samples were analyzed for the depth interval 705 feet to 727 feet, bgl. The average porosity was 14.42%. The seventh sample was taken from the interval between 168.7 and 169 feet and had a measured porosity of 15%. There was excellent correlation between core and log porosity values based on an assumed grain density of 2.65 gm/cm^3. Both the log and laboratory values are likely to represent total porosity rather than effective porosity (COLOG, 1994).

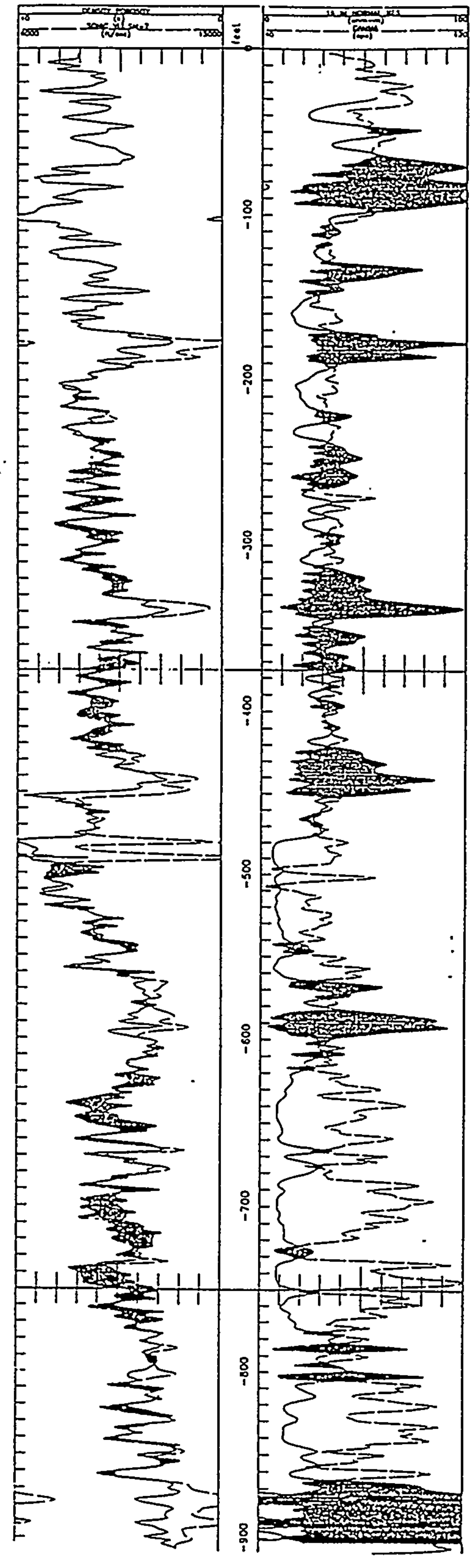


Figure 9. SFR-3P Density Porosity/Sonic Velocity Difference and 16"Normal Resistivity/Natural Gamma Difference Logs

8.0 SUMMARY

The objectives of installing test/monitoring wells in the Santa Fe Group water-table aquifer (SFR-3P), and the uppermost bedrock aquifer (SFR-3T) at the SFR-3 location were accomplished during the South Fence road Phase II field operations summarized in this report. During these field operations, important subsurface geologic and hydrologic data were obtained.

Subsurface geologic data include drill cuttings, core, and borehole geophysical logs. These data will improve the understanding of fault displacement across the Hubbell Springs fault, define the lithologic framework within the Santa Fe Group at this location, identify the stratigraphic relationship across the Santa Fe Group/bedrock contact, and establish the local stratigraphic sequence in the uppermost 600 feet of the underlying bedrock.

Subsurface hydrologic data include borehole geophysical logs, and qualitative information obtained during well completion/well development. These data will help define the local hydrostratigraphic framework within the Santa Fe Group water-table aquifer, and the hydraulic potential between this water-table aquifer and the underlying confined bedrock aquifer. In addition, the test/monitoring wells (including SFR-3S and SFR-3D installed during the Phase I field operations [Neel and McCord, 1994]) provide an excellent grouping of aquifer test and observation wells. This grouping of wells is referred to as the SFR-3 hydropad. Future aquifer testing at the SFR-3 hydropad will generate data for the interpretation of aquifer parameters (transmissivity and storativity), and may yield information on anisotropy within the Santa Fe Group and the hydraulic connection between the Santa Fe Group aquifer and the bedrock aquifer.

9.0 REFERENCES

COLOG, 1993. Geophysical Logging Results for South Fence Road Project Wells SFR-3P and SFR-4P, Sandia National Laboratory, Kirtland Air Force Base, New Mexico.

Foutz, W.L. and D.A. Hyndman, 1993. Coordination and Interpretation of the Geophysical Logging of the South Fence Road Phase II Wells, prepared for Department 7584, Sandia National Laboratories, New Mexico, by Lamb Associates, Inc.

Hawley, J.W. and C.S. Haase (editors), 1992. Hydrogeologic Framework of the Northern Albuquerque Basin, New Mexico Bureau of Mines and Mineral Resources Open-File Report 387.

Neel, D. and J.P. McCord, 1993. Summary of Phase I Field Operations, South Fence Hydrogeologic Wells. SAND93-7038, Sandia National Laboratories, Albuquerque, New Mexico.

Sandia National Laboratories (SNL), 1994. Site-Wide Hydrogeologic Characterization Project Calendar Year 1993 Annual Report, Environmental Restoration Program, 5:59-74.

Wood, C., 1992. Field Operating Procedure - Monitor Well Development, PRO-92-08, Sandia National Laboratories Environmental Restoration Division, 7723.

APPENDIX A

SNL STANDARD WELL COMPLETION DIAGRAMS

SNL GROUND-WATER MONITOR WELL DATA SHEET

PLAN VIEW SURVEY POINTS

GS NW CORNER ELEV. "B" | GS NE CORNER ELE. "C"

GS SW CORNER ELEV. "E" | GS SE CORNER ELEV. "D"

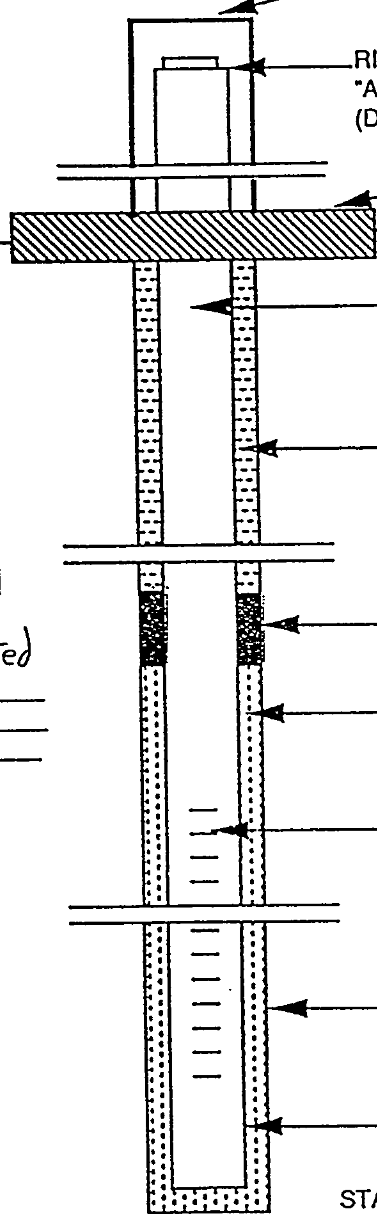
TOP OF CONCRETE PAD

WELL NUMBER: SFR - 3P
LOCATION: South Fence Road
DATE INSTALLATION COMPLETED 7/12/93
DATE OF DEVELOPMENT 7/13 - 7/14 Development completed

PROTECTIVE COVER: 5497.401 elev. "F"

RISER ELEVATION "A": 5496.956 (DATUM) FASL

CONCRETE PAD



SURVEY POINTS

WELL NO.	SFR-3P.
ELEV. "A"	5496.956
ELEV. "B"	5494.281
ELEV. "C"	5494.318
ELEV. "D"	5494.346
ELEV. "~~C~~E"	5494.292

~ 5497.3

ELEV. = FASL
SURVEY DATE: Survey requested 9/24/93
REMARKS:

ELEV FASL	ELEV FBGS	
	133.5	TOP OF SEAL
	144.0	TOP OF SAND
	175.0	TOP OF SCREEN
	195.0	BOTTOM OF SCREEN
	205.0	BOTTOM OF SUMP
	210	BOTTOM OF HOLE (Top of Bottom seal)

RISER TYPE: Schedule 80 PVC (surface to 165')
DIAMETER: 4.5 IN (OD) 3.8 IN (ID)
LENGTH: 205' FT

BACKFILL: Volclay: surface to 133.5'

SEAL: 133.5 - 144.0

SAND: 144.0 - 210.0

SCREEN DIA: 4.5 IN (OD) 3.826 IN (ID) ?
LENGTH: 20 FT
TYPE: Stainless steel (304)
SLOT SIZE: 0.0195 IN (20 slot)
10' 304 S.S. Riser above screen: 165-175

BOREHOLE DIA: 6" IN 7 7/8" - 0 to 520'; 520-580
DRILL METHOD: 5 7/8" 580-TD (914') Mud rotary

SUMP LENGTH: 10' (Sump is 304 S.S.)

STATE PLANER: X 418514.801 FT
Y 1436174.507 FT

GEOGRAPHIC: LATITUDE
LONGITUDE

GENERAL COMMENTS: Borehole drilled to TD @ 914' bgs. Plugged back w/ Volclay: 255' to 914'; 10/20 Sand: 217' to 255'; Bentonite Plug: 210' to 217'.

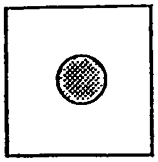
KEY:
GS = GROUND SURFACE
FBGS = FEET BELOW GROUND SURFACE
FASL = FEET ABOVE MEAN SEA LEVEL

SNL GROUND-WATER MONITOR WELL DATA SHEET

PLAN VIEW SURVEY POINTS

GS NW CORNER ELEV. "B"

GS NE CORNER ELE. "C"

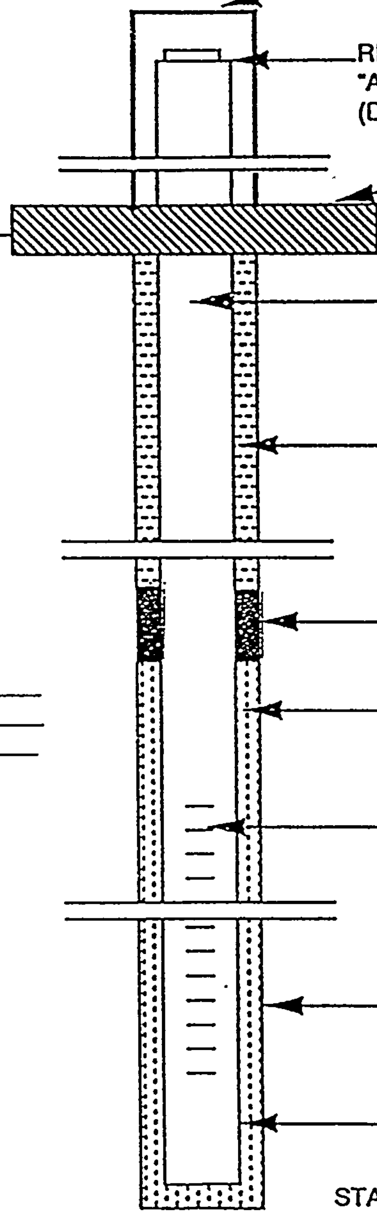


GS SW CORNER ELEV. "E"

GS SE CORNER ELEV. "D"

TOP OF CONCRETE PAD

WELL NUMBER: SFR-3T
LOCATION: South Fence Road
DATE INSTALLATION COMPLETED 9/23/93
DATE OF DEVELOPMENT 9/23 - 9/25 (development not completed)



PROTECTIVE COVER: 5496.341 ("F")

RISER ELEVATION "A": 5495.989 (DATUM) FASL

CONCRETE PAD

SURVEY POINTS

WELL NO.	SFR-3T
ELEV. "A"	5495.989
ELEV. "B"	5494.022
ELEV. "C"	5494.Ø85
ELEV. "D"	5494.084
ELEV. "E"	5493.970

ELEV. F 5496.341

ELEV. = FASL ~ 5493.5
SURVEY DATE:
REMARKS:

RISER TYPE: 304. S.S.
DIAMETER: 5.56 IN (OD) 5.43 IN (ID) ?
LENGTH: 753 FT

BACKFILL: Volclay Surface to 649'.

SEAL: Bentonite Pellets 649'-651'

SAND: 10/20 Sand 651'-654'; 16/40 Sand 654'-655'; 10/20 Sand 655'-760'

ELEV FASL	ELEV FBGS	
	649'	TOP OF SEAL
	651'	TOP OF SAND
	713'	TOP OF SCREEN
	733'	BOTTOM OF SCREEN
	753'	BOTTOM OF SUMP
	760'	BOTTOM OF HOLE

SCREEN DIA: 5.56 IN (OD) 5.43 IN (ID)
LENGTH: 20 FT
TYPE: 304 S.S.
SLOT SIZE: 0.0195 IN (20 Slot)

BOREHOLE DIA: 10' IN
DRILL METHOD: Mud Rotary

SUMP LENGTH: 20'

STATE PLANER: X 418500.658 FT
Y 1436211.726 FT
GEOGRAPHIC: LATITUDE
LONGITUDE

GENERAL COMMENTS: Borehole drilled to TD @ 1154'. Plugged back w/ Volclay: 760 to 1154'.

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

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